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Effects of gamma irradiation and plasma technology on some chemical properties of camel meat

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Abstract : This investigation aims to study the effects of gamma irradiation at doses of 0, 1.5, 3.0 and 4.5 kGy and plasma treatment at exposure times of 1, 2, and 3 min., which approved for some chemical properties of camel meat. Non-irradiated, irradiated and meat samples exposure to plasma were analyzed for amino acids, fatty acids composition whereas their lipids were analysis for some lipid characteristics. It could be concluded that gamma irradiation doses and plasma treatments hadn't any effect on the amino acids of meat samples under investigation. On the other hand these treatments caused decreased in total saturated fatty acids leading to increasing in the total unsaturated fatty acids for extracted lipids of samples under investigation. Refrigerated storage (4±1) had a significant ($P \leq 0.05$) increased in acid and peroxide values of lipids of meat samples which irradiated with gamma irradiation and samples exposure to plasma under investigation and the lipolysis was relatively higher in lipids of control sample compared with other samples under investigation during storage. It could be summarized that gamma irradiation and plasma treatments had no adverse effects on chemical properties of camel meat, therefore their use as safety technological treatments in food preservation.

Keywords : Gamma irradiation; Plasma; Meat muscles; Amino acids lipid characteristics.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) estimated that 25% of all food products are wasted after harvest worldwide. The most economic losses of foods are due to infestation with insects, fungal contamination and premature germination[7,14]. The Joint FAO/ IAEA/ WHO Expert Committee for Food Irradiation (JECFI) concluded that foods irradiated up to 10 kGy (1 Gy=100 rad) are safe and nontoxic[28]. This limit is adapted to Codex Standard in 1983[2]. Later on, JECFI, for the evaluation of toxicological, nutritional, chemical and physical aspects of foods, declared that irradiated up to 10 kGy are safe and nutritionally adequate as long as they are produced according to good manufacturing practices[29].

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Irradiation of food does not induce additional radioactivity, because the sources of radiation approved for use in food irradiation are limited to those producing energy too low to induce sub-atomic particles[3,26].

Plasmas are energetic gases composed of atoms, molecules, radicals as well as excited and charged particles. Furthermore, plasmas emit a characteristic light from infrared over the visible spectral range to ultra violet. Technical progress allows to control plasmas and to use them for industrial applications. This includes modern television, energy saving lamps and e.g. plasma etching for microcontroller manufacturing. A new field of application is the use of plasmas for decontamination of e.g. medical products and food produce[12]. Plasma is a source of different antimicrobial substances including UV photons, charged particles, and reactive species such as superoxide, hydroxyl radicals, nitric oxide and ozone[9,10,13,16]. Number of studies investigating the inactivation of microorganisms inoculated on food surfaces increased with the main focus on the decontamination of fruit, vegetable and poultry carcasses[1,8,15,17,19,21,22,24,27]. Additionally, Moon et al.[18] and Fröhling, et al.[12] reported that plasma treatment as active method to decontaminate fresh meat and meat products.

The aim of this study was to evaluate the quality of some lipid characteristics of meat muscles as acid and peroxide values were measured over a refrigerated storage period of 18 days (4±1). Additionally, total amino acids and fatty acids of meat muscles measurements were conducted to evaluate changes in meat samples after gamma irradiated and plasma treatments.

MATERIALS AND METHODS

Materials

Camel meat was purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to our laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychrophilic bacteria, sporeforming bacteria, total molds and yeasts. Then, meat samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

Gamma irradiation treatments

Four bags from each of meat samples were gamma irradiated at 0.0, 1.5, 3.0 and 4.5 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

Plasma treatments

Character of exposure machine

The plasma generator consisted of a negative dc source, a Blumlein-type pulse-forming network (E-PFN), and a dynamic spark gap switch. A triggered spark gap switch was used as a closing switch of E-PFN. E-PFN had four stages of LC ladder, which were composed of 5 nF of capacitor and 3 μH of inductor. The characteristic impedance (2"L/C) and the pulse width (2N'LC) of E-PFN, calculated from capacitance (C) and inductance (L) of the LC ladder, and number (N) of LC ladder stages were approximately 49 Ω and 1.0 μs, respectively.

A charging resistance value of 50 kΩ was chosen in the present case which corresponds to a charging RC time constant of 1 ms, which is 40 times faster compared to the repetition rate of the pulse.

A schematic of the pulsed atmospheric-pressure plasma jet (PAPPJ) device for generating high voltage pulsed, cold atmospheric plasma jets is shown in Figure 1. The high voltage (HV) wire electrode, which is made of a copper wire, is inserted into a hollow barrel of a syringe. The distance between the tip of the HV electrode and the nozzle is 0.5 cm.

When HV pulsed, DC voltage (amplitudes up to 25 kV, repetition rate up to 25 Hz), was applied to the HV electrode and helium gas was injected into the hollow barrel. This device was made using medical syringe (made out of an insulating material cylinder). The gas was fed into the system via flow meter.

The applied voltage to and the discharge current through the discharge chamber were measured using a voltage divider (Homemade), which was connected between the two electrodes, and a current monitor, which can be located upon returning to the ground. The signals from the voltage divider and the current monitor were recorded in a digitizing oscilloscope (Lecroy, USA) with a 200-MHz bandwidth.

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The high voltage pulses are applied between the needle electrode positioned inside a dielectric cylinder (a simple medical syringe) and a metal ring placed on the exterior of this cylinder. In order to obtain electric discharges at atmospheric pressure, a high voltage pulses (tens of kV) which have limited duration (hundreds of nanoseconds) and are repeated (tens of pulses per second), in addition to an inert gas (argon) is introduced in the cylinder. The gas flows were in the range 0.5-10 l/min. The discharge takes place between the metallic needle top and a metallic ring fit on the outer surface of the syringe. Under optimal conditions, plasma is emitted as centimeter-long jets, just millimeters in diameter or even smaller. The working gases are supplied by high-pressure cylinders. Gas pressure regulators are used to reduce the pressure of gases to a workable level. Then, gas flow controllers deliver the gases with the desired flow. For voltage amplitudes of 15-18 kV, the plasma jet is very weak. The plasma jet disappears for voltage amplitudes lower than 15 kV. When argon is injected from the gas inlet and high voltage pulses, 26 kV voltages is applied to the electrode, the plasma jet is generated and a plasma plume reaching length of 21 mm is launched through the end of the tube and in the surrounding air. The length of the plasma plume can be adjusted by the gas flow rate and the applied voltage. Three bags from each of meat samples were exposure to plasma at 1, 2 and 3 min in Plasma Physics and Nuclear Fusion Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt. After the exposure time of plasma, all samples were stored at 4±1°C.

Quantitative determination of the total amino acids content except tryptophan

Amino acids contents of control and camel meat samples were determined according the method described by Pellet and Young[20] which could be summarized as follows: A known weight of each sample containing 100 mg protein was hydrolyzed in sealed Pyrex test tubes with 10 ml of 6 N HCL at 110°C for 24 hours. The hydrolyzate was quantitatively transferred to porcelain dish and the (HCL) was then evaporated to dryness at 60°C under vacuum. Five ml of distilled water was added to the hydrolyzate and then evaporated to dryness to remove the excess of HCL. The separation of amino acids was performed by (Auto Sampler Version, Analyzer, Biochrom 20 pharmacia biotech) at National Center for Radiation research and Teachnology (N.C.R.R.T), Nasr City, Cairo Egypt.

Lipid extraction

Meat samples were dried at 105 ^{0}C for 6 hr. and ground using stainless steel mill. Then the lipid was extracted by n-hexane using 2 liters capacity. Soxhelt apparatus units for 16 hr. After lipid extraction, the solvent was evaporated under vacuum at 60 ^{0}C and the crude oil was dried over anhydrous sodium sulfate, filtered, packed in dark brown bottles without further purification and kept till analysis, according to A.O.C.S.[4].

Determination of acid and peroxide values

Acid and peroxide values were determined according to the methods described by the A.O.A.C.[5].

Fatty acid composition

Gas liquid chromatographic analysis was applied to identify the fatty acid composition as follows:

Preparation of fatty acids methyl esters

The methyl esters were prepared using sulfuric acid in methanol (2.5:97.5 v/v) as reagent and the methylation process was carried out by refluxing the oil for 2.5 hr according to the method reported by Stahl[25]

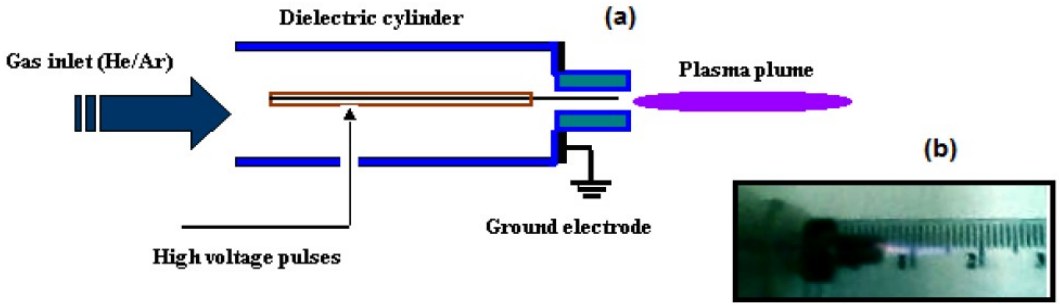

Figure 1 : Schematic diagram of the plasma jet generator (a) Image of the plasma jet with argon gas (b).

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Identification of the fatty acids methyl esters (FAME)

The fatty acid methyl esters were analyzed by using a Hewlett Packard 6890 gas chromatograph instrument equipped with a flam ionization detector. The column used for all analysis was a capillary column, innowax-crosslinked polyethylene glycol column 30 m x.0.32 mm I.D, and 0.5 mm film thickness. Carrier gas was nitrogen at a flow of 1.5 ml/min. The temperature Program was 150 0C for 1 min., then 150 ^{o}C - 235 ^{o}C at 17 ^{0}C / min. 235 ^{0}C - 245 ^{0}C at 1 ^{0}C /min at which the oven was hold for maximum of 5 min. The temperature of injection port and detector was 260 ^{0}C and 275 ^{0}C, respectively. The Peak areas and retention times were measured using A Hewlett Packard 3392 A integrator.

Statistical analysis

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar[30]. The chosen level of significance was $P<0.05$.

RESULTS AND DISCUSSION

The total amino acids were quantitatively determined in non-irradiated, irradiated camel meat and meat muscles exposure to plasma (TABLE 3). It is clearly seen that the total amino acids represented 294.3, 294.0, 294.1, 294.4, 293.5, 293.9 and 294.2mg/g in non-irradiated (control), irradiated meat samples with 1.5, 3.0 and 4.5 kGy gamma rays and meat samples exposure to plasma at 1, 2 and 3 min., respectively. Meat samples treated with gamma irradiation and exposure to plasma contained the same essential and non-essential amino acids. From the same table, it could be observed that gamma irradiation doses and plasma hadn't any effect on the amino acids of meat samples under investigation. Similar observations were reported by Badr[6] who mentioned that the amino acids of breast and leg muscles showed no remarkable changes due to gamma irradiation.

Lipid characteristics: TABLE 2 show the initial acid value of lipids extracted from non-irradiated camel meat

TABLE 1 : Total amino acids of camel meat as affected by gamma irradiation and plasma.

Type of Amino acids	Amino acids	Control	Gamma irradiation doses (kGy)			Exposure time of plasma (min)		
			1.5	3.0	4.5	1.0	2.0	3.0
Essential amino acids	Therionine	15.2	15.6	15	16.8	15	16.8	15.8
	Valine	13.2	13.4	13.6	14.4	12.4	13.2	13.4
	Methionine	6.1	6.4	6.2	6	6.1	6.4	6
	Isoleucine	16.8	15.6	16.6	16.8	18	15.6	17
	Leucine	63.6	63.6	64.6	64.2	64.4	63.8	63.4
	Tyrosine	7.2	7	5	4.2	6.4	7.2	8
	Phenyalanine	18	18.5	18.6	17.8	18.2	17.6	18
	Lysine	27.6	26.9	27.6	27.6	27.2	27.4	26.6
	Histidine	22.7	22.8	22.8	22.4	22.2	22.4	21.9
Total essential amino acids		190.4	189.8	190	190.2	189.9	190.4	190.1
Non-essential amino acids	Aspartic	17.1	16.8	17	16.8	16.4	16.8	16.8
	Serine	13.4	12.9	12.6	13.2	12.8	13.4	13.2
	Glutamic	19.2	18	18.4	19.8	18.2	19.2	19.2
	Prolin	3.5	4.8	4.3	4.2	4.8	4.9	4.8
	Glycine	11.1	10.8	10.8	10.8	11	10.8	10.8
	Alanine	11.7	11.9	12	11.8	12	12	12
	Cystine	6.6	7.4	7.4	7.4	6.8	7.2	6.9
	Arginine	21.6	21.6	21.6	20.2	21.6	19.2	20.4
Total non-essential amino acids		104.0	104.2	104.1	104.2	103.6	103.5	104.1
Total Amino acid (mg/g)		294.3	294.0	294.1	294.4	293.5	293.9	294.2

was 0.408±0.006 lower than that of lipid extracted from irradiated meat samples with 1.5, 3.0, 4.5 kGy (0.422±0.009, 0.445±0.002, 0.453±0.002) and samples exposure to plasma at 1, 2 and 3 min. (0.434±0.002, 0.442±0.001, 0.451±0.001) respectively, while peroxide value of the same samples was 0.607±0.005, 0.622±0.009, 0.644±0.001, 0.651±0.002, 0.633±0.001, 0.640±0.001 and 0.650±0.001, respectively. It could be noticed that gamma irradiation and plasma treatments cased a significant slightly increased in acid and peroxide values of lipid extracted from meat muscels in zero time of storage. This increasing may be due to the effect of irradiation on the ester bonds and liberation of free fatty acids moreover its effects on unsaturated fatty acids[6,23].

TABLE (2 and 3) also shows that refrigerated storage (4±1) a significant markedly affected the acid and peroxide values of lipids of sample under investigation and the lipolysis was relatively higher in lipids of control sample compared with other samples under investigation. And all values were within the acceptable levels.

Gas chromatographic analysis for lipids extracted from camel meat samples of non-irradiated (control), irradiated (1.5, 3.0 and 4.5 kGy) and treated samples by plasma (1, 2, and 3 min.) revealed that the total saturated fatty acids for their lipids amounted to 54.465, 47.405, 47.703, 49.563, 51.562, 54.197 and 51.136%, while the total unsaturated fatty acids reached 45.535, 52.795, 52.297, 50.438, 48.439, 45.803 and 48.865, respectively (TABLE 3). From the same table

TABLE 2 : Lipid characteristics of camel meat as affected by gamma irradiation and plasma treatments during refrigerated storage (4±1)

Determination	Storage period (days)	Control	Gamma irradiation doses (kGy)			Exposure time of plasma (min.)		
			1.5	3.0	4.5	1.0	2.0	3.0
Acid value	Zero time	0.408±0.006	0.422±0.009	0.445±0.002	0.453±0.002	0.434±0.002	0.442±0.001	0.451±0.001
	3	0.528±0.006	0.530±0.006	0.532±0.002	0.525±0.005	0.530±0.006	0.528±0.008	0.526±0.005
	6	0.733±0.001	0.631±0.002	0.571±0.016	0.564±0.016	0.624±0.012	0.567±0.015	0.533±0.031
	9	R	0.637±0.006	0.581±0.013	0.570±0.011	0.637±0.006	0.579±0.011	0.543±0.032
	12	-	R	0.681±0.013	0.557±0.033	R	0.678±0.011	0.564±0.016
	15	-	-	R	0.837±0.049	-	R	0.800±0.02
	18	-	-	-	R	-	-	R
Peroxied value (meq/kg. lipid)	Zero time	0.607±0.005	0.622±0.009	0.644±0.001	0.651±0.002	0.633±0.001	0.640±0.001	0.650±0.001
	3	0.828±0.006	0.829±0.005	0.833±0.001	0.835±0.006	0.829±0.004	0.828±0.008	0.826±0.005
	6	0.932±0.001	0.824±0.012	0.771±0.016	0.764±0.016	0.820±0.011	0.766±0.015	0.743±0.015
	9	R	0.837±0.006	0.780±0.012	0.769±0.024	0.827±0.023	0.777±0.010	0.763±0.025
	12	-	R	0.881±0.013	0.794±0.012	R	0.879±0.011	0.797±0.001
	15	-	-	R	1.037±0.055	-	R	1.02±0.030
	18	-	-	-	R	-	-	R

TABLE 3 : Analysis of variance between treatments for acid and peroxied values of camel meat as affected by gamma irradiation and plasma treatments during refrigerated storage (4±1)

Storage period (days)	*df*	*F crit*	Acid value			Peroxied value		
			SS	*MS*	*F*	*SS*	*MS*	*F*
Zero time	6	2.848	0.005	0.001*	48.701	0.005	0.001*	52.629
3	6	2.848	0.000	1.700^{NS}	0.522	0.000	2.920^{NS}	1.00
6	6	2.848	0.070	0.012*	73.735	0.075	0.012*	71.571
9	5	3.106	0.022	0.004*	17.034	0.015	0.003*	8.821
12	3	4.066	0.043	0.014*	35.875	0.021	0.007*	61.566
15	1	7.709	0.002	0.002^{NS}	1.479	0.002	0.000^{NS}	0.224

^{NS}: Non significant; *significant; Values are means of three replicates. Data were analyzed by ANOVA (Single factor), F test means ($P \leq 0.05$).

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TABLE 4 : Fatty acids of camel meat as affected by gamma irradiation and plasma

Fatty acids (%)	Control	Gamma irradiation doses			Exposure time of plasma (min)		
		4.5	3.0	1.5	3.0	2.0	1.0
Myristic C14:0	7.786	5.300	5.782	5.621	5.976	6.433	6.127
Palmitic C16:0	35.783	28.775	31.032	30.039	33.181	34.108	33.267
Stearic C18:0	10.896	13.330	10.889	13.903	12.405	13.656	11.742
Oleic C18:1	45.535	47.085	48.007	45.138	48.439	45.803	48.865
Linoleic C18:2	0.000	5.710	4.290	5.300	0.00	0.00	0.00
Total saturated fatty acids	54.465	47.405	47.703	49.563	51.562	54.197	51.136
Total unsaturated fatty acids	45.535	52.795	52.297	50.438	48.439	45.803	48.865

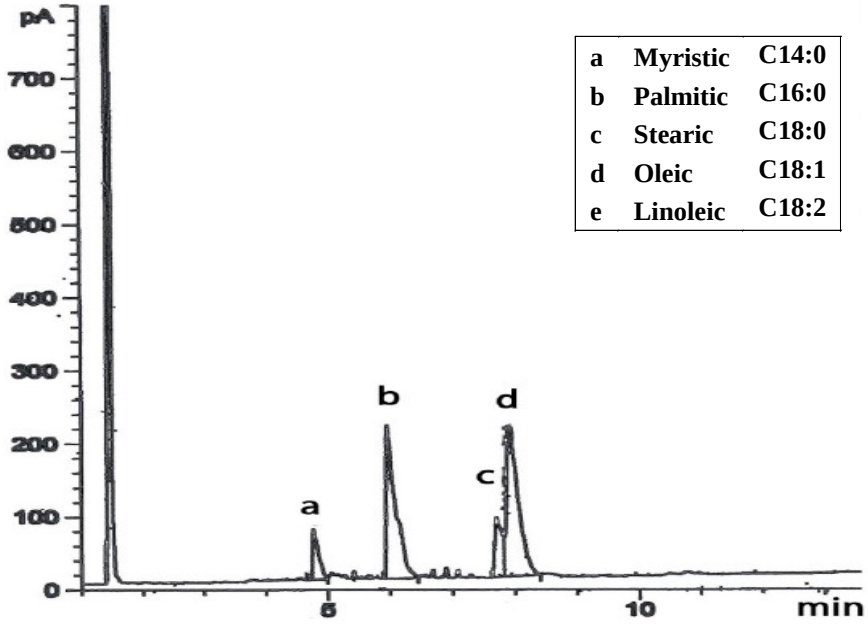

Figure 2 : Chromatogram of fatty acids of control camel meat sample

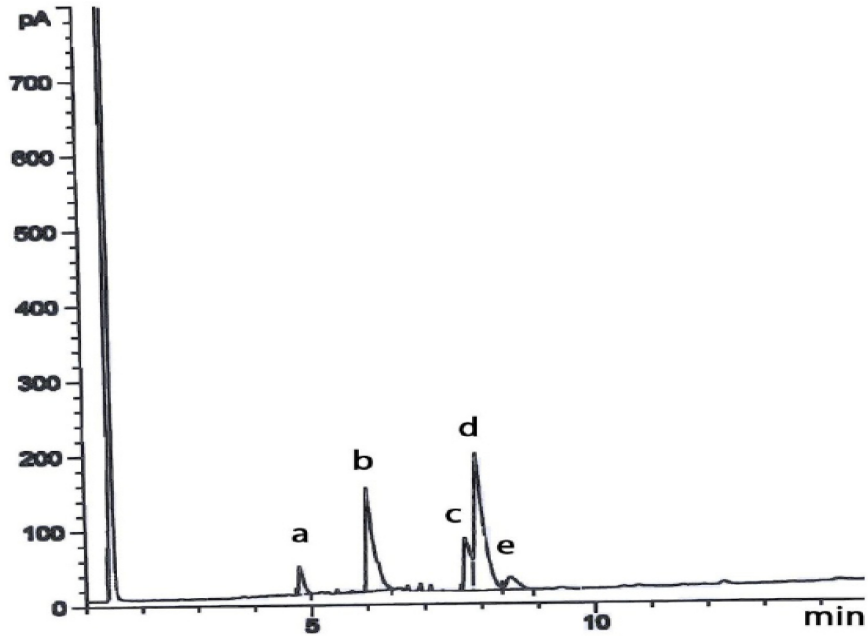

Figure 3 : Chromatogram of fatty acids of camel meat as affected by gamma irradiation at 1.5 kGy

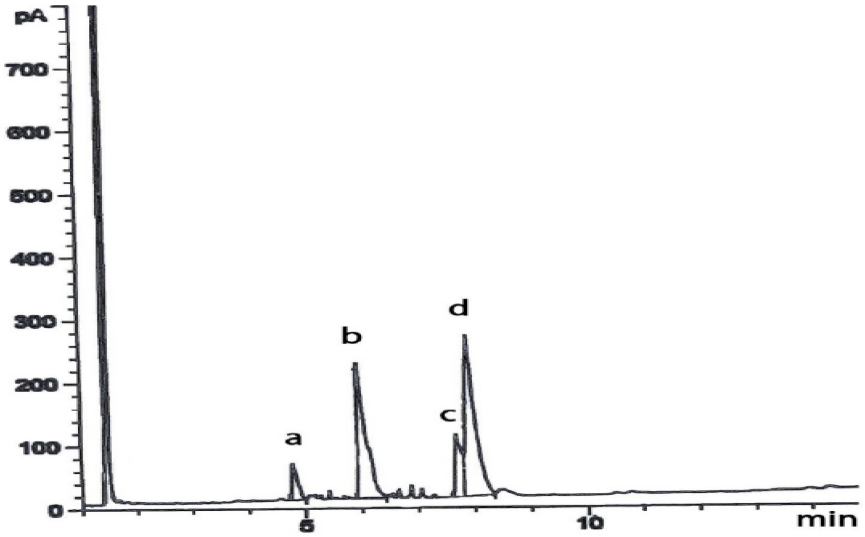

Figure 4 : Chromatogram of fatty acids of camel meat as affected by plasma at 1.0 min.

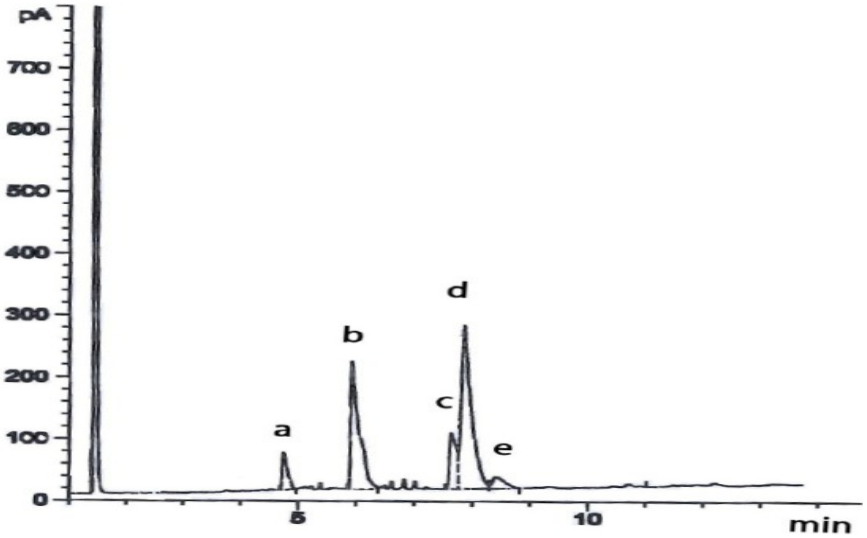

Figure 5 : Chromatogram of fatty acids of camel meat as affected by gamma irradiation at 3.0 kGy

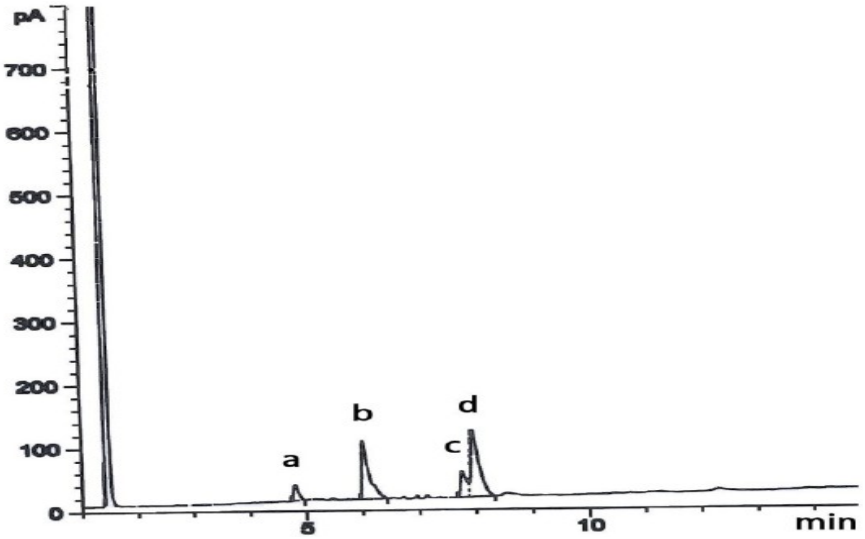

Figure 6 : Chromatogram of fatty acids of camel meat as affected by plasma at 2.0 min.

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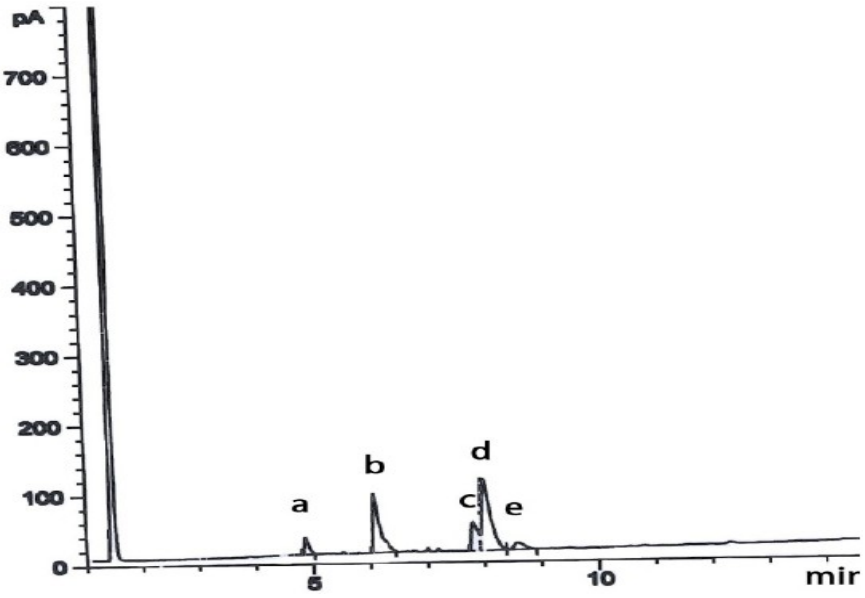

Figure 7 : Chromatogram of fatty acids of camel meat as affected by gamma irradiation at 4.5 kGy

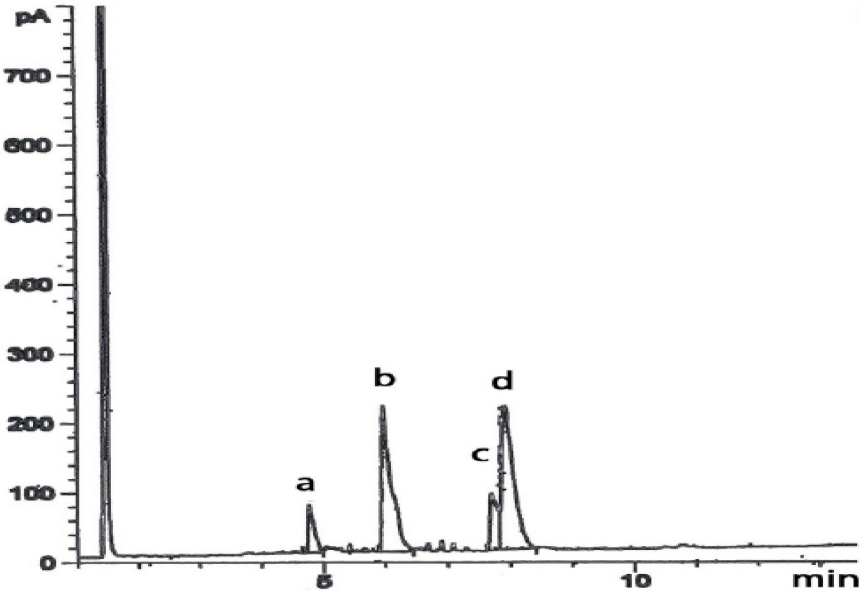

Figure 8 : Chromatogram of fatty acids of camel meat as affected by plasma at 3.0 min.

it can be noticed that palmitic and stearic were the major saturated fatty acids, whereas oleic constituted the major unsaturated fatty acids. Gamma irradiation and plasma treatments caused decreased in total saturated fatty acids leading to increasing in the total unsaturated fatty acids for extracted lipids of meat samples under investigation. It can concluded that upon irradiation of fats, the primary effect of incident electrons or Compton electrons lead to cation radicals and exited molecules and the cation radical is shown generally with the localization of charge unspecified followed by dimerization or disproportionation reaction[11].

CONCLUSION

Refrigerated storage (4±1) of camel meat camel meat induced increase the acid and peroxide values of lipids which were within the acceptable levels. Irradiation and plasma treatments did not appreciably affect the amino acids of meat samples under investigation. While increased the un-saturated fatty acids and decreased saturated fatty acids of their lipids. Moreover gamma irradiation (1.5, 3.0 and 4.5 kGy) and plasma technology (at 1, 2 and 3 min.) treatments can be used

for meat preservation without any adverse affects on its chemical characteristics.

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REFERENCES

[1] A.A.Aly, G.M.El-Aragi; Comparison between gamma irradiation and plasma technology to improve the safety of cold sliced chicken, African Journal of Food Science, **7(12)**, 461-467, December **(2013)**.

[2] Anonymous; International atomic energy agency, Food Irradiation Newsletter, **11(2)**, 6 **(1987)**.

[3] Anonymous; International atomic energy agency facts about food irradiation.available at: http://www.iaea.org/worldatom/inforesource/other/food/q&a.html; Accessed May 12, **(2000)**.

[4] A.O.C.S.; Official and Tentative Methods of the American Oil Chemist's Society, Fourth Edition, American Oil Chemist's Society, 508 South, Sixth Street, Champaign, III Onois, 61820, **(1989)**.

[5] A.O.A.C.; Official Methods of Analysis, of the Association of Official Analytical Chemists, 15th Edition, Published by Association of Official Analytical Chemists, Arlington, Virginia, USA, **(1990)**.

[6] H.M.Badr; Chemical properties of chicken muscles and skin as affected by gamma irradiation and refrigerated storage, Journal of Food Technology, **3(1)**, 01-09 **(2005)**.

[7] R.Braghini, M.Sucupira, L.O.Rocha, T.A.Reis, S.Aquino, B.Corre^a; Effects of gamma radiation on the growth of A.alternata and on the production of alternariol and alternariolmonomethyl ether in sunflower seeds, Food Microb., **26**, 927-931 **(2009)**.

[8] F.J.Critzer, K.Kelly-Wintenberg, S.L.South, D.A.Golden; Atmospheric plasma inactivation of foodborne pathogens on fresh produce surfaces, Journal of Food Protection, **70(10)**, 2290-2296 **(2007)**.

[9] G.Daeschlein, T.von Woedtke, E.Kindel, R.Brandenburg, K.-D.Weltmann, M.Jünger; Antibacterial activity of an atmospheric pressure plasma jet against relevant wound pathogens in vitro on a simulated wound environment, Plasma Processes and Polymers, **7**, 224-230 **(2010)**.

[10] X.Deng, J.Shi, M.G.Kong; Physical mechanisms of inactivation of *Bacillus subtilis* spores using cold atmospheric plasmas, IEEE Transactions on Plasma Science, **34**, 1310-1316 **(2006)**.

[11] J.F.Diehl; Safety of Irradiated Food, Marcel Dekker, New York, NY, USA, **(1995)**.

[12] A.Fröhling, J.Durek, U.Schnabel, J.Ehlbeck, J.Bolling, O.Schlüter; Indirect plasma treatment of fresh pork: Decontamination efficiency and effects on quality attributes, Innovative Food Science and Emerging Technologies, **16**, 381-390 **(2012)**.

[13] L.F.Gaunt, C.B.Beggs, G.E.Georghiou; Bactericidal action of the reactive species produced by gas-discharge nonthermal plasma at atmospheric pressure: A review, IEEE Transactions on Plasma Science, **34**, 1257-1269 **(2006)**.

[14] B.Harris; The battle to minimise losses due to mycotoxins, World Poultry Magazine on Production, Processing and Marketing, **14(4)**, 52-54 **(1998)**.

[15] P.A.Klockow, K.M.Keener; Quality and safety assessment of packaged spinach treated with a novel atmospheric, non-equilibrium plasma system, Proceedings of the ASABE annual international meeting, June 29th - July 2nd, Providence, Rhode Island, USA, Paper Number: 084396, **(2008)**.

[16] M.Laroussi, F.Leipold; Evaluation of the roles of reactive species, heat, and UV radiation in the inactivation of bacterial cells by air plasmas at atmospheric pressure, International Journal of Mass Spectrometry, **233**, 81-86 **(2004)**.

[17] R.R.Montenegro; Inactivation of E.coli O157:H7 using a pulsed nonthermal plasma system, Journal of Food Science, **67(2)**, 646-648 **(2002)**.

[18] S.Y.Moon, D.B.Kim, B.Gweon, W.Choe, H.P.Song, C.Jo; Feasibility study of the sterilization of pork and human skin surfaces by atmospheric pressure plasmas, Thin Solid Films, **517(14)**, 4272-4275 **(2009)**.

[19] B.A.Niemira, J.Sites; Cold plasma inactivates Salmonella stanley and Escherichia coli O157:H7 inoculated on Golden Delicious apples, Journal of Food Protection, **71(7)**, 1357-1365 **(2008)**.

[20] P.L.Pellet, V.R.Young; Nutritional Evaluation of Protein Foods, Published by the United National Univ., **(1980)**.

ORIGINAL ARTICLE

[21] S.Perni, D.W.Liu, G.Shama, M.G.Kong; Cold atmospheric plasma decontamination of the pericarps of fruit, Journal of Food Protection, **71(2)**, 302-308 **(2008a)**.

[22] S.Perni, G.Shama, M.G.Kong; Cold atmospheric plasma disinfection of cut fruit surfaces contaminated with migrating microorganisms, Journal of Food Protection, **71(8)**, 1619-1625 **(2008b)**.

[23] A.H.Rady, D.P.Schwartz; Effect of gamma irradiation on some minor classes of chicken lipids, Arab.J.Nuclear Sci.and Application, **24**, 149-163 **(1991)**.

[24] A.Schwabedissen, P.Lacinski, X.Chen, J.Engemann; Plasma Label - A new method to disinfect goods inside a closed package using dielectric barrier discharges, Contributions to Plasma Physics, **47(7)**, 551-558 **(2007)**.

[25] E.Stahl; Thin layer chromatography, A Laboratory Hand Book, Published by Springer Verloag Berlin, Heidelberg, New York, **(1969)**.

[26] C.Temur, O.Tiryaki; Irradiation alone or combined with other alternative treatments to control postharvest diseases, African Journal of Agricultural Research, **8(5)**, 421-434 **(2013)**.

[27] M.Vleugels, G.Shama, X.T.Deng, E.Greenacre, T.Brocklehurst, M.G.Kong; Atmospheric plasma inactivation of biofilm-forming bacteria for food safety control, IEEE Transactions on Plasma Science, **33(2)**, 824-828 **(2005)**.

[28] World Health Organization (WHO); Wholesomeness of irradiated food, WHO Technical Reports Series, 659, Geneva, World Health Organisation, 34 **(1981)**.

[29] World Health Organization (WHO); High-dose irradiation: Wholesomeness of food irradiated with doses above 10 kGy, Report of a Joint FAO/IAEA/WHO Study Group, Technical Report Series N_890, Geneva, Switzerland, WHO, **(1999)**.

[30] J.H.Zar; Biostatistical Analysis, Prentice Hall, Englewood, N.J., 718 **(1984)**.