

Keeping the quality of cows' butter by γ -irradiation

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RESUMEN

La radiación- γ mantiene la calidad de la mantequilla de vaca

En esta investigación se estudió el uso de la radiación gamma para mantener la calidad de la mantequilla de vaca. Muestras de mantequilla fresca fueron expuestas a diferentes dosis de radiación gamma (0, 2.5 y 5 kGy) y guardadas en frío. Se determinaron parámetros microbiológicos y lipídicos, incluyendo el análisis de ácidos grasos y constituyentes del insaponificable mediante cromatografía gaseosa, y la estabilidad de la mantequilla por rancimat. Los resultados indicaron que la radiación gamma a la dosis de 2.5 kGy reducía el número total de bacterias, bacterias lipolíticas, coliformes, hongos y levaduras, aunque la recuperación era gradual con el tiempo de almacenamiento. A la dosis de 5 kGy, el efecto sobre el número total de bacterias fue más acentuado, hubo una recuperación gradual, pero el resto de microorganismos estudiados desaparecieron completamente. Los tratamientos de irradiación aumentaron la acidez y los peróxidos en la mantequilla, sin alterar el índice de yodo. La radiación gamma aumentó ligeramente el total de ácidos grasos volátiles, de ácidos grasos saturados y de hidrocarburos; mientras que redujo ligeramente el total de ácidos grasos insaturados y el de esteroides. La irradiación de la mantequilla afectó negativamente su estabilidad, aumentando gradualmente la acidez tanto en las muestras irradiadas como en las no irradiadas. Con el presente estudio se demuestra que la irradiación gamma a las dosis de 2.5 y 5 kGy podría mantener la calidad de la mantequilla de vaca e incrementar su vida útil si se mantiene a $4 \pm 1^\circ\text{C}$ durante 8 y 12 semanas cuando se compara con la mantequilla no irradiada y almacenada durante 4 semanas (basado en la apariencia visual del crecimiento de hongos en la superficie de las muestras), sin efectos sobre las propiedades sensoriales.

PALABRAS-CLAVE: Irradiación-Mantequilla-Ácido graso (composición)- Estabilidad-Insaponificable.

SUMMARY

Keeping the quality of cows' butter by γ -irradiation

This investigation aims to study the use of gamma irradiation for keeping the quality of cows' butter. Fresh butter samples were exposed to gamma irradiation at doses of 0, 2.5 and 5 kGy followed by refrigerated storage and the effects of these treatments on the microbiological aspects and lipid characteristics of butter samples were studied. Moreover, fatty acid profiles and unsaponifiable matter constituents were determined by gas chromatographic analysis, while the stability of butter was determined by rancimat. The results indicated that gamma irradiation at 2.5 kGy dose reduced the counts of total bacteria, lipolytic bacteria, coliforms, molds and yeasts, however, these counts gradually increased during cold storage. Also irradiation at 5 kGy dose greatly reduced the total bacterial count which gradually increased upon storage, while completely eliminated the other determined microorganisms. Irradiation treatments increased the acid value and peroxide value of butter, while the

iodine number was not altered. Moreover, gas chromatographic analysis showed that gamma irradiation slightly increased the total volatile fatty acids, total saturated fatty acids and total hydrocarbons, while slightly decreased the total unsaturated fatty acids and total sterols. In addition, irradiation of butter decreased its stability as determined by rancimat and upon storage of both irradiated and non irradiated butter samples, the acid value gradually increased, while a flexuous changes in the peroxide value were observed. The present study proved that 2.5 and 5 kGy gamma irradiation doses could keep the quality of cows' butter and increased its shelf life at $4 \pm 1^\circ\text{C}$ for 8 and 12 weeks as compared to 4 weeks for non irradiated butter (based on the visual appearance of mold growth on the surface of samples) without any effects on its sensory properties.

KEY-WORDS: Irradiation-Butter-Fatty acid (composition)-Stability-Unsaponifiable constituents.

1. INTRODUCTION

A wide variety of consumer and industrial products is manufactured by processing raw milk into dairy products. Among them, butter which is one of the primarily fat sources and an important source of dietary energy. It has been produced since ancient times and was an internationally traded commodity as early as the 14th century. Historically, it was an expensive commodity and its price remained relatively high even after the introduction of large-scale production (Varnam and Sutherland, 1994). The most important selling attribute of butter is its flavor, which is the main reason for its higher selling price than that of other fats (Jebson, 1994). Examples of competitor products include vegetable oil-based margarine, low fat spreads, blended spreads and liquid vegetable oils. However, none can match the desirable flavor and mouth-feel that butter imparts to food, and in many cases butter has secured high value markets based on flavor and natural dairy identity (Holdsworth and Haylock, 1995).

Besides fats, butter contains small percentages of proteins, milk sugar and water which make it a suitable substrate for microorganisms (Catsberg and Kempen-van Dommelen, 1990). Although butter spoilage is most often due to the development of chemical rancidity, microbiological problems do also occur in the form of cheesy, putrid or fruity odors and

the rancid flavor produced by hydrolysis. Many psychrotrophic strains of bacteria, yeasts and molds have been implicated in spoilage and lipolysis of butter at temperatures below 5°C and some even below 0°C. Moreover, some pathogenic bacteria such as *Staphylococcus aureus* and *Listeria monocytogenes* remained recoverable in low temperature stored butter (Varnam and Sutherland, 1994; Murphy, 1981; Smith and Alford, 1984 and Collins et al., 1989).

Recently, great efforts are taken to avoid preservatives in dairy products (Mogenson, 2000). On the other hand, processing food by ionizing radiation is increasingly recognized as the most effective safe method for ensuring the microbiological safety and preserving foods in the fresh state for long periods (Wills, 1986; WHO, 1988, 1999; Monk et al., 1995 and Anon, 2001), and it has been successfully used for keeping the quality of many foodstuffs including dairy products (Ibrahim, 1984; Thayer et al., 1996; Alur et al., 1998 and Rady et al., 1999). Moreover Girgis et al., (1987) found that the application of gamma irradiation at doses up to 10 kGy could prolong the shelf life of butter. However a slight oxidized flavor was observed. Therefore, the present study aims to investigate the possibility of keeping the quality of cows' butter through the application of low doses of gamma radiation.

2. MATERIAL AND METHODS

Preparation and packaging of butter

Unpasteurized fresh cows' milk was separated into cream then, cream was churned into butter. The resultant butter was divided into appropriate samples and packaged in sealed polyethylene pouches for irradiation treatments.

Irradiation procedures

The sealed pouches of cows' butter (except control samples) were gamma irradiated at doses of 2.5 and 5 kGy using a Cobalt-60 source at the National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt. Samples were surrounded by ice to keep them cold during irradiation.

Storage

Irradiated and non irradiated samples were refrigeration stored ($4 \pm 1^\circ\text{C}$) and weekly subjected to the periodical analysis for microbiological aspects, lipid characteristics and sensory properties until the rejection of samples which was mainly based on the visual appearance of mold growth on samples

(depending on the sensory evaluation), while the determinations of fatty acids composition, unsaponifiable matter constituents and stability were carried out post irradiation treatment only. All analyses (except for gas chromatography) were performed using triplicate samples per treatment. The standard deviation was then calculated according to Snedecor and Cochran (1983). For gas chromatographic analyses, the preparation of fatty acids methyl esters (or the separation of unsaponifiable matter) was carried out for each of sample replicates individually, the resultant (methyl esters or unsaponifiable matter) for all replicates per treatment were then mixed well and chromatographically analyzed as one sample.

Microbiological analysis

Before opening, the outer surface of each of butter pouches was sterilized using cotton wipped by 70% ethanol, and under aseptic conditions, pouches were opened for preparing the required serial saline dilutions according to the methods described by Richardson (1985). Before plating, all saline dilution blanks and pipettes were warmed to 40-45°C and kept warm. To prepare the initial 1: 10 dilution, 10 g of butter were aseptically transferred into sterile conical flask and rotated in a water bath at not over 40°C until the sample is fluid enough with avoiding separation of fat and serum fractions. Then 90 ml of warm sterile saline dilution were immediately added to the melted sample and mixed well by shaking. This dilution was immediately used for preparing the other higher dilutions. Then, the total bacterial count was determined according to pour colony count method using plate count agar medium as described by APHA (1992). Plates were incubated at 30°C for 3 days. Total lipolytic bacteria were enumerated using tributyrin agar medium after incubation at 25°C for 48h as recommended by Collins et al. (1989). Total coliforms were counted using violet red bile agar medium after incubation at 37°C for 24 h (Roberts et al., 1995). Total molds and yeasts were enumerated on potato glucose agar medium as described by Collins et al. (1989). Plates were incubated at 23°C for 5 days.

Chemical characteristics

Acid value and peroxide value were determined according to AOCS (1989) Official methods. Iodine number (Hannas) was determined according to AOAC (1995) Official methods.

Fatty acid composition

Fatty acid methyl esters were prepared according to Anon (1966) and analyzed with a PYE Unicam gas

chromatograph (Model 4550) equipped with flame ionization detector. The fractionation of fatty acid methyl esters was conducted using coiled glass column (1.6 m x 4 mm) packed with Chromosorb C and coated with 10% polyethylene glycol adipate (PEGA). The oven temperature was 180°C, while the temperatures of injector and detector were 250°C and 300°C, respectively. The hydrogen, nitrogen and air flow rates were 33, 30 and 300 ml/min, respectively. The peak areas and retention times were measured using Spectra Physics 4719 integrator.

Unsaponifiable matter (USM) constituents

USM constituents were separated according to AOCS (1989) Official methods and analyzed with a Hewlett-Packard gas chromatography equipped with flame ionization detector. The column used for the USM analysis was a 25m x 0.2 mm I.D fused silica capillary column coated with dimethyl silicon fluid. Carrier gas was nitrogen at flow rate 20 ml/min and hydrogen and air flow rates were 30 and 400 ml/min, respectively (split ratio was 1/200). The temperature program was: 100-280°C at 5°C/min then the oven temperature was held at the maximum temperature

for 20 min. Peak areas and retention times were determined using a Hewlett-Packard 3392-A integrator. The identification of fatty acids and USM constituents was performed by comparing the relative retention time (RRT) of compounds with those of standard materials.

Stability of butter

The induction period of cows' butter oil samples was determined at 100°C using the 679 Rancimat instrument. 2.5 g butter oil sample was weighed out in a reaction vessel which was then placed in heating block for 10 min to preheat the sample. The air supply and absorption vessels which contained deionized water (used as absorption solution for conductivity measurements) were connected and recording of the conductivity curves were started (Läubli and Bruttel, 1986).

Sensory evaluation

Non irradiated and irradiated cows' butter samples were sensory evaluated for their color and appearance as well as their flavor (odor, taste and texture) post treatment and during storage. The

Table I
Microbiological aspects of cows' butter as affected by gamma irradiation and cold storage ($4 \pm 1^\circ\text{C}$)

Storage (week)	Microbial counts (Mean \pm SD cfu/g) / Irradiation dose (kGy)											
	Total bacterial count			Total lipolytic bacteria			Total coliforms			Total molds and yeasts		
	0	2.5	5	0	2.5	5	0	2.5	5	0	2.5	5
0	2.8x10 ⁵	7 x10 ⁴	3x10 ³	7.8x10 ³	2x10 ²	N.D	2.8x10 ³	1.1x10 ²	N.D	1x10 ³	N.D	N.D
	$\pm 4.6 \times 10^5$	$\pm 1.6 \times 10^2$	$\pm 2.8 \times 10$	$\pm 4 \times 10$	$\pm 0.8 \times 10$		$\pm 1.8 \times 10$	$\pm 0.4 \times 10$		$\pm 0.8 \times 10$		
1	8x10 ⁵	9.4x10 ⁴	5.1x10 ³	9.2x10 ³	3.1x10 ²	N.D	4x10 ³	2.6x10 ²	N.D	6x10 ³	N.D	N.D
	$\pm 7.7 \times 10^5$	$\pm 3.6 \times 10^2$	$\pm 3 \times 10$	$\pm 7 \times 10$	$\pm 0.7 \times 10$		$\pm 3 \times 10$	$\pm 0.6 \times 10$		$\pm 3 \times 10$		
2	3.3x10 ⁶	2.2x10 ⁵	8x10 ³	1.4x10 ⁴	5x10 ²	N.D	6.6x10 ³	3.2x10 ²	N.D	2.1x10 ⁴	2.8x10 ²	N.D
	$\pm 1.2 \times 10^3$	$\pm 5 \times 10^2$	$\pm 4 \times 10$	$\pm 7 \times 10$	$\pm 1 \times 10$		$\pm 3.7 \times 10$	$\pm 0.9 \times 10$		$\pm 7.2 \times 10$	$\pm 0.5 \times 10$	
3	6x10 ⁶	3.8x10 ⁵	1.2x10 ⁴	2.7x10 ⁴	8x10 ²	N.D	1x10 ⁴	5x10 ²	N.D	6x10 ⁴	7x10 ²	N.D
	$\pm 1.7 \times 10^3$	$\pm 1 \times 10^3$	$\pm 7 \times 10$	$\pm 1 \times 10^2$	$\pm 2 \times 10$		$\pm 6 \times 10$	$\pm 1.2 \times 10$		$\pm 1.3 \times 10^2$	$\pm 1.5 \times 10$	
4	9.4x10 ⁶	6.6x10 ⁵	2.1x10 ⁴	4x10 ⁴	1.4x10 ³	N.D	2.5x10 ⁴	7.3x10 ²	N.D	1.4x10 ⁶	1.6x10 ³	N.D
	$\pm 3 \times 10^3$	$\pm 9 \times 10^2$	$\pm 6.5 \times 10$	$\pm 1.8 \times 10^2$	$\pm 2 \times 10$		$\pm 8 \times 10$	$\pm 1.6 \times 10$		$\pm 3 \times 10^2$	$\pm 1.7 \times 10$	
5	(R)	8.3x10 ⁵	3x10 ⁴	(R)	2x10 ³	N.D	(R)	9.1x10 ²	N.D	(R)	2.4x10 ³	N.D
		$\pm 1 \times 10^3$	$\pm 1.2 \times 10^2$		$\pm 2.5 \times 10$			$\pm 1.4 \times 10$			$\pm 2 \times 10$	
6		1.7x10 ⁶	4.4x10 ⁴		3x10 ³	N.D		1.2x10 ³	N.D		3.7x10 ³	N.D
		$\pm 2 \times 10^3$	$\pm 1 \times 10^2$		$\pm 3.7 \times 10$			$\pm 1.7 \times 10$			$\pm 2.7 \times 10$	
7		2.8x10 ⁶	6.1x10 ⁴		5x10 ³	N.D		2x10 ³	N.D		7x10 ³	N.D
		$\pm 1.8 \times 10^3$	$\pm 1.5 \times 10^2$		$\pm 3 \times 10$			$\pm 2.2 \times 10$			$\pm 3.8 \times 10$	
8		3.6x10 ⁶	8.6x10 ⁴		7.3x10 ³	N.D		2.8x10 ³	N.D		1.1x10 ⁴	8x10
		$\pm 3.5 \times 10^3$	$\pm 3 \times 10^2$		$\pm 5 \times 10$			$\pm 2.6 \times 10$			$\pm 5.5 \times 10$	$\pm 0.3 \times 10$
9		(R)	1.2x10 ⁵	(R)	(R)	N.D		(R)	N.D		(R)	1.4x10 ²
			$\pm 4.6 \times 10^2$									$\pm 0.5 \times 10$
10			2.8x10 ⁵			N.D			N.D			2.6x10 ²
			$\pm 7 \times 10^2$									$\pm 0.4 \times 10$
11			3.4x10 ⁵			N.D			N.D			6.2x10 ²
			$\pm 9 \times 10^2$									$\pm 0.9 \times 10$
12			6x10 ⁵			N.D			N.D			1.3x10 ³
			$\pm 1 \times 10^3$									$\pm 1.6 \times 10$
13			(R)			(R)			N.D			(R)

(R)= Rejected

N.D.= Not detected

panelists consisted of ten non expert members of food irradiation laboratory using the following 9-point quality scores (as described by Wierbicki 1981): 9= excellent, 7= good, 5= fair, 3= poor and 1= extremely poor.

3. RESULTS AND DISCUSSION

Microbiological aspects

Total bacterial count

Data presented in Table I indicate that non irradiated butter samples had a relatively high initial total bacterial count reaching 2.8×10^5 cfu/g. This may be attributed to the effect of both separation and churning processes on the breaking up of bacterial clumps which increases the number of colony forming units for cream and butter (especially in absence of pasteurization and salt) as illustrated by Adams and Moss (1995). The destructive effect of gamma irradiation on bacteria was clearly noticeable and proportional to the applied dose as the total bacterial count reduced by 75% and 98.9% by the application of irradiation at 2.5 and 5 kGy doses, respectively. However, cold storage gradually increased the total bacterial count for both irradiated and non irradiated samples but with lower rates for the former ones. Similar results were observed by Hassan (1984) and Girgis et al. (1987).

Total lipolytic bacteria

Subjecting cows' butter to gamma irradiation at a dose of 2.5 kGy reduced the count for total lipolytic bacteria by 97.4%, while lipolytic bacteria were not detected in samples exposed to 5 kGy dose (Table I). During subsequent storage, further gradual increases in the counts of lipolytic bacteria were observed for non irradiated samples and those exposed to 2.5 kGy gamma irradiation dose with a rates being higher for control samples. Meanwhile lipolytic bacteria remained undetectable during the storage of samples irradiated at 5 kGy dose indicating the complete elimination of these bacteria. These results are in agreement with those observed by Girgis et al. (1987).

Total coliforms

Data given in Table I further illustrate the presence of coliforms in non irradiated butter samples at counts reached 2.8×10^3 cfu/g. The presence of coliforms in butter was previously reported by Hassan (1984) and Collins et al. (1989). Treating butter samples by gamma rays at dose of 2.5 kGy greatly reduced the initial coliforms count which decreased by 1.4 log cycle. However, another

gradual increase in the counts of coliforms was observed for control and 2.5 kGy irradiated samples but at higher rates for control samples. The multiplication of certain coliforms at temperatures even below 4.4°C was also reported by Tompkin (1983). Regarding samples irradiated at 5 kGy dose, coliforms were completely eliminated as they were not detected post treatment and upon storage of samples.

Molds and yeasts

From Table I, the results reveal that the control butter samples had an initial count of 1×10^3 cfu/g for molds and yeasts, while no viable colony forming units were detected for butter samples post treatment by gamma irradiation at doses undertaken. Upon cold storage, the initial count of molds and yeasts gradually increased with high rates in control samples till their rejection. It has been reported that low water activity is a natural condition in butter and with the high lipid content, mold spoilage can be the main problem (Gray and Sørhaug, 1983). Treatment of butter by gamma rays at dose of 2.5 kGy delayed the detection of viable colony forming units of molds and yeasts for one week then, molds and yeasts started to be countable with gradual increase till the rejection of samples. Delaying the presence of viable colony forming units for molds and yeasts was much higher upon irradiation of butter at 5 kGy dose as they started to be countable at low levels after 7 weeks of storage and showed a slight gradual increase till the rejection of samples. The resistance of some species of fungi and yeasts to gamma irradiation had been illustrated by Sommer (1973) and ICMSF (1980).

Chemical characteristics

Acid value (AV)

As shown in Table II, detectable increases in the AV were observed for irradiated butter samples post treatments. This increase may be attributed to the liberation of free fatty acids due to the direct effect of irradiation on the ester bonds of the triglycerides as reported by IAEA (1982) and Rady and Schwartz (1991). Moreover, further gradual increase in the AV was observed for all samples under investigation but with rates being higher for non irradiated ones. Similar results were obtained by Connel et al. (1977). The observed increases in the acid value upon storage of control and 2.5 kGy irradiated samples could be attributable to lipolysis resulting from the presence of the lipolytic microorganisms. Many strains of bacteria, molds and yeasts have been implicated in lipolysis of butter at refrigeration temperatures (Varnam and Sutherland, 1994).

Table II
Chemical characteristics of cows' butter as affected by gamma irradiation and cold storage ($4 \pm 1^\circ\text{C}$)

Storage (week)	Determination (Mean \pm SD) / Dose (kGy)								
	Acid value			Peroxide value (meq/kg)			Iodine number		
	0	2.5	5	0	2.5	5	0	2.5	5
0	0.076 ± 0.001	0.111 ± 0.001	0.186 ± 0.002	0.557 ± 0.001	1.034 ± 0.011	1.966 ± 0.009	25.120 ± 0.007	25.070 ± 0.009	24.960 ± 0.013
1	0.171 ± 0.003	0.188 ± 0.003	0.212 ± 0.003	0.836 ± 0.004	1.522 ± 0.009	2.446 ± 0.017	24.890 ± 0.006	25.000 ± 0.012	24.930 ± 0.017
2	0.344 ± 0.007	0.276 ± 0.003	0.253 ± 0.002	1.278 ± 0.007	2.111 ± 0.017	3.000 ± 0.024	25.070 ± 0.010	24.960 ± 0.017	25.000 ± 0.020
3	0.602 ± 0.011	0.381 ± 0.005	0.334 ± 0.005	1.033 ± 0.012	2.455 ± 0.023	2.365 ± 0.019	25.110 ± 0.012	25.000 ± 0.014	24.940 ± 0.018
4	0.811 ± 0.043	0.510 ± 0.007	0.400 ± 0.007	1.767 ± 0.023	1.860 ± 0.021	2.803 ± 0.031	25.080 ± 0.017	25.010 ± 0.020	25.000 ± 0.016
5	(R)	0.623 ± 0.010	0.474 ± 0.005	(R)	2.202 ± 0.022	3.144 ± 0.070	(R)	25.080 ± 0.018	25.060 ± 0.020
6		0.702 ± 0.009	0.532 ± 0.007		1.921 ± 0.019	3.533 ± 0.056		24.900 ± 0.016	25.100 ± 0.026
7		0.810 ± 0.025	0.641 ± 0.012		2.410 ± 0.027	3.010 ± 0.082		25.000 ± 0.026	24.880 ± 0.019
8		0.893 ± 0.037	0.690 ± 0.009		2.366 ± 0.03	2.776 ± 0.074		24.880 ± 0.018	25.010 ± 0.022
9		(R)	0.800 ± 0.013		(R)	3.200 ± 0.063		(R)	25.070 ± 0.027
10			0.911 ± 0.018			3.732 ± 0.110			24.960 ± 0.019
11			1.107 ± 0.022			4.060 ± 0.170			25.000 ± 0.030
12			1.300 ± 0.019			3.855 ± 0.090			24.870 ± 0.028
13			(R)			(R)			(R)

(R) = Rejected

Regarding samples exposed to the higher irradiation dose, in which lipolytic bacteria were completely eliminated by irradiation, the observed increases in AV may be due to lipases naturally present from milk or introduced by microorganisms and survived treatments as illustrated by Jebson (1994).

Peroxide value (PV)

A marked increase in the PV, proportionally to the applied dose, was noticeable for irradiated butter samples post treatments as compared with non irradiated ones (Table II). Similar results were also reported by Luzac(1970) and Ivanov and Stamatov (1975). Furthermore, a flexuous changes in the PV were observed upon subsequent storage for both irradiated and non irradiated samples, however, all values were within the acceptable levels. It is well known that the types of chemical changes initiated in lipids by ionizing radiation are similar to those occurring in the autoxidation process (Lakritz and Maerker, 1989 and Mörssel, 1998) and the oxidative chemical changes are dose dependent (Katusin-Razem et al., 1992).

Iodine number

Table II clearly indicates that the iodine number of cows' butter samples was not really altered neither

by gamma irradiation nor cold storage as the observed values ranged between 24.87 and 25.12. These results did not agree with the findings of Girgis et al. (1987) who found that gamma irradiation and subsequent storage slightly decreased the iodine number for butter samples.

Fatty acids profiles

Table III illustrates the effect of gamma irradiation on fatty acids profiles of cows' butter post treatments. Cows' butter contained 49.43% saturated fatty acids (SFA) and palmitic acid was the major SFA (22.81%) followed by stearic (10.21%), myristic (6.79%), arachidic (3.64%), lauric (1.49%) and margaric (1.39%), respectively, while other SFA present in cows' butter were found to be in minor concentrations (<1%). On the other hand, total unsaturated fatty acids (UFA) amounted to 50.57% and oleic acid was the predominant mono-UFA (34.83%) followed by palmitoleic acid (3.91%), while the other UFA were present in minor concentrations. Moreover, linoleic and eicosatrienoic acids amounted to 6.98% and 2.73%, respectively. The predominance of palmitic and oleic acids was also previously reported with similar trends for the other major fatty acids in milk fat (Varnam and Sutherland, 1994; Gunstone, 1996) and butter fat (Kamel and Kakuda, 1994; Lawson,

1995). It is obvious from Table III that gamma irradiation slightly increased the total volatile fatty acids from 2.435% in control samples to 2.628% and 2.670% in those irradiated at 2.5 and 5 kGy, respectively. Moreover, subjecting butter samples to the ascendant doses of γ -rays induced a slight gradual decrease in total UFA, while slightly increased the total SFA. This may be due to the oxidation of UFA leading to an increase in the total SFA. These results are in well agreement with the noticeable decrease in butter stability due to gamma irradiation (Fig 1).

Unsaponifiable matter constituents

Upon fractionation of hydrocarbons for non irradiated cows' butter samples, the results revealed that the identified hydrocarbons consisted of 12 compounds, among them, squalene, C₂₁, C₃₁, C₂₀ and C₂₈ were present in comparatively higher concentrations when compared with the other hydrocarbons. While cholesterol was the only sterol compound observed in cows' butter oil (Table IV). It is clearly observed that the application of ascendant doses of gamma rays induced noticeable increases in the total hydrocarbons with appearance of C₁₀ and C₁₁ compounds. Moreover, squalene, C₂₁ and C₁₈ compounds decreased, while the unknown compounds increased with another minor changes for the other hydrocarbons due to gamma irradiation. Nawar et al. (1990) and Mörsel (1998) illustrated the increase in hydrocarbons upon irradiation of lipids. On the other hand, cholesterol, the only sterol compound, showed a slight gradual decreases upon the application of ascendent doses of γ -rays which may be attributable to partial slight oxidation. Oxidation of cholesterol due to gamma irradiation was previously reported by other investigators (Lakritz and Maerker, 1989 and Maerker and Jones, 1992).

Butter stability

The stability of non irradiated cows' butter oil was 8.92 ± 0.01 hours as determined by rancimat at 100°C. Fig. 1 clearly illustrates that exposing butter samples to gamma irradiation gradually decreased their stability with increasing the applied dose. The butter stability decreased to 4.27 ± 0.02 and 3.32 ± 0.02 hours after exposure of butter samples to 2.5 and 5 kGy doses, respectively. The decrease in butter stability might be due to the effect of gamma irradiation on the natural antioxidants present in cows' butter as carotenoids. In addition, this decrease in butter oil stability might be also attributed to the observed partial autoxidation of UFA of cows' butter (Table II).

Table III
Effects of gamma irradiation on fatty acids profiles of cows' butter

Fatty acids	Gamma irradiation dose (kGy)		
	0.0	2.5	5.0
6 : 0	-	0.040	0.051
8 : 0	0.060	0.081	0.080
10 : 0	0.612	0.701	0.751
10 : 1	0.115	0.122	0.101
11 : 0	0.159	0.164	0.165
12 : 0	1.489	1.520	1.522
12 : 1	0.385	0.330	0.328
13 : 0	0.842	0.814	0.811
14 : 0	6.787	6.825	6.827
14 : 1	1.618	1.677	1.674
15 : 0	1.425	1.392	1.390
16 : 0	22.807	22.940	23.001
16 : 1	3.911	3.969	3.966
17 : 0	1.391	1.411	1.415
18 : 0	10.215	10.435	10.433
18 : 1	34.829	34.666	34.601
18 : 2	6.982	6.811	6.812
20 : 0	3.641	3.565	3.558
20 : 3	2.732	2.574	2.514
Total volatile FAs	2.435	2.628	2.670
Total saturated FAs	49.428	49.888	50.004
Total unsaturated FAs	50.572	50.112	49.996
Total monoenes	40.858	40.727	40.670
Total dienes	6.982	6.811	6.812
Total polyenes	2.743	2.574	2.514

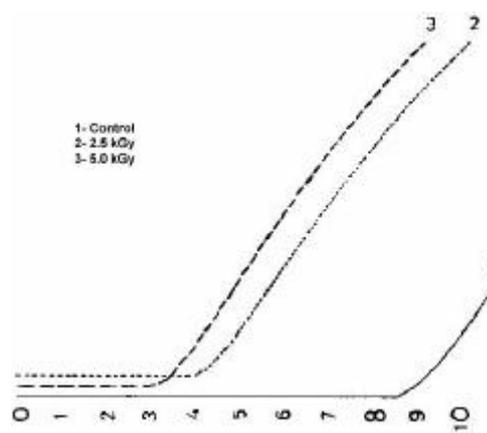


Figure 1
Induction period of non irradiated and irradiated cows' butter in hours at 100°C.

Sensory properties

Table V represents the mean of scores for color and appearance of cows' butter samples as well as their flavor (including aroma, taste and texture) post treatments and upon refrigeration storage. It is obvious that gamma irradiation had no adverse effects on the sensory quality attributes of butter. Both irradiated and non irradiated butter samples were highly acceptable for their color and appearance. Although some carotenoids (the main coloring agent in cows' milk fat) has been assumed to be altered by irradiation, as indicated by the reduced stability (Fig. 1), the visual color was not apparently altered as evaluated by the panelists. It has been reported that the color of butter is not only determined by the level of carotene in the milk fat, but also by the size distribution of the water droplets and the finer the droplets, the greater the scattering of light, the lighter the color of butter (Jebson,1994). Besides, all butter samples had a clean "buttery" flavor with a pleasant mouth feel and free from flavor defects including those caused by the feed of cows', processing, microorganisms and oxidation. These results did not agree with the findings of Girgis et al. (1987) who observed a slight oxidized flavor for butter irradiated at 5 kGy dose. Upon cold storage of samples, the non irradiated butter samples became completely unacceptable and rejected at the 5th week of storage due to pronounced visual growth of molds on the surface of samples as well as the moldy flavor of butter. While small mold spots were visually observed on the surface of butter samples exposed to gamma irradiation at 2.5 kGy dose after 8 weeks of storage, therefore samples were rejected although they still had an acceptable flavor. Irradiation of samples at dose of 5 kGy had more effect on

Table IV
Effects of gamma irradiation on unsaponifiable matter constituents of cows' butter

Component	Gamma irradiation dose (kGy)		
	0.0	2.5	5.0
C ₁₀	-	0.565	0.818
C ₁₁	-	1.236	1.632
Unknown	0.166	0.219	0.300
C ₁₅	0.344	0.634	0.864
Unknown	0.221	0.241	0.378
C ₁₈	0.312	0.200	0.166
C ₂₀	0.974	1.344	1.862
C ₂₁	1.977	1.609	1.410
C ₂₂	0.357	0.369	0.577
C ₂₃	0.322	0.212	0.232
C ₂₄	0.321	0.321	0.321
C ₂₅	0.287	0.407	0.467
C ₂₆	0.411	0.751	0.937
C ₂₈	0.777	0.747	0.595
Squalene	2.385	1.769	1.055
C ₃₁	1.846	1.276	1.476
Cholesterol	89.300	88.100	86.910
Total hydrocarbons	10.313	11.440	12.412
Total sterols	89.300	88.100	86.910
Total unknowns	0.387	0.460	0.678

retardation of visual mold growth as a very small spot of mold growth started to appear on the surface of butter samples at the 13th week of storage leading to the rejection of samples but also they were still acceptable for flavor.

In conclusion, gamma irradiation at 2.5 and 5 kGy could successfully prolong the shelf life of cows' butter for 8 and 12 weeks, respectively, compared to 4 weeks for control samples, based on the visual appearance of mold growth on the surface of samples.

Table V
Sensory attributes of cows' butter as affected by gamma irradiation and cold storage (4 ± 1°C)

Storage (week)	Mean of scores ± SD / Dose (kGy)					
	0.0 kGy		2.5 kGy		5.0 kGy	
	Appearance	Flavor	Appearance	Flavor	Appearance	Flavor
0	8.8±0.10	8.9±0.10	8.8±0.15	8.7±0.15	8.6±0.05	8.8±0.10
1	7.9±0.10	8.6±0.20	7.8±0.05	8.9±0.10	7.9±0.10	8.5±0.25
2	8.5±0.15	8.4±0.15	8.5±0.10	8.6±0.25	8.4±0.08	7.8±0.20
3	8.7±0.10	8.6±0.20	8.8±0.14	7.9±0.10	8.6±0.10	8.7±0.15
4	8.6±0.07	8.7±0.15	7.9±0.10	8.4±0.15	8.8±0.07	8.5±0.10
5	1.4 ±0.05 (R)	2.0±0.10 (R)	8.6±0.14	8.8±0.10	8.3±0.10	7.9±0.25
6			8.4±0.10	8.6±0.16	7.8±0.2	8.8±0.20
7			8.7±0.05	8.8±0.20	8.0±0.25	8.4±0.10
8			8.6±0.10	8.5±0.05	8.4±0.10	8.2±0.05
9			3.1±0.10 (R)	8.7±0.10	8.7±0.05	8.5±0.10
10					8.4±0.10	7.8±0.13
11					7.9±0.20	8.6±0.10
12					8.7±0.10	8.9±0.25
13					3.6±0.25 (R)	8.7±0.12

(R)= Rejected

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