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Quality Characteristics of Gamma Irradiated Beefburger Formulated with Partial Replacement of Beef Fat with Olive Oil and Wheat Bran Fibers

Karema A. Mahmoud[1], Hesham M. Badr[2,*]

[1]Atomic Energy Authority, National Center for Radiation Research and Technology, Cairo, Egypt; [2]Atomic Energy Authority, Nuclear Research Center, Abou Zaabal, Egypt.
Email: *heshambadr_aea@yahoo.co.uk

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ABSTRACT

Five beefburger formulations were prepared with substituting beef fat with olive oil and levels of wheat bran and irradiated at doses of 0 *and* 3 *kGy, then samples were refrigerated stored and their quality characteristics were investigated. The results indicated that replacement of beef fat with olive oil and ascending levels of wheat bran in burger batter significantly decreased their contents of total lipids and saturated fatty acids, while increased their contents of dietary fibers, unsaturated fatty acids and the ratios of unsaturated and polyunsaturated fatty acids to the saturated ones. Moreover, significant improvements were observed in the cooking yield and moisture and fat retention of samples, proportionally to the added wheat bran, and both raw and cooked burger samples showed a high sensory acceptability. Irradiation of samples effectively inactivated Staphylococcus aureus, Salmonella and enterobacteriaceae and significantly reduced the counts of mesophilic and psychrophilic bacteria as well as molds and yeasts without any adverse effects on the quality characteristics of samples. Thus, reducing beef fat levels with the addition of olive oil and wheat bran produced a highly acceptable beefburger products with improved nutritional content as well as improved cooking and binding properties, while irradiation improved their microbiological quality.*

Keywords: *Irradiation, Beefburger, Low-Fat, Microbiological Quality, Olive Oil, Wheat Bran*

1. Introduction

Food and its manufacture are currently attracting significant scientific and public interest due to extensive media coverage of diet-related diseases and their influence on the health and wellbeing of communities. Recent advances in food and nutrition sciences have highlighted that it is possible to help optimize certain physiological functions through the diet and/or dietary components in order to improve health status and wellbeing and/or reduce the risk of disease. Like other food-related sectors, the meat industry is undergoing major transformations, driven among other things by changes in consumer demands [1]. Meat and meat products are seen to be a major source of fat in the diet and provide high amounts of saturated fatty acids and cholesterol, which have been implicated in diseases include various cancers, obesity, hypertension, cardiovascular diseases, and coronary heart diseases [2-5]. A focus of dietary recommendations for cardiovascular disease prevention and treatment has been a reduction of saturated fat intake [6].

However, Fats in meat products play important role in stabilizing meat emulsions, reducing cooking loss, improving water holding capacity, providing juiciness and hardness and have considerable effects on the binding, rheological and structural properties of the meat product [7-9]. Fat reduction can, therefore, increase the toughness of meat products and significantly alter their acceptability [10,11]. The incorporation of vegetable oils in meat products to replace animal fat may have a positive effect on consumer health as they are free of cholesterol and have a higher ratio of unsaturated to saturated fatty acids. Moreover, different fiber-rich ingredients have recently been used as a functional additives to numerous ground and emulsified meat products to support and ensure binding. The reduction of animal fat in meat products and the substitution of animal fat with vegetable oils and dietary fibers could result in healthier products [12-14].

Of vegetable oils, olive is the one that has received most attention, chiefly as a source of monounsaturated fatty acids. It has a high biological value and contains antioxidant substances in optimum concentrations. Olive oil intake is associated with a lessened risk of heart disease and breast cancer and has positive effects on colon cancer [15-18]. In addition, interest in dietary fiber is a consequence of the belief that it contributes positively to the consumer's health and quality of life due to its physiological effects [19].wheat bran is the most popular source of dietary fiber, with widespread recommendations for prevention and treatment of constipation and diabetes and reducing the risk of certain types of cancer [20-23]. It forms a good source of protein and minerals, in addition to its high fiber content and antioxidant activity [24,25].

On the other hand, meat products constitute a major source for pathogens that cause foodborne illness in human and awareness of risks involving their microbial contamination showed a significant continuous increase. Food irradiation is proven to be the best technology in eliminating disease-causing pathogens from raw meat products [26,27]. Gamma irradiation at dose of 3 kGy can be applied for improving the microbiological safety of raw meat products [28]. Therefore, The objective of this study was to evaluate the quality characteristics of gamma irradiated beefburger formulated by partial replacement of the beef fat with different levels of olive oil and wheat bran fibers.

2. Materials and Methods

2.1. Materials

Fresh lean beef and beef fat were excised from three beef carcasses at the butcher's shop (after three hours of slaughtering and dressing) to be used for the preparation of burger formulations in three separate trials (3 different replicates). The lean beef cuts were trimmed off any subcutaneous or intramuscular fats as well as thick or connective tissue, being a very lean beef meat. Then the lean beef and beef fat (within each of the different replicates) were ground separately in a meat grinder. Whole wheat bran was obtained from Al-Sharkia Milling Company, Zagazig, Egypt. Defatted soy flour was obtained from the Agricultural Research Center, Ministry of Agriculture, Egypt. Olive oil and the other ingredients of high quality were obtained from a local market.

2.2. Beefburger Manufacturing

Five different beefburger formulations (F1-F5) were prepared within each trail replicate (**Table 1**). The control beefburger formula (F1) consisted of ground lean beef, ground beef fat, soy flour, salt, Sodium tripolyphosphate, dreied onion, spice mixture (black pepper and cumin), and water (within the percentages described by Feiner, [29]). Since a very lean beef cuts with an expected low fat content were used for burger formulation, ground beef fat was added at level of 200 g/kg meat batter in the control burger formulation. Then the other burger formulations (F2-F5) were prepared by partial replacement of the beef fat with different percentages of olive oil and wheat bran as shown in **Table 1**. The ingredients of each of the formulated burger batter were thoroughly mixed by hand and processed into burgers of about 100 g weight and 10 cm diameter. The prepared burgers were aerobically packaged (individually) in polyethylene pouches and pouches were sealed by heat.

Table 1. Beefburger formulations with varying levels of beef fat, olive oil, and wheat bran.

Ingredients	Amount (g/kg meat batter)/Formulations				
	F1	F2	F3	F4	F5
Lean beef	625	625	625	625	625
Beef fat	200	100	50	25	-
Olive oil	-	50	50	50	50
Whole wheat bran	-	50	100	125	150
Soy flour (defatted)	40	40	40	40	40
Salt	15	15	15	15	15
Sodium tripolyphosphate	2	2	2	2	2
Dried onion	3	3	3	3	3
Spice mixture (Black pepper & Cumin)	15	15	15	15	15
Water	100	100	100	100	100

Formulations: F1, the control meat batter; F2-F5, the different formulations prepared with replacement of beef fat with olive oil and wheat bran.

The observed burgers were divided into two main portions and immediately transported in an ice chest for irradiation treatment.

2.3. Irradiation of Samples

Packaged samples of the prepared beefburger were exposed to gamma irradiation at doses of 0 and 3 kGy. Irradiation was carried out at room temperature using an experimental Co-60 source (providing a dose rate of 2.527 kGy/h) located at the National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt.

2.4. Storage and Sampling

The irradiated and non-irradiated beefburger samples were refrigerated stored at 4˚C ± 1˚C (except samples for the day zero analysis) and subjected to the periodical analysis at 3 days intervals.

2.5. Proximate Composition

Moisture, protein, ash and dietary fibers were determined according to AOAC official methods [30], while total lipids were extracted and determined according to the method of Folch *et al.* [31]. The remaining of other carbohydrates were calculated by difference.

2.6. Fatty Acid Profiles

Fatty acids of the extracted lipids were converted to their methyl esters [32] and the analysis of fatty acid methyl esters (FAME) was accomplished using a 6890 Hewlett Packard gas chromatograph equipped with flam ionization detector. The peak areas and retention times were measured using a Hewlett Packard 3392A integrator. Identification of FAME was based on comparing their relative retention times with those of reference ones.

2.7. Cooking Yield, Moisture Retention and Fat Retention

Samples of beefburger were cooked in a preheated electrical grill for 4 min each side, then cooking yield and fat retention were calculated according to Murphy *et al.* [33], while moisture retention was determined according to El-Magoli *et al.* [34] using the following equations:

Cooking yield% = (Cooked burger weight)/(Uncooked burger weight) × 100

Moisture retention% = (% yield × % moisture in cooked burger)/100

Fat retention% = [(Cooked weight) × (% fat in cooked burger)/(Raw weigt) × (% fat in the raw burger)] × 100

2.8. Measurement of Oxidation

The extent of oxidation in raw beefburger samples was assessed through the determination of thiobarbituric acid reactive substances (TBARS) using the method of Alasnier *et al.* [35] and the results were expressed as mg malonaldhyde per kg burger meat.

2.9. Microbiological Quality

At time of withdrawal from refrigerated storage, 10 g aliquots of burger samples were removed aseptically to prepare the initial 1/10 dilution which was used for the preparation of other serial dilutions in 0.1% peptone water. Then colony forming units for total aerobic mesophelic and psychrophilic bacteria were determined by plating on plate count agar medium and incubation at 30˚C for 3 days and 7˚C for 7 days, respectively [36]. Total molds and yeasts were enumerated on malt agar medium after incubation at 25˚C for 3 - 5 days [36]. Enterobacteriaceae were counted on violet red bile glucose agar medium after incubation at 37˚C for 20 - 24 h [37]. *Staphylococcus aureus* was counted using Baird-Parker RPF medium after incubation at 35˚C for 24 - 48 h [38] and confirmed by the coagulase test as described by Collins *et al.* [39]. The detection of *Salmonella* was carried out using most probable number technique (MPN) according to ISO [40]. The samples were inoculated into buffer peptone for 24 h at 37˚C. After enrichment at 37˚C for 24 h in selenite broth, the cultures were streaked on brilliant green agar and incubated at 37˚C for 24 h, then biochemical examination in triple sugar iron agar (TSI) and lysine decarboxilase broth was conducted.

2.10. Sensory Evaluation

Raw samples of irradiated and non irradiated beefburger were subjected to sensory evaluation for their color & appearance and odor post treatment and during refrigerated storage, while the cooked beefburger samples were evaluated for their appearance and color, odor, taste and texture and juiciness on day zero only for safety precautions. In all sensory evaluation tests, the panelists consisted of ten non expert members from our laboratory, while scores were obtained by rating the examined quality attributes using the following rating scale: 9—excellent, 8—very good, 7—good, 6—below good/ above fair, 5—fair, 4—below fair/above poor, 3—poor, 2—very poor and 1—extremely poor. Rating of 5 and above indicated an acceptable samples, while rating of 4 indicated that the samples were of marginal quality, whereas rating of 3 and below indicated unacceptable samples [41].

2.11. Statistical Analysis

All analyses were performed using three pouches per each separate replicate. Then data were statistically analyzed by using the generalized linear model procedure of the SAS software [42], and the differences among means (at $p < 0.05$) were compared by using Duncan's multiple range test.

3. Results and Discussion

3.1. Proximate Composition

The results of compositional analysis for the different formulated beefburger samples are given in **Table 2**. The percentages of moisture, protein, total lipids, ash, dietary fibers, and carbohydrates in the non-irradiated control burger formula (F1) were 58.76%, 15.67%, 20.20%, 2.72%, 1.11%, and 1.54%, respectively. Incorporation of wheat bran into meat batter with the reduction of the added beef fat significantly increased the contents of total fibers and reduced the contents of total lipids for the resultant beefburger formulations, proportionally to the added bran fibers. The total lipids decreased by 20%, 42%, 53%, and 64%, while the dietary fibers increased by 206%, 412%, 514%, and 618%, respectively, in the different formulated burger samples (F2-F5) as compared with the control burger formulation (F1). Much attention has been recently paid to develop meat products with physiological functions to promote health conditions and prevent the risk of diseases [43]. Increased intake of dietary fibers has been recommended for reducing the risk of colon cancer, diabetes, obesity and cardiovascular diseases in human [43-45].The same results clearly indicate that non of the determined macronutrients for all formulated burger samples showed a significant ($P > 0.05$) changes due to gamma irradiation at dose of 3 kGy (**Table 2**).

3.2. Fatty Acid Profiles

Table 3 represents the fatty acid profiles of lipid separated from non-irradiated and irradiated beefburger under investigation. Lipids of all non-irradiated burger formulations contained the same fatty acids. However, lipids of the control burger formula (F1) had the highest content of saturated fatty acids (SFA) reaching 51.6% of the total fatty acids and the predominant SFA were palmitic, stearic, and myristic, respectively. Meanwhile, the total unsaturated fatty acids (UFA) reached 46.05% and oleic was the most abundant monounsaturated fatty acid, while linoleic and linolenic were the predominant polyunsaturated fatty acids. Similar results were reported for lipids of beef patties [46]. Incorporation of olive oil into the beef batter with decreasing of the added beef fat significantly ($P < 0.05$) decreased the contents of SFA in lipids of the different formulated burger samples accompanied with a significant increase of their USFA content, proportionally to the reduction of the added beef fat. Accordingly, a significant increases ($P < 0.05$) in the ratios of unsaturated/saturated and polyunsaturated/ saturated fatty acids were observed, indicating an improvement of the burger nutritional content (**Table 3**). Similar observations were reported for the replacement of the animal fat with vegetable oils in different meat products [12,47]. Healthier lipid formulation based on processing strategies is one of the most important current approaches to the development of potential meat-based functional foods [16]. It was shown that low-fat, monounsaturated-rich diet reduced the susceptibility of low density lipoprotein peroxidation and may be of therapeutic value in the treatment of hypercholesterolemia [48]. From **Table 3**, it can be also seen that lipids separated from the irradiated burger samples showed the same phenomenon and trends for their fatty acids similar to that observed for the non-irradiated samples. However, irradiation of the different formulated burger samples induced slight, but sta-

Table 2. Proximate composition of raw non-irradiated and irradiated (3 kGy) beefburger formulated with different levels of beef fat, olive oil, and wheat bran.

Components	Mean (g/100 g)									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
Moisture	58.76bc	58.71bc	58.92abc	59.02a	59.12a	58.73bc	58.70c	58.94ab	59.10a	59.09a
Protein	15.67e	15.92 d	16.28c	16.46abc	16.64ab	15.69e	15.93d	16.25c	16.44bc	16.67a
Total lipids	20.20a	16.15 b	11.72c	9.51d	7.30e	20.22a	16.13b	11.73c	9.53d	7.33e
Ash	2.72e	3.01d	3.30c	3.44b	3.59a	2.71e	3.03d	3.29c	3.40b	3.61a
Dietary fiber	1.11e	3.40d	5.68c	6.82b	7.97a	1.13e	3.41d	5.66c	6.79b	7.92a
Other carbohydrates by difference	1.54e	2.81d	4.10c	4.75b	5.38a	1.52e	2.80d	4.13c	4.74b	5.38a

Means with a different letter within each component are different significantly ($P < 0.05$).

Table 3. Fatty acid profiles of lipids separated from different formulated non-irradiated and irradiated (3 kGy) beefburger.

Fatty acids	Mean (g/100 g lipids) / Formulations									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
12:0	0.62b	0.34d	0.27e	0.21f	0.10h	0.71a	0.44c	0.32d	0.29e	0.17g
14:0	4.16a	2.73b	2.14c	1.64d	0.83e	4.15a	2.71b	2.12c	1.62d	0.81e
15:0	0.52a	0.29b	0.23c	0.18d	0.08e	0.52a	0.28b	0.23c	0.17d	0.02f
16:0	25.81a	20.22b	18.00c	16.13d	13.10e	25.88a	20.26b	18.02c	16.15d	13.12e
16:1	3.19a	2.32c	1.97d	1.66e	1.19f	3.13b	2.28c	1.95d	1.65 e	1.18f
17:0	1.28a	0.88b	0.69c	0.29d	0.05e	1.29a	0.89b	0.68c	0.28d	0.06e
18:0	18.98b	13.69d	11.31f	9.31h	6.06j	19.38a	14.19c	11.58e	9.52g	6.27i
18:1	38.97e	51.41d	55.70c	59.34b	65.17a	38.99e	51.44d	55.72c	59.36b	65.19a
18:2	3.28i	4.69g	6.44e	7.94c	10.42a	2.98j	4.25h	6.25f	7.83d	10.33b
18:3	0.48g	0.62e	0.77d	0.89c	1.10a	0.20i	0.38h	0.59f	0.77d	0.99b
20:0	0.23ef	0.22f	0.25d	0.28c	0.32a	0.24e	0.23ef	0.26d	0.30b	0.33a
20:1	0.13e	0.19c	0.21b	0.22b	0.25a	0.12e	0.19c	0.20b	0.21b	0.25a
SFA	51.60b	38.37d	32.89f	28.04h	20.54j	52.17a	39.00c	33.21e	28.33g	20.78i
UFA	46.05i	59.23g	65.09e	70.05c	78.13a	45.42j	58.57h	64.71f	69.82d	77.94b
MUFA	42.29e	53.92d	57.88c	61.22b	66.61a	42.24e	53.91d	57.87c	61.22b	66.62a
PUFA	3.76i	5.31g	7.21e	8.83c	11.52a	3.18j	4.66h	6.84f	8.60d	11.32b
U/S	0.892i	1.544 g	1.979e	2.498c	3.804a	0.871j	1.50h	1.949f	2.465d	3.751b
P/S	0.073i	0.138g	0.219e	0.315c	0.561a	0.061j	0.119h	0.203f	0.304d	0.545b

Means with a different letter within each fatty acid are different significantly ($P < 0.05$); SFA: Saturated fatty acids; UFA: Unsaturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; U/S: Unsaturated/Saturated; P/S: Polyunsaturated/Saturated.

tistically significant ($P < 0.05$), increase in the contents of SFA with corresponding significant decrease in the total UFA in their lipids. Similar results were previously observed [49].

3.3. Cooking Yield, Moisture Retention and Fat Retention

The measurements of cooking yield, moisture and fat retention in irradiated and non-irradiated beefburger samples as influenced by formulation with olive oil and wheat bran are summarized in **Table 4**. Formulation of beefburger with replacement of beef fat with olive oil and wheat bran significantly ($P < 0.05$) improved the cooking yield of samples as well as their moisture and fat retention. The observed improvement was pronounced with increasing the added bran fibers, as shown for the different formulated non-irradiated burger samples. The highest cooking loss was observed for the control formulated burger (F1) which may be attributed to the excessive fat separation and water release during cooking. The high ability of wheat fibers, as all other dietary fibers, to keep moisture and fat in the meat matrix of meat products is well documented and these observations are supported by several authors who used different types of fibers in the formulations of burger and other meat products [12,50,51]. Furthermore, cooking yield is influenced by the amount and type of fat in the meat product [52,53]. Reducing the animal fat content by replacement with vegetable oil increased the cooking yield of meat products [54]. Neither irradiation at 3 kGy nor refrigerated storage (4˚C ± 1˚C) could significantly ($P > 0.05$) affect cooking and binding properties of the different formulated beefburger samples under investigation. As shown, no significant differences ($P > 0.05$) were observed between the measurements of cooking yield, moisture retention and fat retention for irradiated and

Table 4. Cooking yield, moisture retention and fat retention during refrigerated storage of non-irradiated and irradiated (3 kGy) beefburger as affected by formulation with olive oil and wheat bran.

Storage (Days)	Parameter/mean (%)									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
	Cooking yield									
0	76.45e	80.84d	85.23c	87.43b	89.62a	76.52e	80.79d	85.30c	87.63b	89.73a
3	75.98e	81.02d	84.71c	87.88b	88.77a	76.16e	79.94d	85.41c	87.31b	88.93a
6	76.53e	80.65d	85.60c	87.22b	89.11a	75.89e	81.22d	85.71c	88.02b	89.80a
9	77.01e	80.44d	85.03c	88.07b	89.44a	76.32e	80.36d	85.13c	87.70b	89.33a
12	®	®	®	®	®	76.88e	80.72d	84.95c	87.10b	88.78a
	Moisture retention									
0	65.49e	69.25d	73.01c	74.90b	76.03a	65.61e	69.16d	72.88c	75.11b	76.22a
3	66.11e	68.92d	73.32c	75.11b	75.89a	66.18e	68.88d	73.05c	74.79b	76.51a
6	65.72e	69.03d	72.91c	44.79b	76.11a	66.01e	68.91d	73.00c	75.21b	75.93a
9	65.38e	69.43d	73.00c	75.01b	76.00a	65.70e	69.22d	72.73c	75.00b	76.27a
12	®	®	®	®	®	65.22e	69.07d	72.91c	74.92b	76.03a
	Fat retention									
0	71.29e	75.38d	79.48c	81.53b	85.06a	70.92e	75.52d	78.89c	82.01b	84.93a
3	70.99e	75.76d	78.84c	81.30b	84.93a	71.02e	75.38d	78.66c	82.17b	85.03a
6	71.00e	75.22d	79.53c	81.72b	85.00a	71.13e	76.02d	79.01c	81.94b	85.14a
9	71.42e	75.13d	79.31c	81.25b	85.13a	70.91e	75.65d	78.74c	82.00b	84.89a
12	®	®	®	®	®	71.00e	75.41d	79.00c	82.13b	85.00a

Means with a different letter within each parameter are different significantly ($P < 0.05$); ®: Rejected and their values were discarded after statistical analysis.

non-irradiated beefburger samples post treatment and during refrigerated storage at 4˚C ± 1 ˚C (**Table 4**).

3.4. Extent of Oxidation

The development of oxidation during refrigerated storage (4˚C ± 1˚C) of the different formulated irradiated and non-irradiated beefburger samples was assessed through the measurement of TBARS values (**Table 5**). On day zero, the different formulated non-irradiated beefburger samples had an initial TBARS values of 0.23, 0.19, 0.17, 0.14 and 0.13 mg malonaldehyde /kg burger meat, respectively, showing the highest value for the control formulated burger (F1). The oxidative reactions are enhanced in meat products after mincing and restructuring as well as during refrigerated storage due to the interaction of unsaturated fatty acids with prooxidants [55]. Irradiation of the different formulated beefburger samples at 3 kGy dose significantly ($P < 0.05$) increased their TBARS and the control formulated burger samples showed also the highest value. Moreover, subsequent refrigerated storage of the different formulated beefburger samples significantly ($P < 0.05$) increased their TBARS values for both irradiated and non-irradiated samples showing a higher values in the irradiated samples (**Table 5**). The oxidation of lipids due to irradiation and aerobic storage of meat products was previously reported by several authors [27,56]. As can be seen, the extent of oxidation significantly decreased with increaseing the added wheat bran in both non-irradiated and irradiated burger samples and also post irradiation and during storage, indicating the presence of enhanced antioxidant activity with increasing of the added bran fibers. The observed antioxidant activity was also apparent during the formulation of the burger batter as indicated by the significant decrease in the initial TBARS values with increasing of the added wheat bran for the different

Table 5. TBARS values for raw non-irradiated and irradiated (3 kGy) beefburger formulated with different levels of beef fat, olive oil, and wheat bran.

Storage (Days)	Mean (mg malonaldehyde/kg burger meat)/Formulations									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
0	0.23 r	0.19 rs	0.17 st	0.14 st	0.13 t	0.52 kl	0.44 mn	0.40 no	0.34 pq	0.29 qr
3	0.41 no	0.34 pq	0.29 qr	0.25 r	0.23 r	0.63gh	0.54 jk	0.47 lm	0.40 no	0.34 pq
6	0.59 hij	0.48 lm	0.44 mn	0.37 op	0.32 pq	0.81 ef	0.67 g	0.61ghi	0.52 kl	0.45 m
9	0.76 f	0.62 ghi	0.57 ijk	0.48 lm	0.43 mn	1.00 d	0.84 e	0.76 f	0.65 g	0.56 ijk
12	®	®	®	®	®	1.51 a	1.29 b	1.12 c	0.80 ef	0.83 e

Means with a different letter are different significantly ($P < 0.05$); ®: Rejected and their values were discarded after statistical analysis.

non-irradiated burger samples on day zero (**Table 5**). The observed antioxidant activity may be attributed to the added wheat bran fibers. It has been illustrated that wheat bran contains high total phenolic contents with high radical scavenging capability and antioxidant activity [25]. Furthermore, olive oil, virgin and refined, contains also phenolic compounds with high antioxidant power [18].

3.5. Microbiological Quality

The results in **Table 6** reveal a high initial microbial contamination in addition to the presence of *Staphylococcus aureus* and *Salmonella* in all formulated non-irradiated burger samples. It is well established that meats and meat products contain a broad spectrum of microorganisms and constitute a major source for foodborne pathogens [26]. Irradiation of all formulated beefburger samples at dose of 3 kGy appeared to be effective in improving the microbiological quality of samples. The chosen dose effectively destroyed the present *Staphylococcus aureus* and *Salmonella*, which were not detected in the irradiated samples post irradiation and during their refrigerated storage. This is in addition to the observed significant reduction in the counts of mesophelic and psychrophilic bacteria as well as molds and yeasts (**Table 6**) leading to the achievement of a duple refrigerated shelf life (data not presented). Irradiation is among the most effective physical decontamination technologies for inactivating foodborne pathogens and improving the safety of meats [26] and the effectiveness of such irradiation dose in improving the microbial safety of other meat products was also previously observed [57,58].

3.6. Sensory Properties

On day zero, the sensory evaluation of raw non-irradiated beefburger samples indicated that formulation of burger with olive oil and wheat bran had no adverse effects on the acceptability of their color and appearance as well as their odor. As shown in **Table 7**, the different formulated non-irradiated burger samples had a similar scores showing no significant differences between their sensory acceptability. The same results further show that irradiation and refrigerated storage (4˚C ± 1˚C) of the different formulated beefburger samples has no significant effect on the acceptability of these sensory attributes as all raw irradiated samples showed a similar high scores compared to the non-irradiated samples except that all non-irradiated burger samples showed a rejection sensory scores for their odor due to the detection of a putrid off-odor on day 12 of their storage (**Table 7**). Sensory evaluation was also carried out for the cooked burger samples and the sensory traits for cooked samples of the different formulated non-irradiated and irradiated beefburger are given in **Table 8**. Ratings by the sensory panel showed that there were no significant differences between the acceptability of the control formulated burger and those formulated with olive oil and wheat bran except the fifth formulated burger samples (that prepared with the highest addition of wheat) which showed a significantly lower score for their odor and taste, but were still acceptable, due to the absence of the beef fat. The same observations were recorded for the cooked irradiated burger samples indicating that irradiation of raw beefburger samples at the applied dose had no significant effects on their acceptability after cooking, showing a similar preference scores as compared with the non-irradiated samples (**Table 8**).These results show that formulation of beefburger with partial replacement of beef fat with olive oil and wheat bran produced acceptable samples compared to the control formulated burger samples with a consistent texture, adequate juiciness and good flavor. Wheat fiber is neutral in taste and help to retain

Table 6. Microbiological quality of the different formulated beefburger samples as affected by irradiation at dose of 3 kGy and refrigerated storage (4˚C ± 1˚C).

Storage (Days)	Determination/Formulations									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
	Aerobic mesophilic bacteria (mean $\log_{10}$ cfu/g)									
0	6.01d	6.04d	6.08d	6.10d	6.11d	3.88h	3.89h	3.88h	3.89h	3.89h
3	6.27c	6.28c	6.32c	6.35c	6.36c	3.94g	3.94g	3.94g	3.94g	3.95g
6	6.65b	6.66b	6.89b	6.67b	6.68b	3.99g	3.99g	4.00g	3.99g	4.01g
9	6.93a	6.95a	6.95a	6.96a	6.97a	4.08f	4.04f	4.09f	4.07f	4.13f
12	®	®	®	®	®	4.32e	4.36e	4.34e	4.36e	4.37e
	Total psychrophilic bacteria (mean $\log_{10}$ cfu/g)									
0	5.84d	5.85d	5.45d	5.85d	5.86d	3.45h	3.48h	3.46h	3.48h	3.51h
3	5.95c	5.96c	5.99c	6.04c	6.00c	3.51g	3.53g	3.52g	3.58g	3.66g
6	6.00b	6.30b	6.32b	6.33b	6.29b	3.60g	3.63g	3.65g	3.65g	3.69g
9	6.59a	6.60a	6.61a	6.61a	6.60a	3.91f	3.90f	3.91f	3.93f	3.93f
12	®	®	®	®	®	4.04e	4.11e	4.09e	4.12e	4.15e
	Molds and yeasts (mean $\log_{10}$ cfu/g)									
0	4.90d	4.91d	4.92d	4.92d	4.93d	3.68g	3.67g	3.69g	3.69g	3.68g
3	4.99c	5.00c	5.01c	4.07c	5.09c	3.72g	3.70g	3.72g	3.71g	3.72g
6	5.15b	5.18b	5.20b	5.23b	5.26b	3.76g	3.75g	3.76g	3.76g	3.76g
9	5.32a	5.34a	5.35a	5.37a	5.39a	3.85f	3.86f	3.86f	3.86f	3.86f
12	®	®	®	®	®	4.00e	4.00e	4.05e	4.06e	4.08e
	Enterobacteriaceae (mean $\log_{10}$ cfu/g)									
0	4.78d	4.78d	4.79d	4.79d	4.78d	ND	ND	ND	ND	ND
3	4.85c	4.85c	4.85c	4.85c	4.86c	ND	ND	ND	ND	ND
6	4.97b	4.98b	4.98b	4.98b	4.98b	ND	ND	ND	ND	ND
9	5.08a	5.09a	5.11a	5.11a	5.10a	ND	ND	ND	ND	ND
12	®	®	®	®	®	ND	ND	ND	ND	ND
	Staphylococcus aureus (mean $\log_{10}$ cfu/g)									
0	3.94d	3.95d	3.95d	3.96d	3.94d	ND	ND	ND	ND	ND
3	4.03c	4.08c	4.06c	4.05c	4.08c	ND	ND	ND	ND	ND
6	4.13b	4.17b	4.12b	4.13b	4.15b	ND	ND	ND	ND	ND
9	4.26 a	4.30a	4.28a	4.28a	4.30a	ND	ND	ND	ND	ND
12	®	®	®	®	®	ND	ND	ND	ND	ND
	Presence of *Salmonella*									
0	+ve	+ve	+ve	+ve	+ve	−ve	−ve	−ve	−ve	−ve
3	+ve	+ve	+ve	+ve	+ve	−ve	−ve	−ve	−ve	−ve
6	+ve	+ve	+ve	+ve	+ve	−ve	−ve	−ve	−ve	−ve
9	+ve	+ve	+ve	+ve	+ve	−ve	−ve	−ve	−ve	−ve
12	®	®	®	®	®	−ve	−ve	−ve	−ve	−ve

Means with a different letter within each determination are different significantly ($P < 0.05$); cfu: colony forming unit; ND: Not detected. +ve: Positive. –ve: Negative; ®: Rejected and their values were discarded after statistical analysis.

Table 7. Sensory attributes for raw non-irradiated and irradiated beefburger formulated with different levels of beef fat, olive oil and wheat bran.

Storage (Days)	Mean of scores/formulations									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
	Color and appearance									
0	7.8a	7.6a	7.9a	7.5a	7.4a	7.5a	7.7a	7.5a	7.8a	7.7a
3	7.6a	7.8a	7.6a	7.9a	7.4a	7.4a	7.9a	7.7a	7.9a	7.6a
6	7.3a	7.6a	7.4a	7.5a	7.6a	7.9a	7.4a	7.6a	7.4a	7.8a
9	7.5a	7.4a	7.7a	7.4a	7.8a	7.7a	7.6a	7.7a	7.5a	7.4a
12	7.6a	7.5a	7.6a	7.4a	7.6a	7.8a	7.6a	7.7a	7.5a	7.7a
	Odor									
0	7.6a	7.3a	7.5a	7.7a	7.6a	7.5a	7.7a	7.5a	7.8a	7.5a
3	7.0a	7.6a	7.3a	7.5a	7.4a	7.7a	7.4a	7.6a	7.9a	7.2a
6	7.4a	7.6a	7.5a	7.3a	7.7a	7.3a	7.7a	7.2a	7.8a	7.7a
9	6.9a	7.0a	7.2a	7.1a	6.9a	7.6a	7.3a	7.6a	7.4a	7.7a
12	2.3b	2.5b	2.5b	2.2b	2.4b	7.5a	7.4a	7.7a	7.8a	7.4a

Means with a different letter within each of attributes are different significantly ($P < 0.05$).

Table 8. Sensory attributes for cooked non-irradiated and irradiated beefburger formulated with different levels of beef fat, olive oil and wheat bran.

Sensory attributes	Mean of scores/formulations									
	Non-irradiated beefburger					Irradiated beefburger at 3 kGy dose				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
Appearance & color	8.1a	7.9a	8.0a	8.3a	7.8a	8.0a	8.2a	7.8a	7.7a	8.3a
Odor	8.2a	8.0a	7.9a	7.5a	5.8b	8.0a	8.1a	7.6a	7.6a	5.9b
Taste	8.0a	7.9a	7.8a	7.7a	5.4b	8.3a	8.2a	7.8a	7.4a	5.2b
Texture & juiciness	8.2a	7.8a	8.1a	8.1a	7.9a	8.1a	7.9a	8.3a	8.0a	8.2a

Means with a different letter within each of attributes are different significantly ($P < 0.05$).

moisture and fat leading to producing of a more succulent and juicy meat product [29]. The results of sensory traits for the cooked burger samples agree with those observed for cooking and binding measurements in this study.

4. Conclusions

It could be concluded that reducing beef fat levels with the addition of olive oil and wheat bran fibers produced a highly acceptable beefburger product with improved nutritional content and cooking and binding properties. Furthermore, irradiation of the resultant beefburger samples at dose of 3 kGy improved their microbiological quality through the complete inactivation of *Staphylococcus aureus*, *Salmonella* and enterobacteriaceae, in addition to the significant reduction in the counts of mesophilic and psychrophilic bacteria as well as molds and yeasts, thus, produced a safe beefburger products without any adverse effects on their other quality characteristics.

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