EFFECT OF MILD IRRADIATION DOSES ON QUALITY ATTRIBUTES OF MEAT TRIMMINGS FOR PRODUCTION OF PATTIES

Ma de la Paz Xavier[1]; Cecilia Dauber[2]; Paula Mussio[2]; Enrique Delgado[2]; Ana Maquieira[2]; Alejandra Soria[2]; Ana Curuchet[2]; Rosa Márquez[2]; Carlos Méndez[1], Tomás López[2].

1 Instituto Nacional De Carnes. Rincón 545, CP 11000. Montevideo, Uruguay. E-mail: cmendez@inac.gub.uy

2 Laboratorio Tecnológico Del Uruguay. Avda. Italia 6101, CP 11500. Montevideo, Uruguay. E-mail: tlopez@latu.org.uy

The objectives of the present work were to assess the use of moderate doses of irradiation (2 and 5 kGy) as a tool to reduce the microbial load without altering the commercial quality of bovine trimmings and of patties made of irradiated trimmings. Independent series of experiments covered microbiological indicators during 30 days of storage (coliforms, *Pseudomonas* spp. and mesophilic aerobics counts), physicochemical indicators (pH, color and tiobarbituric acid assay) and sensory changes during a 180 day storage period at freezing temperatures. Physicochemical changes observed were mainly the development of slightly higher off flavors in patties due to irradiation at the highest dose assayed (5 kGy). Using moderate gamma irradiation doses of 2 kGy, reductions of at least 1.5log CFU/g of mesophilic aerobic counts were achieved as well as counts of *Pseudomonas* spp. and coliform below detection level during the whole storage period. It seems reasonable to suppose that irradiation can be successfully employed to reduce altering microflora of trimmings while producing minimal sensory changes in patties made from irradiated trimmings.

I. INTRODUCTION

The physicochemical composition of meat provides the conditions for microorganism growth and the precursor compounds for the development of aromas and flavors, desirable or undesirable. Physicochemical parameters such as pH, color and lipid oxidation are gross indicators of meat quality, as well as sensory attributes (Lorenz et al. [1], Shahidi [2], Brewer [3]). Bovine trimmings are the main ingredient of patties produced worldwide. Since this meat results from mechanical disruption of several muscles, assessing microbiological markers becomes mandatory and it is used as a trade standard. In particular, for mechanically recovered meat, ground meat and meat mixes with spices, all shall comply with specifications of microbiological markers such as: total mesophilic counts, *Escherichia coli* counts and absence of pathogenic strains. Irradiation may be applied to packaged products extending their shelf-life and improving their microbiological safety with minimal effects on their chemical composition, nutritional and sensory properties. The effects of ionizing radiation on living organisms depends on the total dose absorbed, the rate of absorption, and the environmental conditions (mainly temperature and gas atmosphere) during irradiation (Brewer [3]). Food spoilage microorganisms are generally very susceptible to irradiation; a 90% reduction of most vegetative cells can be accomplished with 1.0 – 1.5 kGy (ICGFI, 1996; Olson, 1998a; Olson, 1998b; Thayer et al. 1995). Irradiation followed to refrigeration was found to be a very effective way to reduce initial microbial loads in ground beef, improve safety and extend shelf life without affecting sensory quality.

When biological materials are exposed to irradiation energy, the atoms or molecules eject electrons producing ions and free radicals. The electron-deficient carbon-carbon double bonds of unsaturated fatty acids and carbonyl groups (fatty acids and amino acids) are particularly susceptible to free radical attack. This is why, even at low dose, irradiation can initiate or promote lipid oxidation resulting in undesirable off-odors and flavors (Lescano et al. [4], Thakur et al. [5]).

Irradiation produces a variety of color changes which are related to the myoglobin concentration, the state of myoglobin prior to irradiation, pH, water activity, presence of reducing equivalents, temperature and gas atmosphere during irradiation. It should be mentioned that, a maximum of 4.5 kGy is permitted for uncooked, chilled red meat and 7 kGy is permitted for uncooked, frozen meat (FDA, 2012). The objectives of the present work were to assess the use of moderate doses of irradiation as a tool to reduce microbial load without altering the commercial quality of bovine trimmings and of patties made of irradiated trimmings, covering: microbiological indicators during 30 days of storage (coliforms, pseudomonas and mesophilic aerobics counts), and physicochemical indicators (pH, color and oxidation) and sensory changes during a 180 day storage period at freezing temperatures.

II. MATERIALS AND METHODS

Commercial quality was evaluated on irradiated trimmings (at frozen or chilled temperatures of (-18±2) and (2±2)ºC, respectively) and on patties made of irradiated trimmings, all stored at (-18±2)ºC after irradiation.

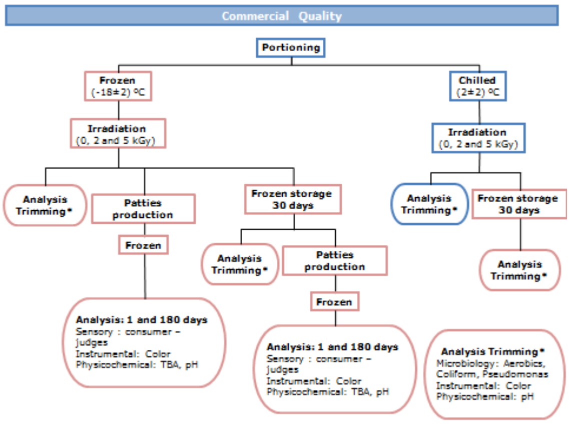

Figure 1. Schematic procedure of sample treatments for commercial quality study.

Beef trimmings (20% fat) were obtained from a local slaughter house. Fresh trimmings (0 days age) from grass-fed animals were divided at deboning room in 2.5 kg and 200g portions for patty production and experiments with trimmings alone, respectively. Trimmings were irradiated at target dose of 2 kGy (D1) and 5 kGy (D2). By used dose-meters real range doses were [2.2 to 3.1] and [4.6 to 5.5] kGy for 2.5kg bags and [2.2 to 2.4] and [4.6 to 5.1] kGy for 200g bags. Non-irradiated (NI, 0 kGy) samples were used as control. Samples were irradiated after 24h of storage, under frozen or chilled conditions in LATU irradiation unit. Irradiated and non-irradiated trimmings bags were stored at (2±2) °C for 24 h before being analyzed. Samples destined to evaluation after 30 days were stored at (-18±2) °C. Irradiation was carried out at room temperature under a Cobalt-60 radiation source. **Production of patties.** For each irradiation dose (NI, D1 and D2) 10kg batches of frozen beef trimmings were fine ground through a 3 mm hole plate. Then ground beef was mixed for 2 minutes with salt (0.75 %), citric acid (0.2 %) and ascorbic acid (0.7 %). Packaging was carried out 24 hours after preparation using. They were immediately placed in cardboard boxes and stored at (-18±2) °C. The same process was repeated with trimmings aged an extra 30 days and stored at (-18±2) ºC during this period.

Analysis. Microbiological (*Total Aerobic* counts, *Coliform* enumerations, *Pseudomonas* spp), pH, and instrumental color analyses were carried out on frozen and chilled trimmings irradiated at NI, D1 or D2 on samples stored 1 and 30 days. Instrumental color, TBA and sensory analysis (trained panel and consumer evaluation) were carried out on patties manufactured from trimmings irradiated at NI, D1 or D2 immediately after elaboration and after 180d of frozen storage.

Statistical analysis. Analyses of Variance (ANOVA) were performed using the statistical software Infostat/L version 2013 and XLSTAT Version 2011. A post-hoc Tukey test was used to obtain paired comparisons among sample means. Level of significance was set to $P < 0.05$.

III. RESULTS AND DISCUSSION

Table 1 shows that for D1 irradiation dose, total aerobic counts of 3log (cfu/g) in trimmings were reduced by at least 1.5log orders. This result agree with previous findings of Chouliara *et al.* [6] who reported that frozen trimmings irradiated at 2 kGy under Co-60 source reduced total aerobic counts of 6.1 log (cfu/g) in 1.6log orders. Karadag *et al.* [7] found that for *Pseudomonas* spp, the same dose (2.2 kGy) caused a reduction of at least 1log order for an initial load of nearly 2log (cfu/g). In this study *Pseudomonas* spp. and coliforms counts were reduced up to the detection level.

Table 1. Mean values of microbiological counts on beef trimmings.

			Total Aerobic log(cfu/g)	Pseudomonas log(cfu/g)	Coliforms (NMP/g)
NI	Chilled	0d	2,68^{a}	1,82^{a}	<3
		30d	2,54^{a}	1,18^{b}	<3
	Frozen	0d	2,68^{a}	2,03^{a}	<3
		30d	2,72^{a}	1,11^{b}	<3
D1	Chilled	0d	0.45^{b}	<1	<3
		30d	<1	<1	<3
	Frozen	0d	<1	<1	<3
		30d	<1	<1	<3
D2	Chilled	0d	<1	<1	<3
		30d	<1	<1	<3
	Frozen	0d	<1	<1	<3
		30d	<1	<1	<3

Counts were obtained from beef trimmings irradiated at Ni (0kGy), D1 (2kGy) and D2 (5kGy) under chilling (2±2ºC) or freezing (-18±2ºC) temperatures (n = 6). Non irradiated samples were used as controls. Within rows, means values with common letters (a, b) do not significantly differ (P>0.05).

The temperature of the different irradiation treatments (chilling vs freezing) did not significantly affect the results. Overall, irradiation at D1 dose had a significant improvement on hygienic quality which was practically similar to that caused by an irradiation dose of 5 kGy. For both irradiation doses, reductions obtained on day 0 after treatment were preserved during a 30 day storage period at freezing temperatures. Most spoilage microorganisms in meat are gram negative with *Pseudomonas* spp. predominant for aerobic storage at chilling temperatures.

The pH results of all samples tested varied between 5.56 and 5.68. pH values did not show significant differences (P>0.05) within the different treatments performed: irradiation dose, temperature and storage time. These results agree with those reported by Fu et al. [8] and Brewer [3].

TBA values of patties made of trimmings irradiated at both D1 and D2, and stored 0 and 30 days did not significantly differ (P >0.05; data not shown). Absence of differences could be due to the fact that, trimmings used was from grass-fed animals. Brito et al. [9] reported that trimmings from grass-fed animals, usually contains high levels of vitamin E that might help to prevent increases in fat oxidation due to irradiation processing. Furthermore, the ascorbic acid used in patties formulation at 0.7%, could be responsible of preventing oxidation increases. Ahn et. al [10] did not report significant differences on TBA values of ground beef with ascorbic acid at 0.1% irradiated at 2.5 kGy along 7 days, while control samples (without ascorbic acid) did show an increase.

Regarding instrumental color measures on beef trimmings, samples showed great variability considering that they consisted of a mix of pieces from different muscles. NI samples presented higher a* and b* values than irradiated ones, but there was no significant difference between D1 and D2 samples. Visual evaluation also suggested that irradiated samples were less red. Nanke et. al [11] reported, as well, lower a* and b* values in beef irradiated with doses ranging from 1.5 to 10.5 kGy compared to control samples non-irradiated. According to Lycometros [12], changing from oxymyoglobin to metmyoglobin at the surface could explain the lower a* values on the exterior surface of irradiated beef. a* and b* values were significantly lower in chilled samples than in frozen ones. For non-irradiated samples, this difference was not significant. In agreement with Brewer [3], this suggests that chilled irradiated samples experimented more changes related to non-irradiated ones, than frozen irradiated samples. Reducing the temperature during irradiation process reduces the effects on odor, flavor and color. Temperature may determine which radiolytic products are generated and in what ratios, affecting also food matrix viscosity and water mobility. Ion and free radical dispersion are lower when free water is in the frozen state. Also, free radicals tend to recombine when water in foods is frozen because they are less likely to diffuse and react with other food components (Taub et al. [13]) Storage time did not affect a* and b* values. Lightness (L*) was not affected by irradiation dose or temperature, but it did decrease with storage time, being lower on samples stored for 30 days after irradiation. The same behavior was observed for the saturation index, decreasing with storage.

Instrumental color on beef trimmings and patties are not comparable in this study, since color measures on beef trimmings were made exclusively in the muscle (excluding the fat) and patties were made by grinding and mixing these two components; thus, differences explained by the contribution of fat to final color of patties were expected.

Irradiation dose did not significantly affect L*, a* and b* values on beef patties (p>0.05). These results agree with those reported by Murano et al. [14], who found that the only differences between non irradiated and irradiated (2 kGy) beef patties were due to packaging atmosphere. All color scores were significantly higher in patties made of trimmings aged for 30 days related to patties made with fresh trimmings. Values of L*, a* and saturation indexes decreased significantly during the 180 days of storage while b* values remained unchanged.

Off-flavor intensity of patties was the only parameter where judges detected differences caused when increasing irradiation dose. Table 3 shows that off flavor intensity scores of patties made of aged irradiated trimmings did not differ (p>0.05) from patties made of fresh irradiated trimmings. Patties made of trimmings irradiated at D2 significantly differed from patties made of non-irradiated trimmings for both fresh and aged ones. Nevertheless, values obtained for off flavor were all below 2 in a 0 to 10 scale and they experienced no changes during the 180d storage period at freezing temperature. Giroux et al. [15] with the use of a trained panel, concluded that there was no significant difference in odor and taste between irradiated (4 kGy) and non-irradiated ground beef patties (23% fat) during 7 days of storage at 4°C. Fan, *et al*. (2004) performed a study evaluating frozen ground beef patties (15% fat) irradiated and non-irradiated at doses of 1.35 and 3 kGy. Irradiation had no significant impact on the ratings of any of the sensory attributes either at 0 day or after 6 months of storage.

Table 2 Odd flavor intensity means rates for patties

Off flavor intensity (0 to 10)				
	Patties made of Fresh trimmings(0d)		Patties made of Aged trimmings(30d)	
Dose	1d	180d	1d	180d
Ni	$0.3^{a,x}$	$1.5^{a,y}$	$0.1^{a,x}$	$0.2^{a,x}$
D1	$0.7^{a,b,x}$	$1.3^{a,x}$	$0.7^{a,b,x}$	$0.7^{a,b,x}$
D2	$1.4^{a,b,x}$	$1.8^{a,x}$	$1.4^{b,x}$	$1.7^{a,b,x}$

Patties made of fresh and aged trimmings. Within columns, treatment means with common letters (a-b) are not significantly different (P>0.05). Within row treatment means with common letters (x-y) are not significantly different (P>0.05).

The other attributes assayed showed no significant changes due to irradiation treatment or storage time of trimmings and patties. Their values, in a 0 to 10 continuous scale ranged as follows: odor intensity [5 to 6]; off odor intensity [0.3 to 1.4]; initial tenderness [4.2 to 5.9]; final tenderness [4.7 to 5.8]; initial juiciness [4.2 to 5.7]; final juiciness [3.9 to 5.7] and flavor intensity [5.0 to 6.2].

Consumer acceptability is one of the tools used to predict market product success and the likelihood of rejection of consumers if this is the case. Table 3 shows that irradiated patties did not differ from non-irradiated ones (P>0.05) for both 0 and 180 d storage times. Irradiated patties 180d old showed less acceptability (P<0.05) than 1d old patties though these values were barely minor than the original ones.

Table 3 Acceptability means values for patties

Acceptability				
	Fresh trimming (0d		30 days aged trimming	
Dos	1 d	180 d	1d	180d
Ni	$6.6^{a,x,y}$	$6.0^{a,y}$	$7.0^{a,x}$	$6.7^{a,x,}$
D1	$6.6^{a,x}$	$5.8^{a,y}$	$6.1^{b,x,}$	$6.2^{a,x,}$
D2	$6.2^{a,x,y}$	$5.5^{a,y}$	$6.0^{b,x,}$	$6.5^{a,x}$

Patties made of fresh and aged trimmings. Within columns, treatment means with common letters (a,b) are not significantly different (P>0.05).ns, Within row, treatment means with common letters (x,y) are not significantly different (P>0.05).ns

Results from judges and consumers indicate that there are no sensory differences between patties produced from fresh or 30d stored irradiated trimmings at 2 or 5 kGy, suggesting that it is possible to commercialize irradiated trimmings as such to markets that require 30 days for transport and beef patties for up to a 180 d period (p>0.05) taking into account only sensory results.

IV. CONCLUSION

The results of the indicators studied for commercial quality (pH, color, TBA, sensory analysis, *Pseudomonas* spp., coliforms and mesophilic counts) implies that irradiation may provide an alternative capable of decreasing the microbial load of meat products while slightly altering its physicochemical and sensory properties of trimmings and patties.

REFERENCES

1. Lorenz, G., Stern, D. J., Flath, R. A., Haddon, W. F., Tillin, S. J., & Teranishi, R. (1983). Identification of sheep liver volatiles. Journal of Agriculture and Food Chemistry, 31, 1052–1057.
2. Shahidi, F. (1994). Flavor of meat and meat products—an overview. In F. Shahidi (Ed.), Flavor of meat and meat products (pp. 1–3). London: Blackie Academic and Professional.
3. Brewer, M. S. (2004). Irradiation effects on meat color–a review. Meat Science, 68,1–1
4. Lescano, G., Narvaiz, P., Kairiyama, E., & Kaupert, N. (1991). Effect of chicken breast irradiation on microbiological, chemical and organoleptic quality. Lebensmittal Wissenund Technology, 24, 130–134.
5. Thakur, B. R., & Singh, R. K. (1994). Food irradiation. Chemistry and applications. Food Reviews International, 10(4), 437–473.
6. Chouliara, I., Samelis, J., Kakouri, A., Badeka, A., Savvaidis, I. N., Riganakos, K. & Kontominas, M. G. (2006). Effect of irradiation of frozen meat/fat

trimmings on microbiological and physicochemical quality attributes of dry fermented sausages. Meat Science, 74, 303-311.

7. Karadag, A., Günes, G. (2007). The effects of gamma irradiation in the quality of ready to cook meatballs. Turkish Journal of Veterinary and Animal Science, 32, 269-274.
8. Fu, A. H., Sebranek, J. G., & Murano, E. A. (1995). Survival of Listeria monocytogenes, Yersinia enterocolitica and Escherichia coli 0157:H7 and quality changes after irradiation of beef steaks and ground beef. Journal of Food Science, 60, 972–977.
9. Brito, G., Luzardo, S., Montossi, F., San Julián, R., Silveira, C., del Campo, M., Lagomarsino, X. (2010). Differentiation of Uruguayan bovine and ovine meats as for its nutritional properties and product conservation. Meat Quality Actualization Seminar (INIA). Tacuarembó, Uruguay.
10. Ahn, D. U. and Nam, K.C. (2004). Effects of ascorbic acid and antioxidants on color, lipid oxidation and volatiles of irradiated ground beef. Radiation Physics and Chemistry, 71,149-154.
11. Nanke, K. E., Sebranek, J. G., & Olson, D. G. (1999). Color characteristics of irradiated aerobically packaged pork, beef, and turkey. Journal of Food Science, 64, 272–278.
12. Lycometros, C., & Brown, W. D. (1973). Effects of gamma irradiation on myoglobin. Journal of Food Science, 38, 971–977.
13. Taub, I. A., Karielian, R. A., Halliday, J. W., Walker, J. E., Angeline, P., & Merritt, C. (1975). Factors affecting radiolytic effects of food. Radiation Physics and Chemistry, 14, 639–653.
14. Murano, P. S., Murano, E. A., & Olson, D. G. (1998). Irradiated ground beef: Sensory and quality changes during storage under various packaging conditions. Journal of Food Science, 63, 548–551.
15. Giroux, M., Ouattara, B., Yefsah, R., Smoragiewicz, W., Saucier, L., & Lacroix, M. (2001). Combined effect of ascorbic acid and gamma irradiation on microbial and sensorial characteristics of beef patties during refrigerated storage. Journal of Agriculture and Food Chemistry, 49, 919–925.