Original article

Effect of different treatments on nutritional, microbiological and rheological properties of flours

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Abstract. Among the different types of flours wheat flour, semolina and gram flour are commonly used. Wheat flour is a leading source of cereal protein having the higher protein content than either rice or maize (corn). Semolina is very popular food product made by milling wheat. It is a rich source of Carbohydrates, Iron and Protein and is widely used worldwide for making pasta, cereals and spaghetti etc. Gram flour or chickpea flour is an important pulse flour and a rich source of protein and carbohydrates. Present study was carried out to study the effect of gamma radiation, microwave radiation and ETO treatment on the nutritional, microbiological and solubility properties of different flours i.e. wheat flour, gram flour and semolina. In the present study flour samples were exposed to 5KGy Gamma radiation, 900W (for 40s) Microwave radiation and ETO treatment. The nutritional value of samples after different radiation treatments was analyzed to determine the change in proximate composition. Through experimentation, it was evaluated that there was no significant difference in the nutritional characteristics of flours after being exposed to different radiations. Microbial bioburden of flours was reduced significantly after treatment with different radiations specifically by treatment with gamma radiation and microwave radiation. However, treatment with microwave radiation resulted in loss of some sensory characteristics. While ETO treated flour, samples showed more microbial growth than other types of radiations. Therefore, gamma radiation is the most promising technique to ensure food safety with no significant change in the sensory and nutritional properties of flours.

Key words: Flour, Nutrition, Properties, Radiation, Treatment

Introduction

Cereal grains and flours have been a prolific source of food and the most important suppliers of food energy for more than 24 centuries (1). Wheat is of different varieties involving the common wheat and durum wheat (2). Semolina is produced by durum milling primarily and Its production involves the grinding and bottling of cleaned durum wheat (3).

The shelf life of any food product depends on largely on the packaging material used for storing it, as it conserves the product integrity and also plays a great role in consumer health. Generally used packaging materials as approved by FDA include plastic bags, glass and ceramic containers, rigid containers, plastic paper and foil wraps (4).

Microbes and food borne pathogens result in the decrease in quality and loss of the immense nutritional and health benefits of food products. Considering the immense nutritional benefits of wheat flour, semolina and gram flour; it is the need of time to protect them from several contaminants and increase their shelf life (5).

Gamma irradiation is a technique for cereal preservation that seems to be powerful in protecting grains from insect infection and bacterial contagion during storage. Apart from this defensive role, gamma irradiation also has a major influence on many quality measures of cereal grains such as functional properties, baking quality and dough properties. The safe use of this technique can enhance the attributes and extend the shelf-life of wheat flour products (6).

Ethylene oxide sterilization procedure was considered as the last option of sterilization procedure due to harmful gas residue. In 1929, Ethylene oxide was identified as an anti-bacterial agent. It is widely used, because it evades heat and radiation stress often associated to irradiation with steam or gamma irradiation. ETO is an excellent gaseous sterilant because of its characteristically high penetrating power through solid surfaces. In several studies the it is reported that ETO has strong bacteriological activity as well as capable of inactivating viruses and fungi (7).

Microwaves are the unionized form of energy that results in rise in heat inside an environment because of quick changes of the magnetic force at high recurrence. Microwave light appears to be pertinent to starch preparing, however it has not yet been utilized for this reason on a business scale (8)

Inside the electromagnetic range, microwave radiation has a range between 300 MHz and 300 GHz, with those ordinarily utilized for the mechanical preparing of nourishments being in the vicinity of 915 and 2450 MHz and, for household use, of 2450 MHz. The upsides of the utilization of microwaves, in contrast with customary handling strategies, are a reduced preparing time, increase production yield and improve nature of the last item (9).

This study was undertaken to determine the effect of different sterilization treatments such as microwave radiation, gamma radiation on microbial count, sensory, nutritional and rheological properties of different flour samples with maximum export potential in the international market and to enhance hygienic quality by targeting microbes on semolina, wheat flour and gram flour.

2. Materials and methods

2.1. Sample collection, packaging and their treatment

Different flour samples was obtained and treated with a 5kGy dose of gamma radiation, ETO and microwave radiation (900W for the 40s). Both control and treated samples were stored in a dry place away from direct sunlight and at room temperature for 2 months. After the storage period (after each 30-day interval) the microbial and proximate analysis of samples were carried out in biotechnology laboratory, LCWU.

2.2. Sensory analysis

Sensory parameters like change in color, texture, and odor was measured after each interval.

2.3. Microbial analysis

The microbiological examination was carried out for the identification of bacteria and fungi by using the spread plate technique and pour plate method as proposed by (10) followed by gram staining for bacterial identification.

2.4. Proximate analysis

For proximate analysis, the parameters such as moisture, ash, crude fat, fiber, carbohydrates and protein in the different flour samples on a dry weight basis were carried out according to (10). Samples were analyzed in triplicates.

2.5. Rheological properties analysis

Rheological properties such as Water absorption capacity, emulsification capacity, foaming capacity and bulk density were determined (8).

3.0. Results

3.1. Effect of different treatments on sensory properties

There was no significant change observed in the smell, texture and color of Control and treated samples. However, a little bit of changes that were observed in these sensory properties. are as given below.

There was no significant change observed in the sensory properties of semolina upon treatment with Ethylene oxide and gamma radiation. However some changes were observed in the samples upon microwave irradiation as given in the Table 1). There were no any notable extreme changes in color, texture and other sensory parameters in radiated and microwave samples.

Table 1. Effect of different treatments on sensory parameters of Gram flour

Color of Gram flour			
Treatments	**Day 0**	**Day 30**	**Day 60**
Control	Pale yellow	Pale yellow	Pale yellow
Radiated (5kGy)	Pale yellow	Pale yellow	Pale yellow
Microwave	Cadmium yellow	Cadmium yellow	Cadmium yellow
EtO treated	Dull yellow	–	–

Table 2. Total Bacterial and Fungal Count on Nutrient Agar

Treatments	**Total bacterial count (CFU/ml) (mean ± SD)**					
	Wheat Flour	**Gram Flour**	**Semolina**	**Wheat Flour**	**Gram Flour**	**Semolina**
Control	$3\times10^{4a}\pm0.05$	$3.33\times10^{5}\pm0.16^{a}$	$2.8\times10^{5}\pm1.5^{a}$	$1.9\times10^{3a}\pm.005$	$7.6\times10^{3}\pm0.57^{a}$	$1.5\times10^{4}\pm\mathbf{1.0}^{a}$
Gamma Radiation	$1\times10^{4}\pm0.05^{c}$	$1.66\times10^{3}\pm0.57^{b}$	$1.3\times10^{3}\pm0.5^{b}$	Nil	$3.6\times10^{3}\pm0.57^{b}$	$1.6\times10^{3}\pm\mathbf{0.5}^{b}$
Microwave Radiation	Nil	No growth	$1.0\times10^{3}\pm0.0^{b}$	Nil	$3.3\times10^{2}\pm0.57^{c}$	0.0 ± 0.0^{c}
ETO treatement	$1.8\times10^{3b}\pm0.05$	$1.66\times10^{3}\pm0.57^{b}$	$1.6\times10^{3}\pm\mathbf{0.5}^{b}$	$1.7\times10^{3b}\pm0.1$	$3.3\times10^{2}\pm0.57^{c}$	3.0 ± 0.0^{c}
Significance with 2 and 8 df	*	*	*	*	*	*

Results in the table are mentioned as mean±Standard Deviation followed by alphabets representing significant difference between group $p<0.05$ determined by Duncan's multiple range test.

The color of control and radiated samples remain the same with the passage of time, however after microwave treatment the color of sample changes to cadmium yellow. ETO treatment also changes the color of sample to dull yellow (Table 2). There was no change occurring in the color, odor and taste of treated and untreated sample of wheat flour after the storage. This study was undertaken to determine the effects of different radiations on sensory, nutritional, rheological and microbiological properties of wheat flour, gram flour and semolina.

As far as the sensory properties are concerned, there was no significant change in wheat flour, gram flour and semolina samples (Figure 1-3). There was no change in the color, odor and taste of treated and untreated sample of wheat flour during and after the storage duration.it has been reported that after microwave heating the color of raw bran changes from light tan to darker. No significant change in the sensory properties was observed in the radiated and ETO treated semolina samples (11). However, in microwave radiated sample, change in color was observed i.e. the color lightens and also it resulted in a burning smell

3.2. Microbial analysis

For the enumeration of microorganisms present in control and treated samples of wheat flour, gram flour and semolina , different types of media were used (Figure 4-6). It was observed that there is a reduction in microbial load after all the sterilization treatments (Table 3). Gamma radiation can reduce the microbial bioburden and kill the grain attacking insects (12). Microwave treatment is also found to be responsible for the enhancement of shelf life by using the destructive energy of ionizing radiations by causing minimum changes in the food components. These irradiation treatments along with ETO treatment might be able to swap the use of toxic fumigants such as phosphine and methyl bromide for removal of harmful microorganisms and insects (13). Application of higher doses of gamma radiation results in 97.70-99.90% reduction

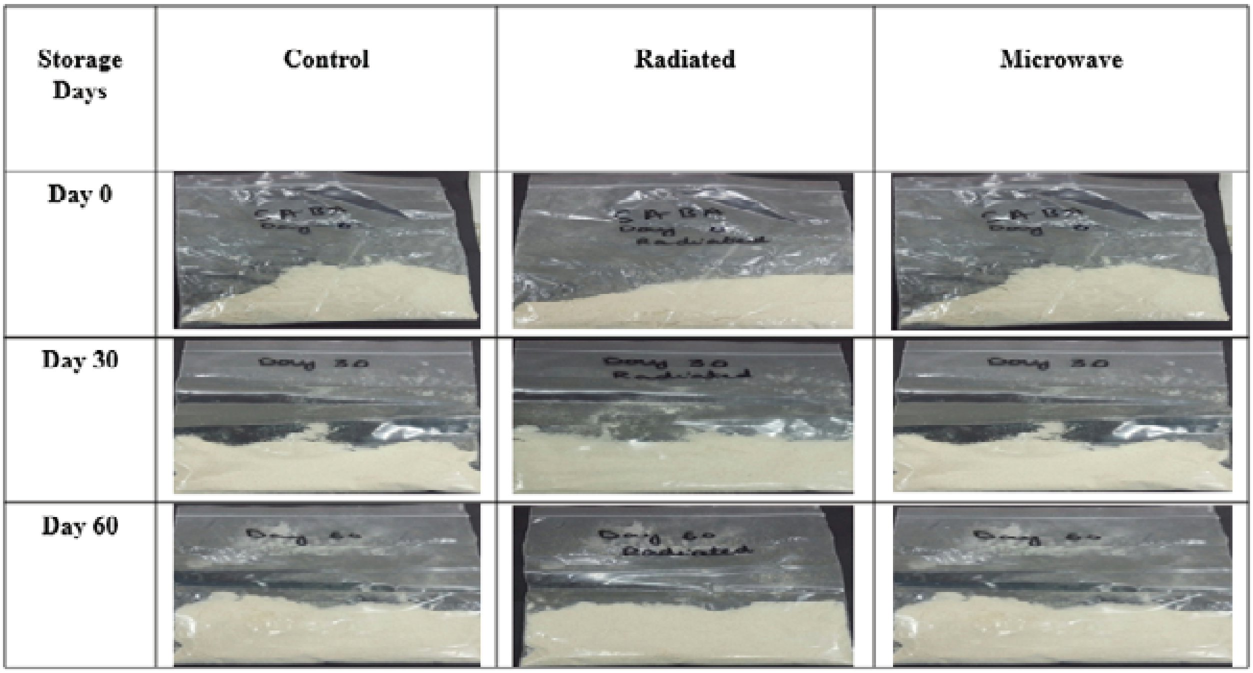

Figure 1. Effect of different treatments on color of wheat flour

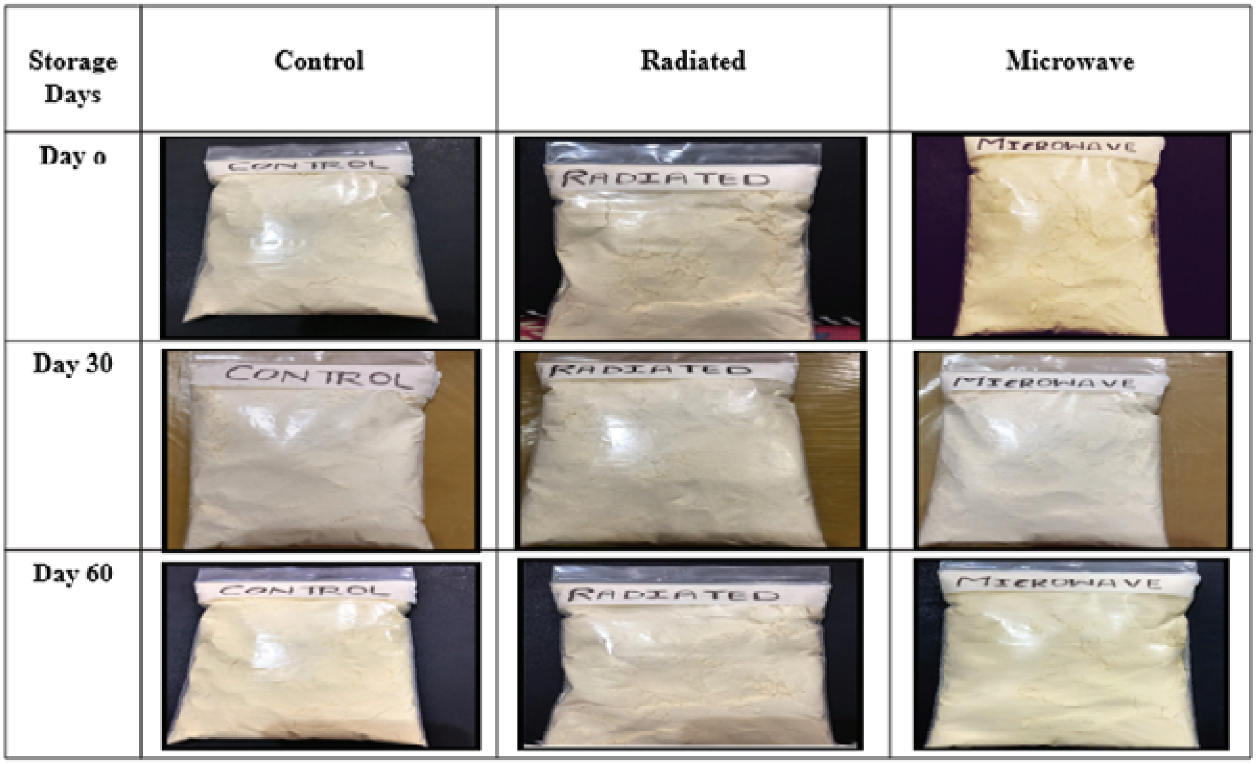

Figure 2. Effect of different treatments on color of Gram flour

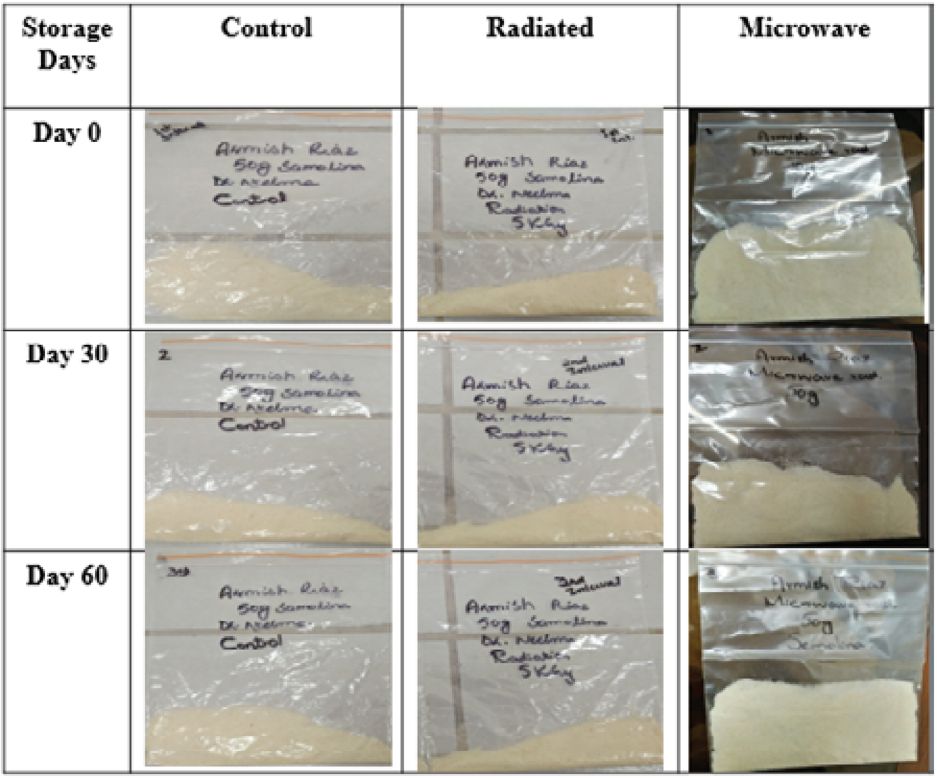

Figure 3. Color of semolina after treatment with different radiations at different days

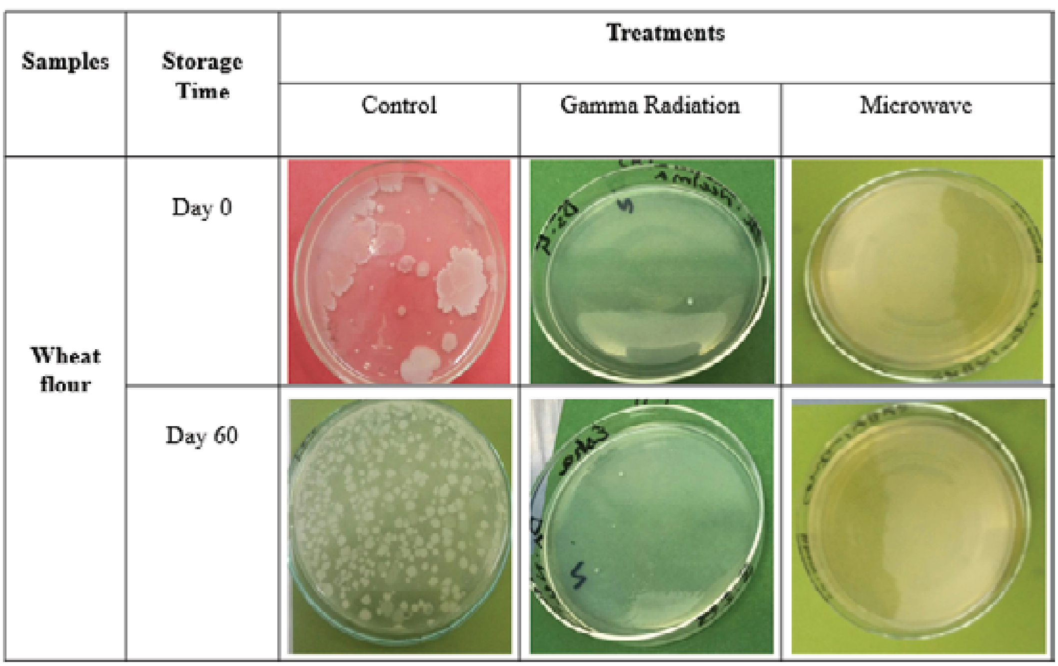

Figure 4. Microbial growth in Wheat flour samples on agar after treatment with different radiations

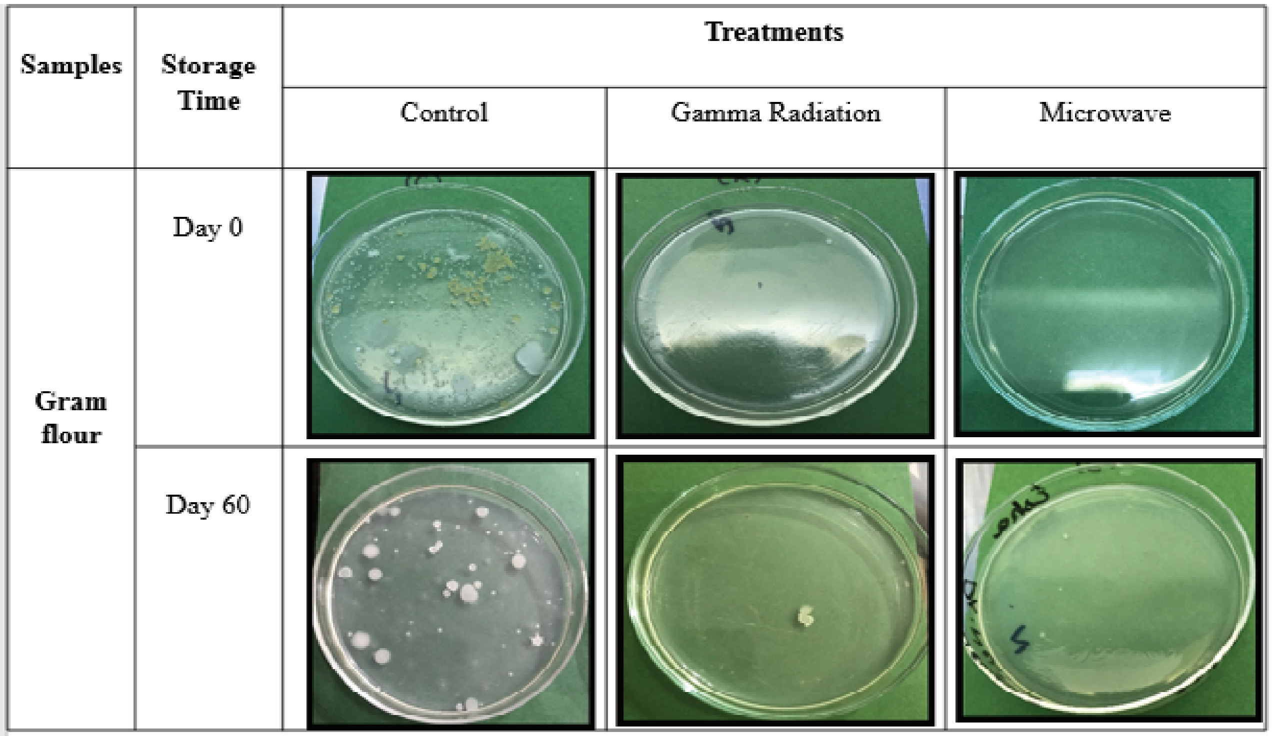

Figure 5. Microbial growth in Gram flour samples on agar after treatment with different radiations

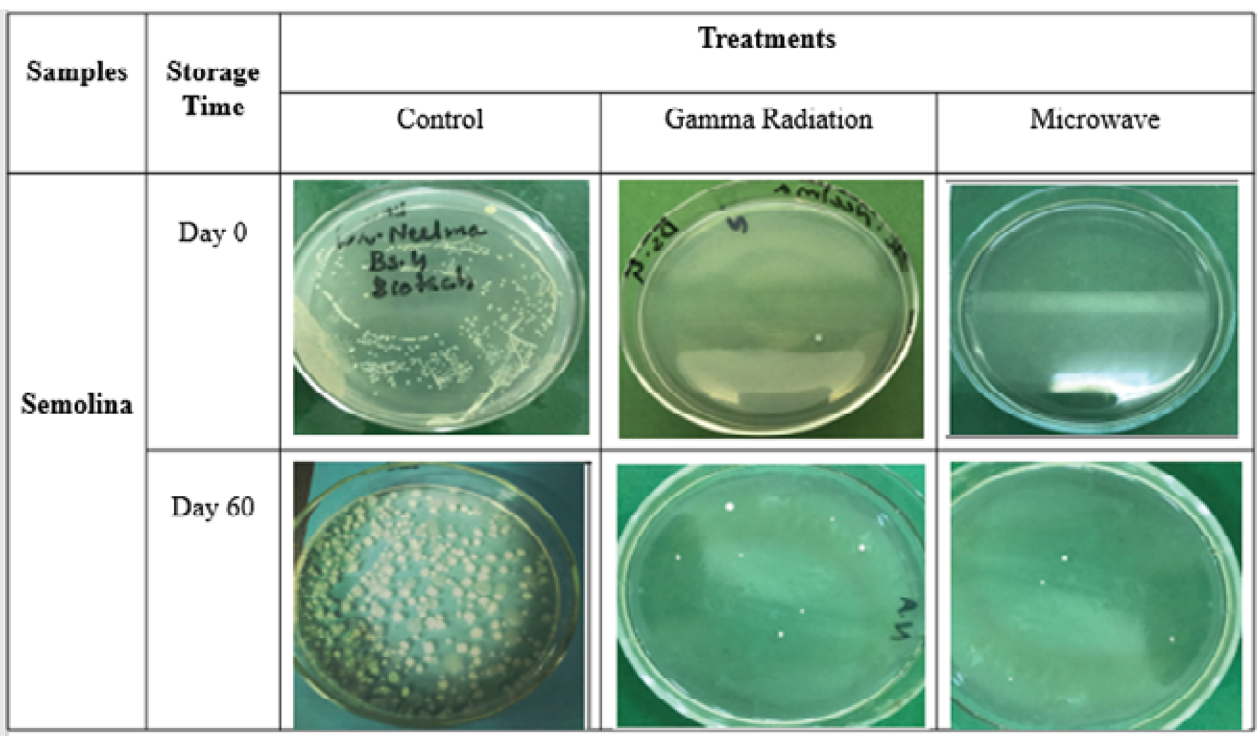

Figure 6. Microbial growth in Semolina samples on agar after treatment with different radiations

Table 3. Total Bacterial and Fungal Count on Potato Dextrose Agar

Treatments	Total Fungal count (CFU/ml) (mean ± SD)					
	Wheat Flour	Gram Flour	Semolina	Wheat Flour	Gram Flour	Semolina
Control	$1.5\times10^{4}\pm1.0^{a}$	$9\times10^{3a}\pm.005$	$2.8\times10^{5}\pm1.5^{a}$	$1.9\times10^{3a}\pm.005$	$1.3\times10^{5a}\pm0.05$	$4.8\times10^{4}\pm3.5^{a}$
Gamma Radiation	$1.6\times10^{3}\pm0.5^{b}$	Nil	$1.3\times10^{3}\pm0.5^{b}$	Nil	$3\times10^{4b}\pm0.1$	$6.3\times10^{3}\pm0.5^{b}$
Microwave Radiation	Nil	Nil	$1.0\times10^{3}\pm0.0^{b}$	Nil	Nil	$8.0\times10^{3}\pm1.0^{b}$
Significance with 2 and 8 df	*	*	*	*	*	*

Results in the table are mentioned as mean±Standard Deviation followed by alphabets representing significant difference between group p<0.05 determined by Duncan's multiple range test.

in the fungal counts that were previously observed in the control samples. These findings are in line with the findings of (14). A direct benefit of good food irradiation practices is the reduction of food borne illness and significant shelf-life extension of the irradiated product. Irradiation caused the significant decrease in the bacterial and fungal count in sample. These results correspond with the results of studies conducted by the (15).

The viable bacterial count on control samples of gram flour showed continuous growth with the storage time. However, all irradiated samples showed no noticeable microbial growth during initial days. Thus, ETO treated sample showed more microbial growth than gamma radiated sample. These results are in accordance with the findings of (16) who stated that gamma radiation is more effective method than ethylene oxide in reducing the bacterial count of spices. (17) reported that some fungal species are resistant to ethylene oxide. EtO sample also showed fungal growth with a viable count of 10^3 cfu/ml. (18) reported that ETO treatment is not very effective in reducing the microbial growth in spices. There was no microbial growth on microwave sample as reported by (19) that microwave radiation results in the inactivation of bacterial cells.

3.3. Effect of different treatments on Proximate analysis

Figure 7-9 show the effect of different treatments on the properties of wheat ram, gram flour and semolina. It is evident from the table 4 that control, radiated and microwave sample had a significant effect on the functional properties of all the flour samles. Gamma radiation, microwave radiation and ETO treatment are all effective in reducing the microbial bioburden of semolina by killing microbes and insects without effecting nutritional constituents. However, Gamma radiation is the most promising technique of the other radiation types used, as it effectively reduces microbial bioburden with no significant change in the nutritional, rheological and sensory properties. ETO treatment however, is not that much effective in reducing the microbial bioburden. During the present work it was observed that the proximate composition of all the samples was not affected significantly by gamma radiation. The results are in accordance with the findings of (20) who reported that gamma radiation increases the shelf-life of pulses owing to a reduction in insect infestation.

Moisture content increased significantly($P<0.05$) for both treated and untreated samples of wheat flour, gram flour and semolina with the passage of time. This finding agrees with the result of (21. Increase in moisture content can also be attributed to the hygroscopic nature of all stored grain, that is, they absorb moisture from humid air and lose moisture to dry air until equilibrium is established (22). Microwave heating result in loss of moisture might be because of the thermal effects that are encountered as microwave heating proceeds resulting in the loss of moisture from the sample (23).

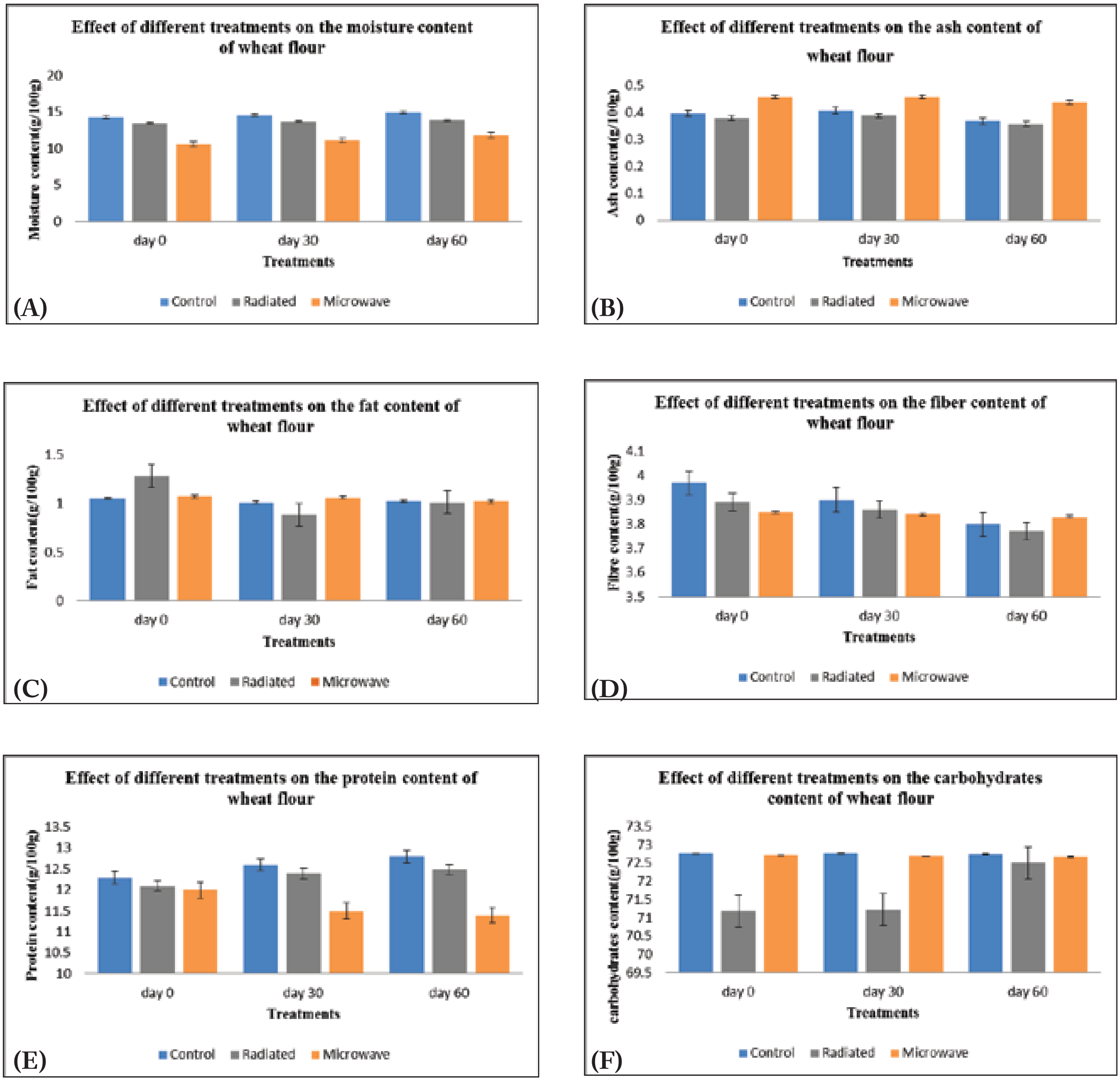

Figure 7. Effect of different treatments on Proximate values of Wheat flour (a) Moisture content (b) Ash content (c) Fat content (d) Fiber content (e) Protein content (f) Carbohydrate content

The ash content of control, radiated and microwave samples of Wheat flour, Gram flour and semolina decrease with the increase storage time. This finding agrees with the result of (24).

The fat content of all control, radiated and microwave samples showed a decrease in value with the passage of time due to the lipolytic activity of enzymes (25).

Similarly there was significant change in the fiber content of wheat flour. The fiber content also decreased for both treated and untreated sample. The fiber content of control, radiated and microwave samples of Gram flour increased with the passage of time as eported earlier (26).

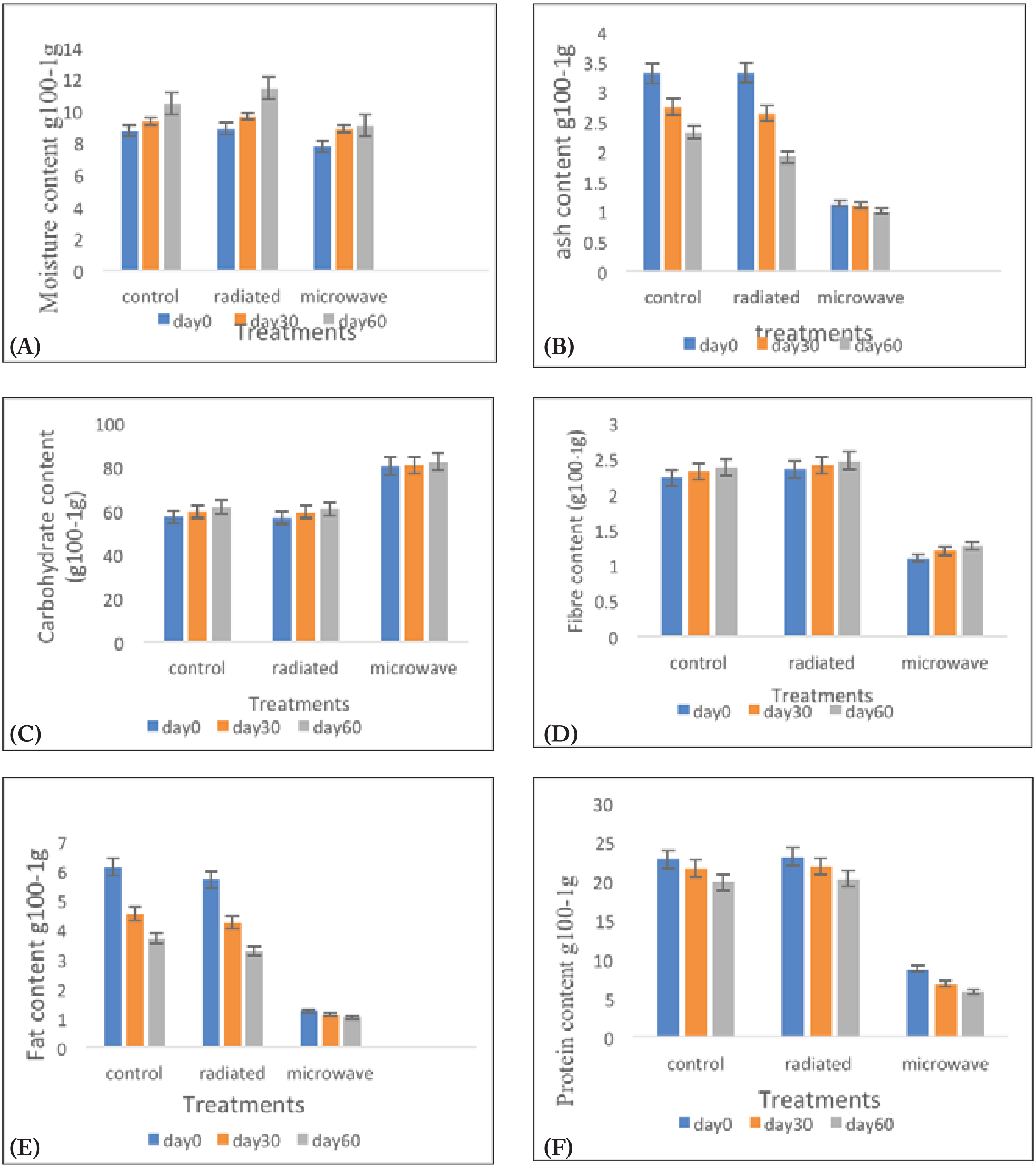

Figure 8. Effect of different treatments on Proximate values of Gram flour (a) Moisture content (b) Ash content (c) Fat content (d) Fiber content (e) Protein content (f) Carbohydrate content

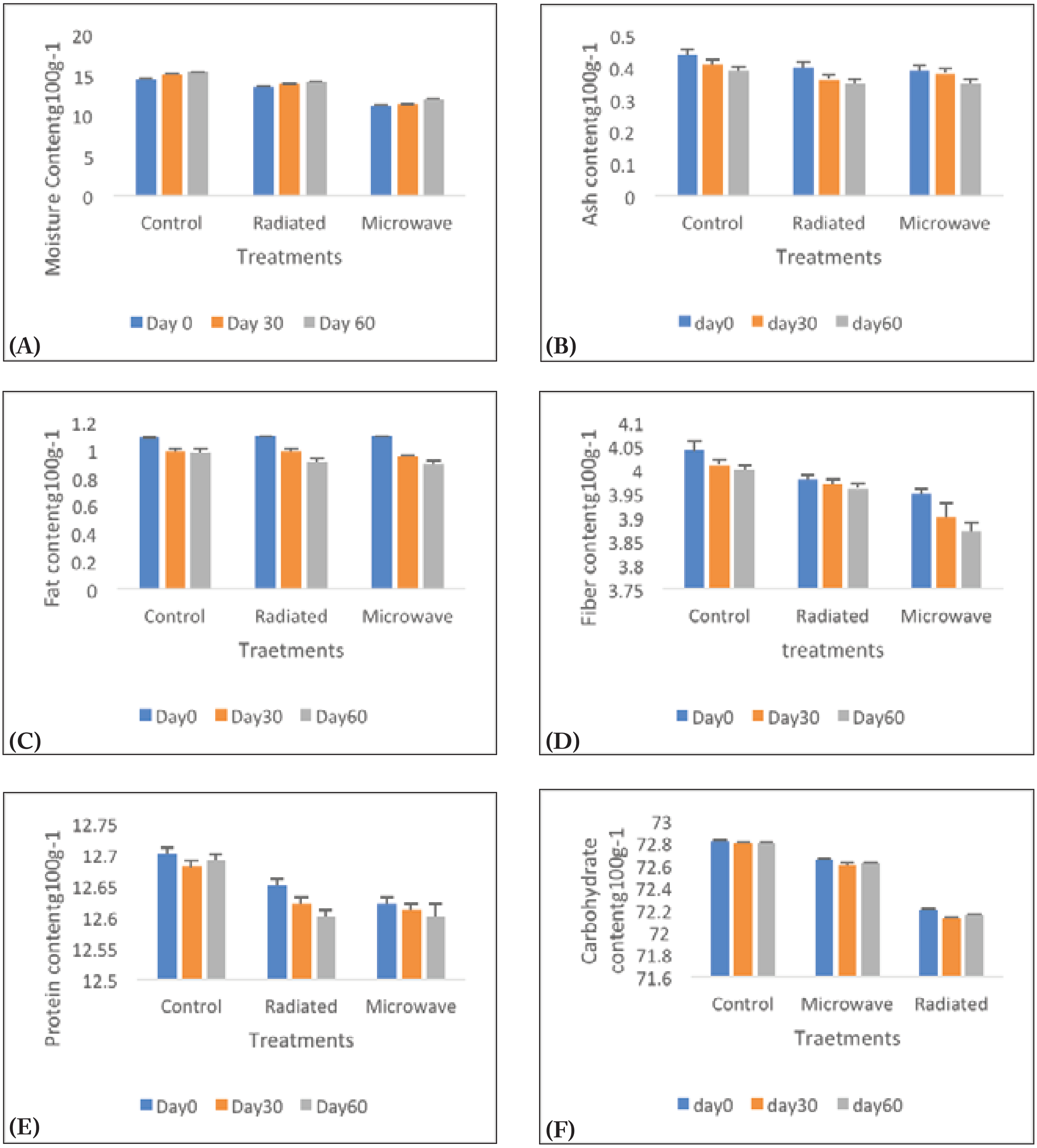

Figure 9. Effect of different treatments on Proximate values of Semolina during 60 days (a) Moisture content (b) Ash content (c) Fat content (d) Fiber content (e) Protein content (f) Carbohydrate content

Table 4. Effect of different treatments on proximate analysis of Wheat Flour, Gram Flour and Semolina

Treatments	Storage days	Moisture ($g100g^{-1}$)	Ash ($g100g^{-1}$)	Fat ($g100g^{-1}$)	Fiber ($g100g^{-1}$)	Protein ($g100g^{-1}$)	Carbohydrate ($g100g^{-1}$)
Wheat flour	Cotrol	14.33±0.57[a]	0.40±0.10[b]	1.05±.005[c]	3.97±.005[a]	12.3±.10[a]	72.76±0.01[a]
	Gamma radiated	13.53±0.30[b]	0.386±.005[c]	1.28±.010[a]	3.89±.010[b]	12.1±..10[b]	72.19±.005[c]
	Microwave treated	10.63±0.52[c]	0.467±.005[a]	1.07±.005[b]	3.85±.005[c]	12.0±0.05[b]	72.72±.005[b]
	ETO treated	10.28±0.98[d]	0.473±.005[d]	0.950±.010[d]	3.84±.010[d]	11.7±0.05[d]	72.90±.005[d]
Gamma Radiation	Control	8.73±0.41[a]	3.30±0.005[a]	59.73±0.21[a]	6.12±0.47[a]	22.73±1.64[a]	2.22±0.02[c]
	Gamma radiated	x8.83±0.05[a]	3.31±0.01[a]	58.69±0.04[b]	5.70±0.04[a]	23.03±0.32[a]	2.34±0.01[a]
	Microwave treated	7.80±0.14[b]	2.10±0.005[c]	58.41±0.08[c]	5.35±0.05[b]	23.13±0.25[a]	2.29±0.03[b]
	ETO treated	7.70±0.04[b]	1.12±0.02[b]	57.27±0.11[d]	1.23±0.02[c]	8.68±0.05[b]	1.10±0.005[d]
Semolina	**Control**	14.43±0.05[a]	0.44±0.005[b]	1.09±0.03[a]	4.04±0.5[a]	12.7±0.1[a]	72.81±0.01[a]
	Radiated	13.5±0.05[b]	0.41±0.05[b]	1.32±0.47[a]	3.97±0.01[b]	12.6±0.1[a]	71.29±0.61[b]
	Microwave	11.10±0.05[c]	0.50±0.10[a]	1.10±0.02[a]	3.96±0.02[b]	12.6±0.1[a]	72.76±0.31[a]
	ETO	10.25±0.25[d]	0.45±0.01[b]	0.98±0.001[a]	3.95±0.01[b]	12.5±0.1[b]	71.97±0.02[b]
	Significance with 3 and 11 df	*	*	NS	*	*	*

All values are the sum of means of five parallel replicates. ± indicates standard deviation(±SD) among the replicates. Mean followed by different letters in the same column differ significantly at $P < 0.05$ according to Duncan's new multiple range test.

Table 5: Effect Of Different Treatments On Rheological Properties At Day 0, 30 And 60

Treatments	Storage days	Water absorption capacity ($g100^{-1}g$)	Foaming capacity ($g100^{-1}g$)	Emulsification capacity ($g100^{-1}g$)	Bulk density (g100 g-1)
Wheat flour	Control	52.49[c]±.01	19.45[d]±.005	42.98[a]±.005	0.55[a]±.005
	Radiated	53.08[a]±.01	44.82[b]±.005	31.22[c]±.01	0.54[a]±.005
	Microwave	52.57[b]±.01	44.97[a]±.005	31.35[b]±.005	0.55[a]±.01
	EtO	52.48[b]±.01	44.08[c]±.01	31.22[c]±.01	0.53[a]±.005
Gram Flour	**Control**	1.27±0.01[d]	12.91±0.06[d]	43.7±0.05[b]	0.76±0.005[a]
	Radiated	2.03±0.07[c]	14.5±0.11[c]	41.2±0.05[d]	0.72±0.005[b]
	Microwave treated	2.23±0.05[b]	15.5±0.29[b]	42.3±0.15[c]	0.71±0.005[b]
	EtO treated	2.25±0.05[a]	16.6±0.08[a]	44.5±0.10[a]	0.75±0.005[a]
Semolina	**Control**	54.5[c]**±.1**	20.56[b]**±1.2**	46[a]**±1.0**	0.86±0.005[a]
	Radiated	56.2[a]**±0.1**	46.86[a]**±0.28**	34.33[b]**±0.37**	0.82±0.005[b]
	Microwave	55.8[b]**±.26**	46.00[a]**±0.5**	34.49[b]**±0.50**	0.71±0.005[b]
	ETO	55.59[b]**±0.6**	46.5[a]**±0.5**	34.33[b]**±0.58**	0.83±0.005[a]
	Significance with 3 and 11 df	*	*	*	*

All values are the sum of means of five parallel replicates. ± indicates standard deviation (± SD) among the replicates. Mean followed by different letters in the same column differ significantly at $P < 0.05$ according to Duncan's new multiple range test.

There was significant change in the protein content of radiated samples of wheat flour after the storage. An increase in the protein content was observed similar to as reported by the (27).

The carbohydrate content increased for control, radiated and samples of flours. This finding agrees with the result of (28).

Effect of different treatments on Rheological properties

The rheological properties of control, radiated and microwave samples of wheat flour, gram flour and semolina did change significantly with storage (table 5). The water absorption capacity of treated wheat flour and semolina samples increased significantly ($P<0.05$) as compared to the control samples during two months of storage. Both types of samples showed an increase in water absorption. This increase in water absorption might be due to higher amylase activity on the damaged starch along with the production of higher levels of reducing sugars. These findings agree with the results of (29). The foaming capacity of treated samples of wheat flour, Gram flour and semolina increased after the storage. Foaming properties depend on the proteins, carbohydrates and some other components present in the wheat and durum wheat semolina (30).

Emulsification capacity increased for the control samples after the storage. Gamma irradiated and microwave treated samples showed decrease in the emulsification capacity. This decrease in the emulsification capacity might be due to the protein denaturation or/and protein-protein aggregation upon treatment with radiations. This finding agrees with the results proposed by (31) for cowpea flours. Emulsification capacity is the surface-active property that helps in the stabilization and formation of emulsion that is a mixture of liquids (two or more) that are immiscible normally

The bulk density of all irradiated and microwave treated samples did not change significantly. A slight increase in the bulk density occurs after the storage. These observations are supported by those of (32) on irradiated lotus seed flour. Bulk density of the native and irradiated Semolina samples was in the range of 0.50-0.57 g/mL. Bulk density of the control, microwave treated and irradiated samples did not show significant ($p<0.05$) differences.

Conclusion

Gamma radiation, microwave radiation and ETO treatment are all effective in reducing the microbial bioburden of differerent flours by killing microbes and insects. However, Gamma radiation is the most promising technique of the other radiation types used, as it effectively reduces microbial bioburden with no significant change in the nutritional, rheological and sensory properties. While loss of sensory properties occurs as a result of exposure of sample to microwave radiation renders it less preferred technique and also ETO treatment is not that much effective in reducing the microbial bioburden. Therefore, it can be concluded that prior to selecting the radiation sterilization process for flours, it is important to consider the effects that radiation will have on the microbiological, proximate and rheological properties. The chosen radiation sterilization process must be efficient and cost effective.5

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