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Irradiation and Packaging-Food Safety Aspects and Shelf Life Extension of Solar Dried Garlic (*Allium sativum*) Powder

Nizakat Bib, Amal Badshah Khattak, Aurang Zeb and Zahid Mehmood
Nuclear Institute for Food and Agriculture Tarnab, Peshawar, Pakistan

Abstract: Influence of gamma irradiation and packaging material on physicochemical characteristics (moisture, protein, ascorbic acid, pH, mineral contents and browning value) and shelf life extension of garlic powder was investigated. Garlic cloves were meshed with skin, dried in solar dryer and then ground to 100 mesh. The dry powder was packed in polyethylene pouches of 0.015 (PE1), 0.03 mm (PE2) and polypropylene bottles (PP) of 0.1 mm thickness. One part of the packed samples was irradiated with 1.0 k Gy gamma rays and the other one kept as control. The data revealed no effect of irradiation on moisture (8.02-8.29%) and protein (13.00-13.30%) content during storage. The ascorbic acid content decreased from 20.82 to 19.56 mg 100 g^{-1} in irradiated and control samples and maximum retention of this vitamin was noted in samples packaged in polypropylene bottles. The effect of irradiation and packaging material on mineral content in garlic powder was also non-significant. The browning value increased from 0.17-0.22 ΔA420 in irradiated and control samples. Irradiation improved the microbial quality of the product in all the packaging materials throughout the entire storage period. It is inferred from this study that the irradiated solar dried garlic powder packaged in polypropylene (PP) pouches can be stored beyond 5 months with no significant change in quality, appearance and nutrients.

Key words: Garlic powder, irradiation, packaging, solar drying , storage and nutrients

INTRODUCTION

Garlic (*Allium Sativum)* is a member of the Amaryllis family (Amaryllidaceae), which also includes leeks, onions and shallots. It is a perennial with an underground bulb (head) composed of pungent bulblets commonly called cloves (Linda, 1997). Garlic is mainly used as a condiment in food preparations (mayonnaise, tomato ketchup, sauces, salad dressings, meat sausages, gravies, stews, spaghetti, chutneys, pickles, curried dishes, etc) and also serves as carminative and gastric stimulant. It aids in digestion and absorption of food. It also possesses anthelmintic and antiseptic properties and because of these properties it is used in a number of medical preparations. The researchers found that water extracts of garlic, deodorized garlic powder and onions each blocked the ability of two chemicals, nitrite and morpholine, to form N-nitrosomorpholine, a known liver carcinogen (Amagase, 2006; John Milner, 1996). The major biological responses of garlic include reduction of risk factors for cardiovascular diseases and cancer, a stimulation of immune function, enhanced foreign compound detoxification, radioprotection, restoration of physical strength, resistance to various stresses and potential anti aging effects (Benjamin, 2001). Garlic provides a suitable basis for anti-H. Pylori therapy due to its antimicrobial properties (Jonkers *et al*., 1999; Katey *et al*., 2005). Growth and respiration of *Candida albicans* are sensitive to extracts of *Allium sativum*, particularly allyl alcohol. Peeled garlic cloves are convenient minimally processed vegetable and its volumes have increased in retail and food service markets due to its extensive utility as medicinal and domestic purposes (Cantwell and Suslow, 2002; Harunobu *et al*., 2001).

Corresponding Author: Nizakat Bibi, Nuclear Institute for Food and Agriculture Tarnab, Peshawar, Pakistan
Tel: 009192-2964060-2 Fax: 009192-296059

Although manufacture and marketing of garlic powder is a well established industry in USA and Europe, evidence on its storage stability with respect to its nutrient and relevant packaging is not available. In most of the developing nations, garlic was consumed as such and no efforts were made to produce dehydrated garlic or garlic powder with a result that reasonable portion of the crop was wasted due to respiration, transpiration and micro-biological spoilage during ordinary storage of garlic bulb. Keeping in view the post harvest problems faced by this worldwide nutraceutically important food commodity, the present study was conducted with the objectives to minimize these problems and improve/maintain the quality of the product by irradiation and proper packaging. Availability of raw garlic at cheaper prices in many developing nations offers a very attractive opportunity for entrepreneur to produce this product at competitive prices.

MATERIALS AND METHODS

Fresh garlic (80 kg) purchased from local market (Nowshera during April) was sorted for healthy bulbs and damaged bulbs were discarded. The outer papery skin of the garlic bulb was removed manually by hand. Garlic cloves were meshed with skin using ordinary blender (France) and dried in solar dryer at 60°C for 24 h. Dried material was processed to loosen and separate the adhering husk layer from the meat by aspiration and reground to fine powder (100 mesh). The powder from all bulbs were combined and packed (100 g each in polyethylene pouches of 0.015 (PE1) and 0.03 mm (PE2) thickness and polypropylene bottles of 0.1 mm (PP) thickness for further analysis. One part of the packed samples was irradiated (1 k Gy) using CO-60 gamma source (ISSELDOVATEL, Russian origin) with a dose rate of 0.01 k Gy min^{-1} at the time of irradiation and the other part was kept as control. The irradiated and control samples were kept in separate containers/packages properly labeled. The dose rate was calibrated for the experiment using Fricke dosimetry. The samples were stored at ambient temperature for four months; analyzed fresh garlic powder followed by monthly analysis for different (one pack from each treatment) physicochemical parameters in triplicates.

Physico-Chemical Determinations

The direct colorimetric method was used for the measurement of vitamin C which is based on the measurement of the extent to which a 2,-dichlorophenol-indophenol solution is decolorized by ascorbic acid in sample extracts and in standard ascorbic acid solutions (AOAC, 1984, 9 # 43.064). Protein and moisture contents were determined by micro kjeldahl and oven drying methods # 10-177 and 10-231, respectively (AOAC, 1984). Hanna pH meter (HI 8417) was used for pH determination and Browning value, were assayed spectrophotometrically (Srivastava and Sanjeev). Iron (Rangana, 1978) and Phosphorous (AOAC, 1984, 9 # 22.040-0.43) contents were estimated also spectrophotometrically.

Microbiological Analysis

Total Bacterial Counts (TBC)

Total bacterial counts were determined by standard dilution plate method using nutrient agar medium (Khan *et al*., 2005). A 10 g sample was taken in 90 mL sterilized peptone water and thoroughly mixed. One milliliter of each sample (in triplicate) was poured Petri plates using sterilized pipettes. Sterilized nutrient medium (15-20 mL) was added to each plate and incubated for 24-48 h at 28±1°C. The colonies were counted using a colony counter (Gallen Kamp, Loughborough, Leicestershire, UK, Model CNW-300-010 M) and the Total Bacterial Counts (TBC) were determined.

Statistical Analysis

The data were subjected to ANOVA (Table 1 and 2) using Completely Randomized Design (CRD) with a 2 factorial arrangement (Steel and Torrie, 1984). Duncan Multiple Range test was used for means separation when the F-test was significant ($p<0.05$).

Table 1: Analysis of variance table showing mean sum of the squares for dried garlic powder (Irradiated samples)

Source	Degrees of freedom	pH	Browning	Ascorbic acid	Protein	Moisture	Iron	Phosphorus
Storage	4	0.844***	0.006***	7.764***	0.315	0.848**	0.050***	0.011***
Packaging	2	0.177***	0.001ns	9.581***	0.128	0.569***	0.006**	0.002
Storage X Packaging	8	0.115***	0.001ns	2.455***	0.429	0.119***	0.005**	0.005***
Error	30	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	44	44.000	44.000	44.000	44.000	44.000	44.000	44.000

ns: Non significant, **: Significant (p<0.01), ***: Significant (p<0.001)

Table 2: Analysis of variance table showing mean sum of the squares for dried garlic powder (control samples)

Source	Degrees of freedom	pH	Browning	Ascorbic acid	Protein	Moisture	Iron	Phosphorus
Storage	4	0.222***	0.010***	13.571***	0.383***	1.557***	0.026***	100.984***
Packaging	2	0.010***	0.001ns	1.331***	1.198***	0.194***	0.040**	101.565***
Storage X Packaging	8	0.014***	0.000ns	0.528***	0.448***	0.305 ***	0.017***	100.784***
Error	30	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Total	44			..				

ns: Non significant, **: Significant (p<0.01), ***: Significant (p<0.001)

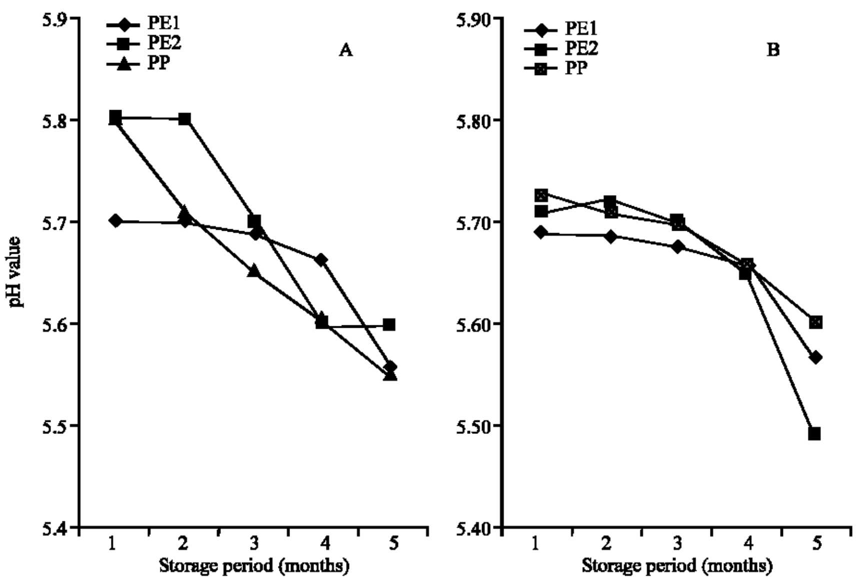

Fig. 1: (A) Effect of storage and packaging on pH values of irradiated solar dried garlic powder, (B) Effect of storage and packaging on pH values of control solar dried garlic powder

RESULTS AND DISCUSSION

Data regarding the effect of ambient storage and packaging on pH of irradiated and control solar dried garlic powder (Fig. 1A and B, Table 1 and 2) revealed a decrease in pH during storage for all the packaging materials ($p<0.001$). During first month of storage the pH values for all the samples were comparable ranging from 5.7-5.8 for irradiated samples. During subsequent storage PE2 (polyethylene packaging of 0.03 mm thickness) samples retained the pH while samples with PE1 (polyethylene, 0.015 mm thickness) and PP (polypropylene, 0.10 mm thickness) packages showed progressive decrease during the entire storage period ($p<0.001$). An overall significantly negative correlations (R^2 = 0.73-0.98 and 0.71-0.91) were found between the pH and storage period for all the packaging

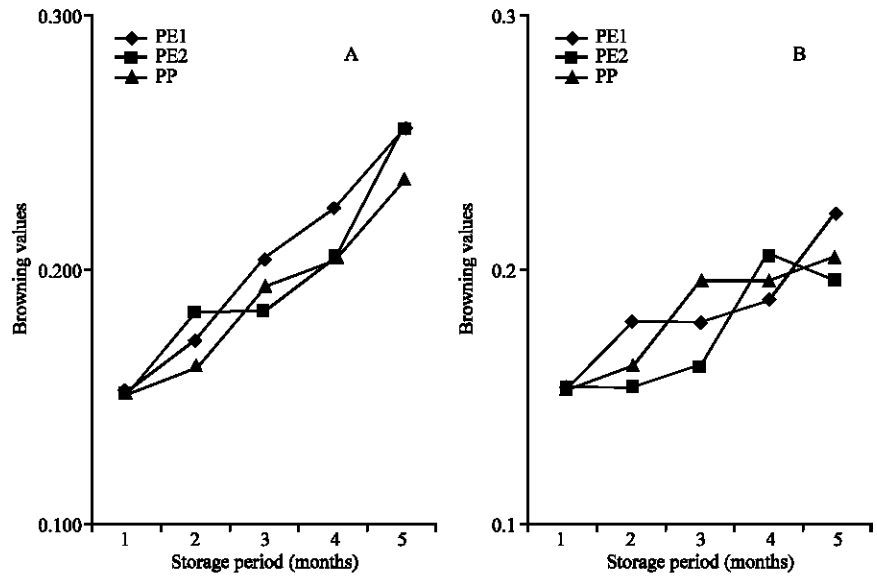

Fig. 2: (A) Effect of storage and packaging on browning values of irradiated solar dried garlic powder, (B) Effect of storage and packaging on browning values of control solar dried garlic powder

materials in irradiated and control samples. The pH of irradiated and control samples ranged from 5.80 to 5.55 and 5.70 to 5.45, respectively during five months ambient storage. The results of the current study are in agreement with those of Linda (1997). According to his study garlic is a low acid vegetable with the pH ranging from 5.3 to 6.3.

The first and foremost parameter is the color by which a product is purchased by the consumer. Data regarding browning/color presented in Fig. 2A and B showed increase ($p<0.001$) with increase in storage time averaged across the packages. However, effect of packaging was non significant (Table 1). The minimum changes were observed for samples packed in polypropylene bottles throughout the entire storage period of five months. All the samples (irradiated and controlled) experienced an increase in color with increase in storage time.

Vitamin C also known as ascorbic acid has a variety of functions in the human body. It is critical for collagen synthesis, acts as an antioxidant, enhances iron absorption and plays a role in the synthesis of vital compounds within the body's cells. Changes in ascorbic acid content during five months ambient storage of irradiated and control solar dried garlic powder are depicted in Fig. 3A and B, respectively. Ascorbic acid decreased with increase in storage period ($p<0.001$). However, PE1 samples experienced more changes in ascorbic acid content as compared to PE2 and polypropylene packaging. Maximum ascorbic acid was retained by the samples packaged in polypropylene bottles.

The effect of storage and packaging on ascorbic acid content was significant for both irradiated as well as control samples (Table 1 and 2). The correlation coefficient of storage and ascorbic acid content was significant and negative as reported earlier (USDA, 1998). The vitamin C content of fruit/vegetables is higher when it is immature and declines as the fruit ripens. Similar to our findings, Khan *et al*. (2005) reported decrease in vitamin C content during storage as well as radiation in bitter gourd. It was observed (Fan *et al*., 2003) that ascorbic acid in fresh cilantro leaves decrease in control and irradiated samples during storage. Thayer and Rajswoki (1999) reported that irradiation oxidized a portion of total ascorbic acid to the dehydro form and both of these forms of the vitamins are biologically active, suggesting minimal nutritional impact. It was also reported (Farkas *et al*., 1997) that a dose of 1.0 k Gy caused 12% loss of ascorbic acid content in pre-cut bell pepper.

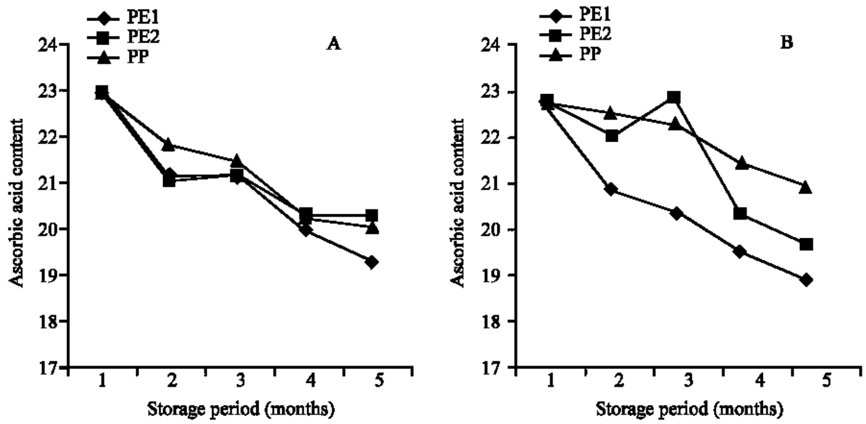

Fig. 3: (A) Effect of storage and packaging on ascorbic acid content of irradiated solar dried garlic powder, (B) Effect of storage and packaging on ascorbic acid content of control solar dried garlic powder

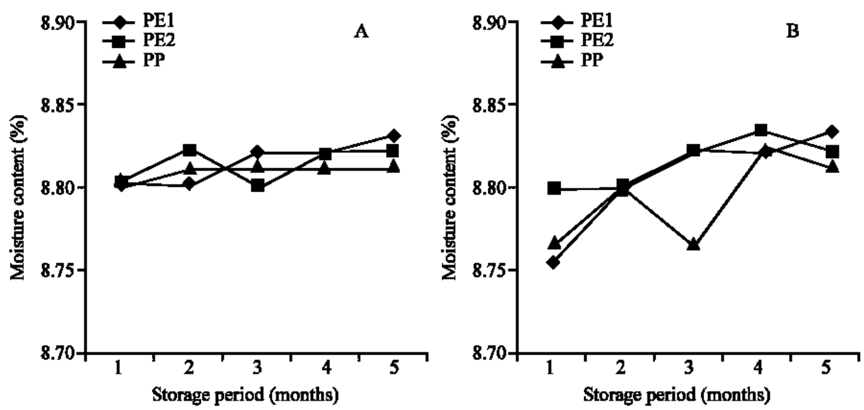

Fig. 4: (A) Effect of storage and packaging on moisture content of irradiated solar dried garlic powder, (B) Effect of storage and packaging on moisture content of control solar dried garlic powder

The data revealed that the effect of storage period and packaging material on moisture content (Fig. 4A and B) and protein content of garlic powder (Fig. 5A and B) were also significant ($p<0.001$). The moisture and protein content of irradiated samples ranged between 8.02 to 8.29% and 13.00 to 13.30% and in control between 8.76 to 8.83% and 13.28 to 13.42%, respectively. The values of correlation coefficient revealed significant increase in moisture content of PE1 samples as compared to PE2 and PP packaging while there was no effect of irradiation on moisture level of all the samples.

Contrary to our results, it was reported that surface discoloration, moisture loss and microbial spoilage contribute to loss of shelf life and quality in peeled cloves (Kang and Lee, 1999; Ramirez *et al*., 2001). Cantwell and Suslow (2002) reported that sprouting and rooting are also important causes of quality loss in peeled garlic cloves.

The effect of packaging and storage on iron (Fig. 6A and B) and phosphorous (Fig. 7A and B) content of irradiated and non irradiated garlic powder was also significant ($p<0.001$).

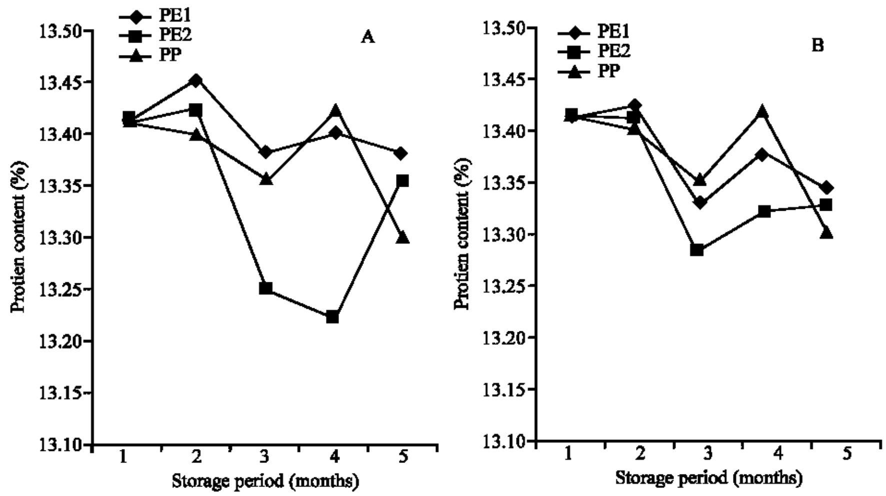

Fig. 5: (A) Effect of storage and packaging on protein content of irradiated solar dried garlic powder, (B) Effect of storage and packaging on protein content of control solar dried garlic powder

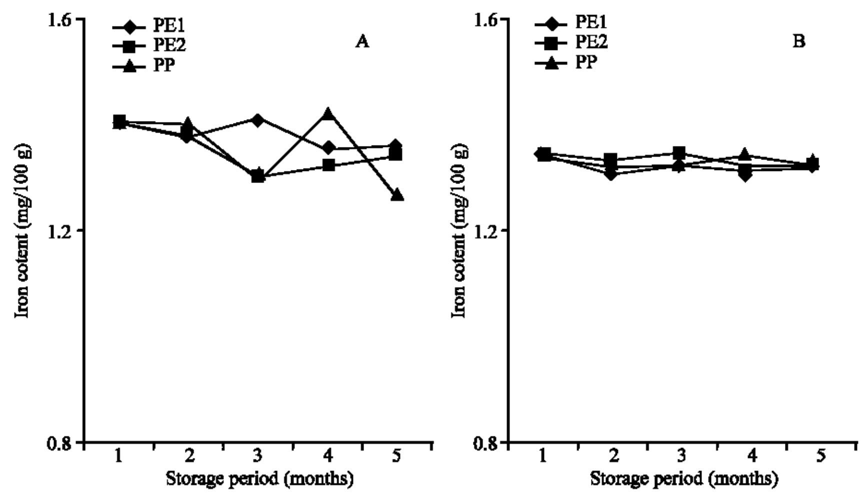

Fig. 6: (A) Effect of storage and packaging on iron content of irradiated solar dried garlic powder, (B) Effect of storage and packaging on iron content of control solar dried garlic powder

Iron is a part of both hemoglobin and myoglobin. This nutrient is essential for the uptake and release of oxygen in the body. Cooked peas, spinach, navy beans and red kidney beans are all good sources of iron. Phosphorous is essential for the human body. This mineral plays a role in cell regulation, nerve transmission and the maintenance of strong teeth and bones. In general, fruit and vegetable products provide only small amounts of phosphorous. However, these can be utilized beneficially if fruits/vegetables are processed properly.

It is clear from the figures for control and irradiated solar dried garlic powder that there was no adverse effect of irradiation (1 k Gy) on pH, browning, ascorbic acid content, proximate composition and mineral content. It was reported earlier that the changes that occur in irradiated food is usually the same as with cooked food and that there were no toxicological effect found in irradiated foods 9

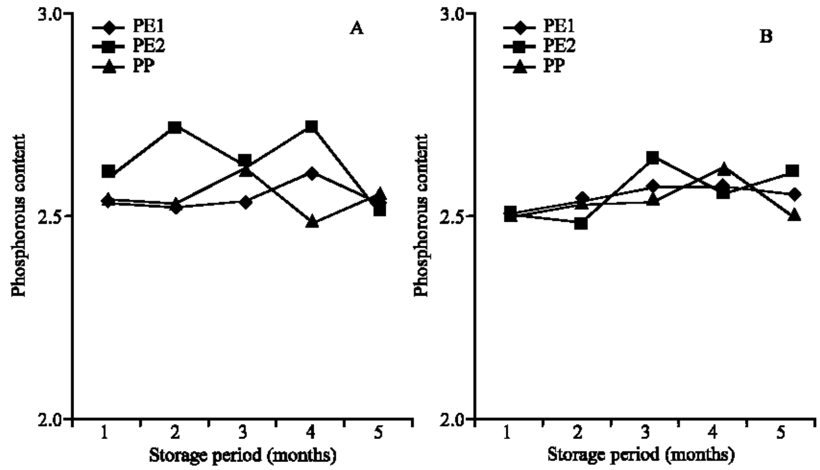

Fig. 7: (A) Effect of storage and packaging on phosphorus content of irradiated solar dried garlic powder, (B) Effect of storage and packaging on phosphorus content of control solar dried garlic powder PE1 is Polyethylene packaging of 0.015 mm thickness; PE2 is Polyethylene packaging of 0.030 mm thickness; PP is Polypropylene packaging of 0.10 mm thickness

Table 3: Effect of storage and packaging on microbiological quality of solar dried garlic powder

Storage period (months)	Total fungal counts (TFC g^{-1})		Total bacterial counts (TBC g^{-1})		Total coliform counts (TCC g^{-1})	
	1	2	1	2	1	2
PE1						
1	8.7×10^1	Nd	4.7×10^1	Nd	Nd	Nd
2	9.6×10^1	Nd	6.1×10^1	Nd	Nd	Nd
3	1.5×10^2	1.1×10^1	8.7×10^1	Nd	Nd	Nd
4	5.9×10^2	3.6×10^1	1.2×10^2	1.3×10^1	Nd	Nd
5	4.4×10^3	4.2×10^1	4.3×10^2	2.5×10^1	Nd	Nd
PE2						
1	6.4×10^1	Nd	4.2×10^1	Nd	Nd	Nd
2	8.6×10^1	Nd	5.8×10^1	Nd	Nd	Nd
3	9.5×10^1	1.8×10^1	8.7×10^1	Nd	Nd	Nd
4	2.2×10^2	4.5×10^1	1.0×10^2	1.0×10^1	Nd	Nd
5	3.4×10^3	4.9×10^1	3.5×10^2	1.8×10^1	Nd	Nd
PP						
1	5.7×10^1	Nd	3.6×10^1	Nd	Nd	Nd
2	7.2×10^1	Nd	5.3×10^1	Nd	Nd	Nd
3	8.4×10^1	Nd	7.5×10^1	Nd	Nd	Nd
4	1.9×10^2	1.5×10^1	9.8×10^1	Nd	Nd	Nd
5	7.7×10^2	2.3×10^1	2.3×10^2	1.2×10^1	Nd	Nd

1 = Control PE1 = Polyethylene packaging of 0.015 mm thickness, 2 = Irradiated PE2 = Polyethylene packaging of 0.030 mm thickness, Nd = Not detected PP = Polypropylene Packaging of 0.10 mm thickness

(Lutter, 1999). Another study comparing tofu prepared from irradiated and non-irradiated soybean shows that there is no significant difference of both products in moisture, lipid, protein, carbohydrate and ash content (Byun *et al*., 1995). Moreover, studies have shown that irradiated food has no greater effect in nutrient loss compared to other processed food, such as cooked and canned food (Olson, 1998).

The use of low dose ionizing irradiation of minimally processed fruits and vegetables to increase food safety and security during storage is of prime importance. The data summarized in Table 3 reflects microbiological changes of control and irradiated solar dried garlic powder during storage. No coliform counts were detected in irradiated as well as control samples during the entire storage period. Total fungal counts and total bacterial counts were with in the acceptable limits for both irradiated and control samples of all the packaging materials. Irradiation reduced the TFC/g and TBC/g to a negligible amount as compared to control samples throughout the entire ambient storage while among packages, the propylene packaged samples showed the least microbial load followed by PE2 packaged samples. Similar to present studies, Khan *et al*. (2005) reported that the radiation dose of 2 k Gy significantly lowered the microbial load to a negligible level (5 D10) just after irradiation and during refrigerated storage hence ensuring the microbiological safety of minimally processed bitter gourd for 7 days without loss in texture and sensory quality. According to Prakash *et al*. (2000) irradiation (1.0 k Gy) of diced celery reduced *E. coli* and *L. monocytogenes* to undetectable levels (>5 logs). Farkas *et al*. (1997) recommended a dose of 1.0 kGy for ensuring hygienic quality of carrots during two weeks refrigerated storage. According to Tournas (2005). Yeasts were the most prevalent organisms found in these samples, at levels ranging from less than 100 to $4.0\times10[8]$ cfu g^{-1}.

Concluding Remarks

It is inferred from this study that Irradiation (1 k Gy) treatment combined with PE2 and PP packaging can extend the shelf life of the product by improving the microbial quality and without significant changes in most of the physicochemical characteristics up to five months ambient storage. It was also observed that irradiated solar dried garlic powder stored in polypropylene bottles at room temperature experienced less changes in commercially most important parameter (color/ browning), moisture content and nutritional aspects (ascorbic acid content) as compared to polyethylene packages at the end of five months storage period.

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