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Research Article

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Radiation processing of dried *Ker* (*Capparis deciduas*): Effect on microbial safety and nutritional quality

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ABSTRACT
Radiation processing of fresh and market (0-6 months old) dried *ker* at different doses of 2.5, 5.0 and 7.0 kGy was investigated. The effect of radiation treatment on total bacterial counts and nutritional quality parameters like moisture, protein, fat, ash, fibre, total sugar and starch contents were determined over a storage period of 3 months at ambient temperature. The findings of the study indicated that the radiation treatment reduces total bacterial counts in both fresh and market-dried *ker* at all doses. However, a dose of 5 kGy eliminated total bacterial counts in samples after storage. No significant changes were found in the proximate composition of both fresh and market-dried *ker*. On the contrary, total sugar content was observed to be increased in both control as well as irradiated samples during storage. Thus, radiation processing with 5.0 kGy did not affect significantly the nutritional quality of fresh and market-dried *ker* samples.
Keywords: Gamma irradiation, *Ker*, Nutritional quality, Microbial safety, Storage.

INTRODUCTION
The incidence of food-borne disease arising from the consumption of food contaminated with pathogenic microorganisms is increasing, and there is a heightened public awareness of the health threat posed by pathogens (ICGFI, 1999). Foods may be contaminated naturally during any stage from production to consumption. The contamination may be in the form of microbes including those that cause food spoilage or diseases in humans, in contrast, food may be infected and destructed by insect infestations (Loaharanu, 2003). In earlier times, attempts have been made to explore various means of preserving food and protecting it from microorganisms, insects and other pests. All food preservation methods have played a role in improving the quality, quantity and safety of the food supply, protecting it against destruction, microbial contamination and spoilage.

Food irradiation is a non-thermal and most acceptable technique for the preservation of fresh as well as dried foods (Bisht *et al.*, 2021). In this technique, controlled amounts of either non-ionizing or ionizing radiations have been applied to the foods. It has a positive influence on spoilage and pathogenic microorganisms, including viruses, without compromising the product's quality or nutritional properties (Pathak *et al*., 2018; Nair and Sharma, 2016; Kalaiselvan *et al*., 2018). Gamma rays or electron beams are used to irradiate foods. Irradiation has received approval for use in several food categories from the Food and Drug Administration (FDA) and has been proven as an effective food safety measure.

Ker (*Capparis decidua*) is a woody shrub which grows in hot arid and semi-arid zones of the world. In India, it is commonly known by several names such as *Kair* or *Ker* in Rajasthan, *Teent* or *Dela* in Haryana and Caper berry in English. *Ker* is also known to have medicinal properties and is useful in the mitigation of various diseases hypertension, diabetes, rheumatism and various stomach problems (Goyal and Sharma, 2009). Its raw fruits are consumed as vegetables and also processed and preserved in the form of pickles or dried and stored for off-season, when other vegetables are scarce (Sharma, 2000). *Panchkutta* (five mixed vegetables) is one of the traditional and most prestigious vegetables, giving delicacy to Indian meals. Dried *ker* is valued as it is an important ingredient of *Panchkutta*, being transported from one place to another would affect the quality of vegetables. Processing of *ker* in a more useful and convenient manner is a most vital component of value addition which ultimately improves the economic value of the product. In arid regions owing to plenty of solar radiation, value addition of *ker* through dehydration is more common (Pareek, 2000). Consequently, sufficient care is needed to ensure that the final product is safe and stable.

Ionizing radiation is highly effective in inactivating microorganisms in various vegetables and it offers a safe alternative as a food decontamination method. For a long time, there have been several research studies directed at probing the effect of gamma radiation on fresh as well as dried vegetables and fruits for controlling pathogens and pest and exploring nutritional and functional qualities (Galetto *et al*., 1979; Farkas, 1985; Kader 1986; Wang and Chao, 2003; Pezzutti *et al*., 2005; Bozoglu and Erkmen, 2016; Bhoir and Kanatt, 2023). No information in the literature is available on radiation processing of *ker* samples. Hence, the present study was intended to examine the effect of radiation processing on the microbial safety and nutritional qualities of dried *ker*.

MATERIALS AND METHODS

All the chemicals used were of analytical grade and were procured from SISCO Research Laboratories Pvt. Ltd., Mumbai, India.

Sample preparation

A locally available variety of *ker* in fresh form as well as market (0-6 months old) dried was purchased from the market of Bikaner city of Rajasthan State in India. Damaged and non-edible portions were discarded. Fresh *Ker* was thoroughly washed with water to remove adhering impurities and soaked in buttermilk for 7 days to become softer and then spread singly on a clean and dry muslin cloth. The drying process was continued till the samples became brittle. Both types of *ker* were weighed and transferred to poly bags and sealed properly.

Gamma radiation process

Gamma irradiation was carried out in a cobalt-60-based gamma chamber (GC-1200, BARC, Mumbai, India) at Radio Tracer Laboratory, S.K. Rajasthan Agricultural University, Bikaner. Properly sealed samples were irradiated at different doses of 2.5, 5.0 and 7.0 kGy. Treated and control samples were stored at ambient temperature until the analyses were carried out.

Microbiological analysis

For determining total bacterial counts (TBC) method of Collin and Lyne (1976) was used after some modifications using a nutrient agar (NA) medium. A 10 g sample was taken aseptically in the blender jar, to which 90 ml of sterilized saline (0.85 per cent) water was added and blended for 2 min. This provided a 1:10 dilution. Further, required dilutions were made by transferring 1 ml of this homogenate to 9 ml of sterile saline water. One millilitre of each dilution (in triplicate) was poured into petri plates using sterilized pipettes. A sterilized nutrient medium (15 to 20 ml) was added to each plate and incubated for 24 h at 37 ± 1 °C. Calculations were made by multiplying the total number of colonies by the dilution factor.

Nutritional analysis

Dried *ker* was ground using an electronic food grinder before analysis. Proximate values i.e. moisture, crude protein, crude fat, total ash, and crude fibre in the fresh dried *ker* (FDK), as well as market dried ker (MDK) samples, were determined by Official analysis methods of the AOAC (1995).

Total sugar was estimated by refluxing the samples in ethanol for 30 minutes. The extract was cooled and centrifuged at 8000 rpm for 15 minutes, then the supernatant was separated. To evaporate ethanol, the extract was kept in a boiling water bath and then residue was dissolved in 50 ml of distilled water. This solution was further diluted to 1:10 with distilled water and used for total sugar estimation. Freshly made anthrone reagent was taken in test tubes and kept in an ice bath. After that diluted sample was poured from the side of the test tubes and the solutions were cooled for 5 minutes and the contents were thoroughly mixed. The tubes were heated in a boiling water bath for 10 minutes, again cooled and absorbance was read at 625 nm in a spectrophotometer (Systronics Model 117) using a suitable blank (Yemm and Willis, 1954).

Starch content was estimated with the method described by Clegg (1956). The residue that remained after centrifugation in total sugar estimation was used for the estimation of starch content. The perchloric acid was added to test tubes containing samples and vortexed for 5 minutes, centrifuged at 8000 rpm for 20 minutes and diluted to 100 ml, the solution was filtered and absorbance was measured at 600 nm using a spectrophotometer.

Rehydration ratio

The rehydration ratio was used to express the rehydration of dried *Ker*. The rehydration ratio of the dried *ker* was evaluated by immersing 20 g samples in water at room temperature. Samples were drained and weighed after 6 h. The ratio of the sample was weighed before and after rehydration expressed as a percentage which was taken as a measure of the rehydration ratio (Jayaraman *et al*., 1990; Farkas and Singh, 1991; Lewicki, 1998).

$$\text{Rehydration ratio} = \frac{\text{Mass after rehydratio}}{\text{Mass before dehydration}} x100$$

Statistical analysis

The experiment was laid out in a complete randomized design with three replications described by Cochran and Cox (1975). Data was analyzed by factorial design with three factors: (1) three doses of gamma irradiation (2) a month storage period (3) two types of *ker* (fresh and market-dried). The least significant differences were calculated for mean differences between controls and irradiated (2.5-7.0 kGy) samples for all the parameters.

RESULTS AND DISCUSSION

Microbiological analysis

The data representing the total bacterial count of both FDK and MDK is depicted in Table 1. The initial bacterial load of control samples of FDK was maximum (3.65 log CFU/g) followed by 2.5 kGy irradiated samples (2.15 log CFU/g). A similar pattern of reduction of TBC was found in MDK samples i.e. 3.95 log CFU/g in control samples and 2.38 log CFU/g in 2.5 kGy irradiated samples, when examined after radiation treatment. No significant changes were found in these counts during the storage period. After 3 months the counts were 3.67 and 3.98 log CFU/g in controls and 2.16 and 2.39 in irradiated (2.5 kGy) samples in FDK and MDK, respectively. At 5.0 and 7.0 kGy radiation treatment, the samples were completely sterilized ensuring that no bacterial growth was found in FDK and MDK samples. No information in the literature is available on the effect of gamma irradiation on the microbial load of dried *ker* samples. But decrease in microbial load of other plant materials following gamma irradiation was reported by several researchers. Farkas (1998) reported that radiation doses ranging between 2 and 7 kGy could effectively eliminate non-spore-forming bacteria such as Salmonella spp. *Staphylococcus aureus*, *Campylobacter* spp., *Listeria monocytogenes*, and *Escherichia coli* (O157:H7). Mishra *et al*. (2006) conducted a study on the radiation processing of fresh ginger pieces and reported that a radiation dose of 5 kGy is best suited for a shelf-life extension of more than 2 months, maintaining superior microbiological quality. A similar study carried out by Joshi *et al*., (2011) reported that a dose of 5 kGy was found appropriate to eliminate total bacterial counts in dried *sangari*. Generally, the main foodborne pathogens of unlike species are sensitive to irradiation and might be eliminated by medium and low doses of radiation ranging between 1 and 7 kG y. Moreover, increased sensitivity to irradiation was seen in moulds followed by yeasts, bacteria and viruses (Bhatnagar *et al*., 2022).

Table 1. Effect of Irradiation and Storage on Total Bacterial Counts (Log CFU/g)

Storage days	Total bacterial counts (CFU/g)	
	Non-irradiated	2.5 kGy
FDK[a]		
0	3.65 ± 0.19	2.15 ± 0.11
30	3.64 ± 0.22	2.16 ± 0.13
60	3.69 ± 0.21	2.17 ± 0.14
90	3.67 ± 0.15	2.16 ± 0.21
MDK[b]		
0	3.95 ± 0.23	2.38 ± 0.19
30	3.96 ± 0.18	2.39 ± 0.11
60	3.94 ± 0.12	2.41 ± 0.09
90	3.98 ± 0.09	2.39 ± 0.18

[a] FDK= Fresh dried *ker*. [b] MDK= Market dried *ker*.
CFU = Colony-forming unit.
ND = No colony-forming unit detected in samples treated with irradiation dose of 5.0 and 7.0 kGy.

Nutritional analysis

Table 2 summarizes the proximate values of control and irradiated samples of FDK and MDK over a storage period of 3 months. In general, no significant change in proximate constituents amongst the samples of FDK and MDK was observed. The data showed that the moisture, protein, fat, ash and fibre content of FDK and MDK remained unchanged following gamma irradiation, as compared to that of the control. The values of proximate composition of the present study are in agreement with those reported by Inayatullah *et al*. (1987) who observed that irradiation with 0.25, 0.5, 1.0, 2.5 and 5 kGy had no significant effect on the proximate composition (water, fat, ash and carbohydrate) of soybean. Khattak *et al*. (2009) also reported that there were no substantial changes in proximate constituents of *Nelumbo nucifera* rhizome at a dose of 1 to 6 kGy. A similar trend was observed by Joshi *et al*. (2011) who found no significant change in the proximate composition of fresh dried and old dried *sangari* treated with different radiation doses (2.5-7 kGy). Recent study conducted by Arapcheska *et al*. (2020), revealed that irradiation does not cause any significant loss of macronutrients. Proteins, fats and carbohydrates undergo minimal modifications in nutritional value, which are less significant compared with traditional methods of food preservation.

Fig. 1 summarizes the changes in total sugars in irradiated and control samples of FDK and MDK during storage at ambient temperature. In controls, the total sugar content was increased from 1.85 to 2.14 percent and 2.44 to 2.65 per cent respectively, in both FDK and MDK stored for 3 months. In the case of irradiated samples, the total sugar content ranged from 1.94 to 2.37 per cent (FDK) and 2.48 to 2.89 percent (MDK). The significant increase in total sugar content could have been due to the degradation of starch during storage. The results reported in present investigation were compatible with those of Ogawa *et al*. (1969) who stated that irradiation increase total and reduces sugar contents in sweet potatoes. Likewise, Campbell *et al.* (1968) reported that the reducing sugars content of *Agaricus campestris* mushrooms treated with 1.0 kGy was slightly higher than that of non-irradiated mushrooms after storage for 4 d at 1 °C and 85 percent RH. Roushdi *et al*. (1981) observed that irradiation of dried corn increased the reducing sugars and total soluble sugars in proportion to the dose.

Fig. 2 shows the starch content of controls and irradiated samples of both FDK and MDK. After 3 months of storage Starch content was degraded from 0.82 to 0.7 percent and 0.72 to 0.44 percent in both control and irradiated (7.0 kGy) samples of FDK, respectively. While in the case of MDK samples, starch content was altered from 0.74 to 0.62 percent and 0.6 to 0.32 percent in both control and at the highest dose of irradiation (7.0 kGy), respectively, during storage. The result revealed that starch content continuously decreased with an increase in irradiation dose (2.5-7.0 kGy) in both FDK and MDK samples. A storage period of 3 months also contributed to some changes in the starch content of control and irradiated samples. The possible reason for the decrease in starch content might be due to the breakdown of starch into sugars because of irradiation or during storage. The progressive decrease in starch content as the irradiation dose was raised may be due to the breakdown acceleration of glucosidic linkages (Roushdi *et al*., 1982). A similar study was conducted by Lu *et al*. (2007) that starch and texture tended to decrease with an increase in dose rate in sweet potatoes. Moreover, no significant effect of gamma irradiation was recorded for grain amaranth starch irradiated up to 10 kGy by Kong *et al.* (2009)

Rehydration ratio

Fig. 3 shows the rehydration ratio of dried samples of both FDK and MDK. The rehydration ratio of control samples was higher than that of irradiated ones in both FDK as well as MDK. The results indicated that the rehydration ratio gradually decreased with increasing irradiation dose. Similar results were observed by Wang and Chao (2003) that an irradiation dose of 6 kGy affected the rehydration ratio more as compared to lower doses in dried apple samples. Wang and Du (2005) stated that rehydration ratios were greatly affected by irradiation dose in dried potatoes and also explained that the greater the dose of irradiation lower the rehydration ratio.

Table 2. Proximate composition of control and irradiated FDK and MDK

Moisture (%)										
Irradiation dose (kGy)	FDK[a]					MDK[b]				
	Storage periods (months)									
	0	1	2	3	Mean[c]	0	1	2	3	Mean[c]
0	7.33	7.31	7.31	7.32	7.32	6.98	6.98	6.98	6.97	6.98
2.5	7.32	7.31	7.32	7.32	7.32	6.97	6.98	6.97	6.97	6.97
5.0	7.31	7.32	7.31	7.31	7.31	6.98	6.97	6.98	6.97	6.98
7.0	7.30	7.31	7.30	7.30	7.30	6.97	6.98	6.98	6.97	6.98
Mean[d]	7.32	7.31	7.31	7.31		6.98	6.98	6.98	6.97	
Mean of strain	7.31					6.98				
Protein *(%)*										
Irradiation dose (kGy)	FDK[a]					MDK[b]				
	Storage periods (months)									
	0	1	2	3	Mean[c]	0	1	2	3	Mean[c]
0	13.95	13.94	13.93	13.92	13.94	13.59	13.59	13.59	13.59	13.59
2.5	13.94	13.93	13.92	13.92	13.93	13.58	13.58	13.59	13.59	13.59
5.0	13.93	13.92	13.92	13.92	13.92	13.58	13.59	13.58	13.58	13.58
7.0	13.93	13.91	13.92	13.91	13.92	13.58	13.59	13.58	13.57	13.58
Mean[d]	13.94	13.93	13.92	13.92		13.58	13.59	13.59	13.58	
Mean of strain	13.93					13.59				
Fat *(%)*										
Irradiation dose (kGy)	FDK[a]					MDK[b]				
	Storage periods (months)									
	0	1	2	3	Mean[c]	0	1	2	3	Mean[c]
0	6.63	6.63	6.62	6.61	6.62	6.29	6.28	6.28	6.28	6.28
2.5	6.63	6.62	6.61	6.62	6.62	6.29	6.29	6.28	6.27	6.28
5.0	6.62	6.62	6.61	6.61	6.62	6.29	6.28	6.28	6.27	6.28
7.0	6.62	6.61	6.61	6.59	6.61	6.28	6.27	6.28	6.27	6.28
Mean[d]	6.63	6.62	6.61	6.61		6.29	6.28	6.28	6.27	
Mean of strain	6.62					6.38				
Ash *(%)*										
Irradiation dose (kGy)	FDK[a]					MDK[b]				
	Storage periods (months)									
	0	1	2	3	Mean[c]	0	1	2	3	Mean[c]
0	5.96	5.94	5.93	5.92	5.94	5.92	5.92	5.92	5.91	5.92
2.5	5.95	5.94	5.91	5.92	5.93	5.91	5.92	5.92	5.91	5.92
5.0	5.94	5.91	5.91	5.91	5.92	5.91	5.91	5.91	5.91	5.91
7.0	5.91	5.91	5.91	5.90	5.91	5.91	5.91	5.91	5.91	5.91
Mean[d]	5.94	5.93	5.92	5.91		5.91	5.92	5.92	5.91	
Mean of strain	5.92					5.91				
Fibre *(%)*										
Irradiation dose (kGy)	FDK[a]					MDK[b]				
	Storage periods (months)									
	0	1	2	3	Mean[c]	0	1	2	3	Mean[c]
0	11.85	11.82	11.83	11.82	11.83	11.48	11.50	11.49	11.49	11.49
2.5	11.83	11.81	11.82	11.82	11.82	11.49	11.49	11.48	11.48	11.49
5.0	11.82	11.81	11.82	11.81	11.82	11.49	11.48	11.48	11.48	11.48
7.0	11.81	11.81	11.82	11.81	11.81	11.48	11.48	11.48	11.48	11.48
Mean[d]	11.83	11.81	11.82	11.82		11.49	11.49	11.48	11.48	
Mean of strain	11.82					11.48				

[a] FDK= Fresh dried *ker.* [b]MDK= Market dried *ker.* [c] Mean within the columns followed by the same letters do not differ significantly ($p < 0.05$).[d] Mean with the row followed by the same letters do not differ significantly ($p < 0.05$). All values are expressed as replicates of three determinations (n=3).

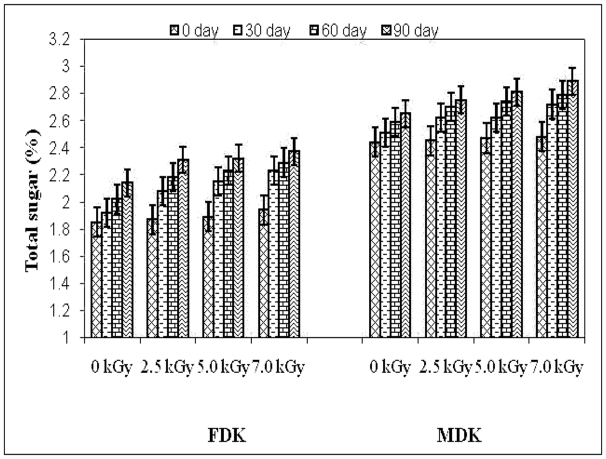
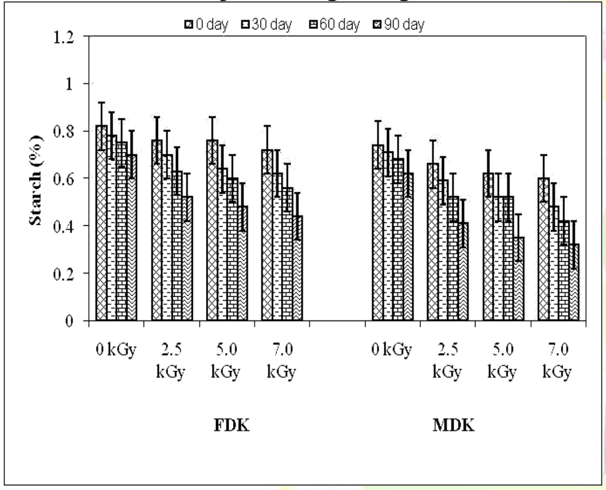
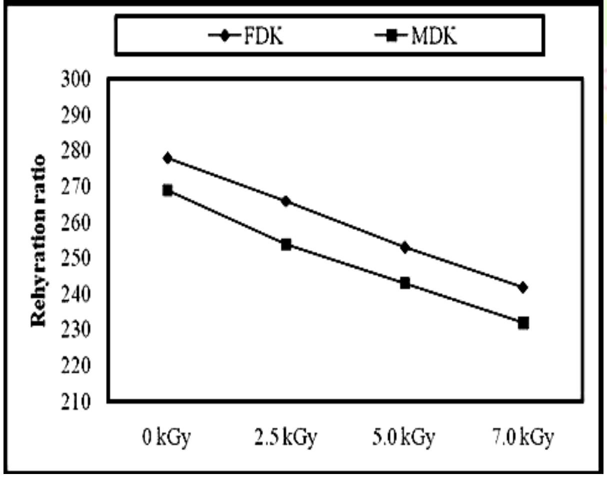


Figure 1. Changes in total sugar content of irradiated FDK and MDK samples during storage.



FDK= Fresh dried *ker*. MDK = Market dried *ker*. Values are mean ± SD of three replicate determinations (n=3).

Figure 2. Changes in starch content of irradiated FDK and MDK samples during storage



FDK= Fresh dried *Ker*, MDK = Market Dried *Ker*, Values are mean ± SD of three replicate determinations (n=3)

Figure 3. Effect of irradiation on rehydration ratio of FDK and MDK

CONCLUSION

The present study was an effort to examine the effect of radiation processing on different quality parameters of dried *ker*. In both fresh and old dried *ker*, irradiation of 2.5-7.0 kGy significantly reduced microbial contamination whereas, a dose of 5.0 kGy completely sterilized *ker* samples. Radiation processing had no significant effect on the proximate composition of both fresh as well as market-dried *ker*. Total sugar content was significantly increased in controls and irradiated samples of both types of *ker* samples. It is concluded that a dose of 5.0 kGy extends the storage life of *ker* without any significant changes in nutritional quality.

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CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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