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Effect of Gamma Irradiation on Nutritional Quality Parameters of Dehusked Foxtail Millet (*Setaria italica* (L.) Beauv.)

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ABSTRACT

This study evaluated the effect of gamma irradiation on nutritional quality parameters of dehusked foxtail millet such as moisture content, carbohydrates, crude protein, crude fat, crude fibre, total ash, total phenols, tannin and phytic acid. Dehusked foxtail millet samples of 500g each, packaged in polyethylene terepthalate packaging material (PET, 400 gauge), were irradiated using gamma Cobalt - 60 (^{60}Co) radiator. The packaged samples were evenly exposed to different irradiation doses [T_1(0.25), T_2(0.50), T_3(0.75), T_4(1.00), T_5(1.25), T_6(1.50), T_7(1.75) and T_8(2.00) kGy] and unirradiated sample served as control. The irradiated and unirradiated (control) dehusked foxtail millet were stored for a period of 6 months at room temperature. The results showed that irradiated dehusked foxtail millet with a concentration of 1.75 kGy reduced the moisture content, crude protein, crude fat, crude fibre, tannin and phytic acid and increased the carbohydrates, total ash and total phenols compared to unirradiated samples. Hence, it was concluded that the application of irradiation technology is a promising technology with no adverse effects on nutritional quality and to reduce the post harvest loss.

Introduction

Foxtail millet (*Setaria italica*) is native to Southern Asia and is considered as one of the oldest cultivated millets (Oelke*et al.*, 1990). Foxtail millet belongs to family *Poaceae* and subfamily *Panicoideae*. Nutritional value of foxtail millet (*Setariaitalica*) per 100 g of edible portion contains moisture 12.5 g, protein 12.3 g, lipid 4.3 g, carbohydrate 60.1 g, ash 1.2 g, fat 4.3 g, dietary fibre 9.0 g, calcium 3.1 g, minerals 3.3 g, vitamins and thiamine 590 mg (Malleshi and Desikachar, 1985). It contains fair amount of phenols, which is a strong antioxidant. Most millets with hulls have excellent storage properties and can be kept for 4 - 5 years in simple storage facilities such as traditional granaries. This is because the seeds are protected from insect attack by the hard hull covering the endosperm. Simple milling process might trigger oxidative rancidity and development of off flavor during storage of both grits and flour, so it is better to grind the flour right before it is to be used.

Generally, chemical fumigants are used to disinfest grains (Arthur, 1996). However, continuous application of these pesticides has a negative impact either on the environment or human health (Cherry *et al.*, 2005). Therefore, the industry has been forced to explore nonchemical alternatives. One possible alternative would be the application of irradiation (Khalid and Manjeet, 2016).

Irradiation is the process of exposing food to ionizing radiation to destroy microorganisms, bacteria, viruses or insects that might be present in the food (Fombang *et al.,* 2005). It is already recognized as a technically feasible method and safe alternative technology to chemical methods, which maintains the quality and nutritional characteristics of stored products as well as their shelf-life (Jyoti *et al.*, 2009). Apart from disinfestation, irradiation can cause subsequent changes in food components; especially in carbohydrates, proteins, lipids and vitamins.

In lipids, it has been found that a relatively high dose of irradiation would give rise to a relatively milder decomposition compared to decomposition produced by normal cooking temperature (Nawar, 1983). Irradiation has also been successfully used for the inhibition and removal of food allergens and anti-nutritional factors such as saponins and tannins (Al-Kaisey *et al.,* 2002; Byun *et al.*, 2002; Diehl 2002; Bhat *et al.,* 2007). FAO/IAEA/WHO Joint Expert Committee has recommended that the food items irradiated up to an average dose of 10 kGy can be accepted as safe from the health angle and do not present any toxicological hazards. In 2001, FDA determined that food should be pre-packaged before irradiation. It protects irradiated food from recontamination and maintains the quality of food.

The irradiated foods are labeled with “Radura” logo and along with the words “Processed by irradiation method” (Nagat *et al.,* 2015).

Foxtail millet is commonly infested by stored pests like rice moth, *Corcyra cephalonica* which is also known to infest cereals, millets, oil seeds, pulses, etc (Nirmala *et al.*, 2009).

After dehusking of foxtail millet due to the exposure to ambient conditions, rancidity sets in rapidly reducing the shelf-life drastically. In this context, the objective of this research was to study the effect of gamma irradiation on quality parameters of dehusked foxtail millet.

Materials and Methods

Raw material

The foxtail millets (Variety: HMT 100-1) were procured from the seed unit, University of Agricultural Sciences, Raichur.

Cleaning and destoning of foxtail millets

The foxtail millet grains were cleaned using specific gravity separator and destoner. Later, the cleaned materials were fed into millets destoner for removing stones and other impurities present in the grain mass.

Dehusking of foxtail millets

The centrifugal double disc type dehusker was used for dehusking of foxtail millets. The cleaned and destoned foxtail millets grain was fed into the millet dehusker.

Packaging of dehusked foxtail millets

In 2001, the Food and Drug Administration (FDA) recommended that, the foods should be pre-packaged before irradiation. Because food once irradiated, it can be prone to recontamination unless appropriately packaged. Hence, the dehusked foxtail millets (500 g each) were packaged in polyethylene terephtalate (PET, 100 micron) before irradiation for further storage studies.

Irradiation of dehusked foxtail millets

Dehusked foxtail millets samples of 500 g each, packaged in polyethylene terepthalate (PET, 100 micron), were irradiated using gamma Cobalt – 60 (^{60}Co) radiator. The packaged samples were evenly exposed to different irradiation doses of T_1(0.25), T_2(0.50), T_3(0.75), T_4(1.00), T_5(1.25), T_6(1.50), T_7(1.75) and T_8(2.00) kGy with a dose rate of 9.50 kGy/h and unirradiated sample served as control.

Storage quality evaluation

Proximate composition of dehusked foxtail millets

The moisture content of the foxtail millets was determined by following AOAC, 2005 (Method No. 945.43) using hot air oven drying method. The estimation of carbohydrates in foxtail millets was carried out as per standard procedure outlined by AOAC, 2005 (Method No. 975.14).The nitrogen content of foxtail millets was estimated by using Kjeltech apparatus, (Model: D-40599, Behr Labor Technik GmbH, Germany) (AOAC, 2005; Method No. 950.36). Crude fat of foxtail millets was determined by using Soxhlet apparatus (AOAC, 2005; Method No. 922.06). The crude fibre content of foxtail millets was determined by following sequential acid and alkali hydrolysis method using Fibra-Plus (Make: Pelican Equipments; Model: FES-08S) apparatus (AOAC, 2005; Method No. 962.09 E). The total ash content of foxtail millets was determined as per the standard procedure (AOAC, 2005; Method No. 925.23) by using muffle furnace (MAC; MSW-251).

Anti-nutritional properties of dehusked foxtail millets

Total phenols

The concentration of total phenols in foxtail millets was estimated with Folin Ciocalteau reagent. The alcoholic extraction of 100 µl was added to 900 µl of distilled water and 0.5 ml of Folin Ciocalteau reagent and mixed thoroughly for 3 min. After 3 min, one ml of 15% Na_2CO_3 solution was added, the contents were mixed and the volume was made upto 10 ml with distilled water. After 45 min of incubation at room temperature, the absorbance was measured at 750 nm against the reagent blank. Gallic acid was used as the standard for preparing the calibration curve (0.05-0.4 mg/ml). The sample absorbance was interpolated on the standard graph and the total phenolic compound (such as gallic acid) was calculated and expressed as mg GAE/g (Sun *et al.,* 2007).

Tannin

Tannin content of foxtail millets was determined by Folin Denis method described by Price *et al.,* (1978). One gram of sample was dissolved in 10 ml distilled water and agitated, left to stand for 30 min at room temperature. The sample was centrifuged and the extract was recovered, then 2.5 ml of the supernatant was dispersed into 50 ml volumetric flask. Similarly, 2.5 ml of standard tannic acid solution was dispersed into a separate 50 ml flask. One milliliter Folin Dennis reagent was measured in flask followed by 2.5 ml of saturated Na_2CO_3 solution. The mixture was diluted to 50 ml by distilled water in the flask and incubated for 90 min at room temperature. The absorbance of sample was measured at 250 nm with the reagent blank at zero. To calculate the concentration of tannin present in the sample, a graph of absorbance versus concentration of tannic acid was plotted along with a standard curve generated from the analysis of tannic acid. The percentage tannin was calculated by using the equation given below.

$$\text{Tannin (\%)} = \frac{X}{W} \times 100$$

Where,

X = Concentration of tannic acid from standard graph, ppm

W = Weight of sample, g

Phytic acid

The phytic acid of foxtail millets was determined by using the procedure described by Wheeler and Ferrel (1971). Half gram of sample was poured into 250 ml conical flask. One hundred milliliters of 2% concHCl was used to soak the sample in the conical flask for 3 h and then filtered through a double layer filter paper. Fifty milliliters filtrate was placed in a 250 ml beaker and 10 ml of distilled water was added to give proper acidity.

Ten milliliters of 0.3% ammonium thiocyanate solution was added to sample solution as indicator and titrated with standard iron chloride solution which contained 0.00195 g iron/ml and the end point was signified by brownish-yellow colouration that persisted for 5 min. The percentage of phytic acid was calculated by using the following equation.

Phytic acid (%) = y × 1.19 ×100

Where,

y = titre value (ml) × 0.00195

Statistical analysis

Completely randomized design (CRD) was used to analyse the data. The statistical procedures for agricultural research given by Gomez and Gomez (1976) were referred.

Results and Discussion

Effect on moisture content

The results showed that the average initial moisture content before irradiation was 10.60 per cent. The moisture content after first month of storage of irradiated foxtail millets ranged from 10.48 to 10.34 per cent (d.b), whereas the highest moisture content was recorded in control (10.50 per cent). It was also observed that for all the treatments there was a decrease in the moisture content with the increase in storage period and increase in irradiation dosage as shown in Figure 1.

The maximum moisture content after 6 months of storage was 9.83 per cent in control, whereas the minimum was 9.68 per cent in treatment T_8 which was statistically on par with treatment T_7 (9.70 per cent) and treatment T_6 (9.71 per cent).After irradiation the decrease in moisture content might be attributed to the radiolysis of water by irradiation (Pankaj, 2013).Similar results were recorded by Bamidele and Akanbi(2013) who found that the initial moisture content of irradiated pigeon pea flour was 6.22 to 7.99 per cent and after irradiation, moisture content decreased to 6.00 to 7.50 per cent for 20 kGy. Saad and Kabbashi (2014) reported that, before irradiation the moisture content of composite flour (wheat and sorghum) as 9.84 per cent and after irradiation gradually decreased to 9.66 per cent for 8.00 kGy.

Effect on carbohydrates

As shown in Figure 2, it is revealed from the results that the initial carbohydrate content of foxtail millets after irradiation was found to be 64.76 per cent for all the samples. It was observed that for all the treatments there was an increase in the carbohydrate content with increase in storage period. There was a significant difference in the carbohydrate content of foxtail millets during initial, 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} month of storage. The minimum carbohydrates after six months of storage was recorded in control as 65.82 per cent and higher level of carbohydrates was observed in treatment is T_8 (65.98 per cent) which was statistically on par with T_7 (65.96 percent) and T_6 (65.94 per cent).Similar results were reported by Anwar *et al.,* (2015) for wheat grains, the carbohydrate content before irradiation was found to be 72.67 per cent and after irradiation increased upto 72.70 per cent at 9.00 kGy. The increase in carbohydrate content after irradiation could be due to depolymerization of polysaccharides by radiolysis of starch.

Effect on crude protein

It was observed that the initial crude protein content of foxtail millets was found to be 12.23 per cent and after irradiation crude protein content of foxtail millet ranged from 12.04 to 11.93 per cent as compared to 12.08 per cent in control after first month of storage. After 6 months of storage there was a significant difference in protein content of foxtail millets as shown in Figure 3. The maximum crude protein content after 6 months of storage was 11.35 per cent in control, whereas, minimum was 11.20 per cent in treatment T_8 which was statistically on par with treatments T_7 (11.21 per cent) and T_6 (11.23 per cent). Lee *et al.,* (2005) reported that the gamma irradiation affected the proteins by causing conformational changes, oxidation of amino acids, rupturing of covalent bonds and formation of protein free radicals. Kabbashi *et al.,* (2012) found a similar difference between untreated (control) and irradiated samples of wheat flour. They found that the protein content of wheat flour (control) was 13.67 per cent while the sample treated with 3 kGy was 11.43 per cent.

Effect on crude fat

It was observed that for all the treatments there was a decrease in the crude fat content with increase in storage period as shown in Figure 4. The results showed that the initial fat content of irradiated dehusked foxtail millets was 4.38 per cent. The fat content after first month of storage ranged from 4.20 to 4.11 per cent, whereas the highest was recorded in control as 4.26 per cent (T_0). It was also observed that for all the treatments there was a decrease in the fat content with increase in storage period and also the fat content decreased with increased dosage. The maximum fat content after 6 months of storage was 3.48 percent in control, whereas the minimum was 3.34 per cent in treatment T_8 which was statistically on par with treatments T_7 (3.35 per cent), T_6 (3.37 per cent). It was observed that there was a decrease in the crude fat with increase in storage period. This decrease in fat might be due to the radiolytic degradation of fat. Because fat is more sensitive to irradiation and after irradiation, radiolytic degradation of lipid takes place.

The crude fat of fresh wheat germ was found to be 10.94 per cent and it gradually decreased upto 10.57 per cent at 30 kGy (Pankaj *et al.,* 2013). The present results were also similar to the result reported by Tresina and Mohan (2012), for fat content of cowpea seeds. Initially it was found to be 4.68 per cent but after irradiation treatment at 25 kGy it decreased to 3.21 per cent.

Effect on fibre

It was observed that the initial crude fibre content after irradiation of foxtail millets was found to be 6.05 per cent. The crude fibre content of dehusked foxtail millets after first month of storage ranged from 5.88 to 5.77 per cent, whereas the highest was recorded in control as 5.92 per cent. It was observed that for all the treatments there was a decrease in the fibre content with the increase in storage period and decreased with increase in dosage as shown in Figure 5. The maximum fibre content after 6 months of storage was 5.19 per cent in control, whereas the minimum was 5.03 per cent in treatment T_8, which was statistically on par with treatment T_7 (5.04 percent), T_6 (5.06 per cent).The fibre content decreases as the storage time increases. The irradiation dose dependent decrease in fibre on irradiation has been attributed to depolymerization and delignification of the plant matrix (Bhat *et al.,* 2008). Bamidele and Akanbi (2013) reported that these results were in good agreement with the pigeon pea flour, the fibre content of pigeon pea flour was found to be 5.59 per cent but after irradiation at 20 kGy it was reduced to 3.77 per cent. Similar results were reported by Tresina and Mohan (2012) for cowpea, as the crude fibre content of cowpea was found to be 5.58 g.100 g^{-1} before irradiation, but it was reduced to 3.54 g.100 g^{-1} after irradiation at 25 kGy.

Effect on total ash

It was observed that the initial total ash content of foxtail millets after irradiation was found to be 1.95 per cent. The total ash content of foxtail millets after first month ranged from 1.86 to 1.95 per cent, whereas the lowest was recorded as control as 1.83 per cent. It was observed that for all the treatments there was a decrease in total ash content with the increase in storage period and increase with increase in dosage as shown in Figure 6. The minimum total ash content after 6 months of storage period was 1.10 per cent in control, whereas the maximum was 1.28 per cent in treatment T_8 which was statistically on par with treatments T_7 (1.25 per cent), T_6 (1.23 per cent), T_5 (1.24 percent) and T_4 (1.22 per cent).Results were comparable with the findings of Manjula *et al.,* (2015) who reported the initial iron and calcium content of the finger millet flour were 9.96 and 418 mg.100g^{-1} respectively and after irradiation treatment it was increased to 10.24 and 495.81 mg.100g^{-1} respectively.

Effect on total phenols

It was observed that for all the treatments there was increase in the phenolic content with increase in storage period as shown in Figure 7. It was observed that the initial phenols content of foxtail millet was found to be 16.24 mg.g^{-1} and total phenols content after first month of storage of foxtail millets ranged from 16.40 to 16.54 mg.g^{-1}, whereas the lowest was recorded in control as 16.36 mg.g^{-1}. The maximum phenols content after 6 months of storage was 17.46 mg.g^{-1} which was statistically on par with treatments T_7 (17.44 mg.g^{-1}) and T_6 (17.42 mg.g^{-1}) and the lowest was recorded as 17.30 mg.g^{-1} in control (unirradiated).

The reason for increase in total phenols is that as the dosage concentration increased there was increase in total phenols to higher extractability by depolymerization and dissolution of cell wall polysaccharides by irradiation (Adariano *et al.,* 2012).The results are in good agreement with those of Singh *et al.,* (2014) for legume seeds (chick pea, lentils and mung bean). Initially total phenols was found to be 2.14, 3.5, 5.8 mg.g^{-1} for chick pea, lentils and mung bean respectively and after irradiation treatment at2.00 kGy it was increased to 2.32, 3.71 and 5.97 mg.g^{-1} for chick pea, lentils and mung bean respectively.

Fig.1 Effect of dosage of gamma irradiation on moisture content of foxtail millets during storage

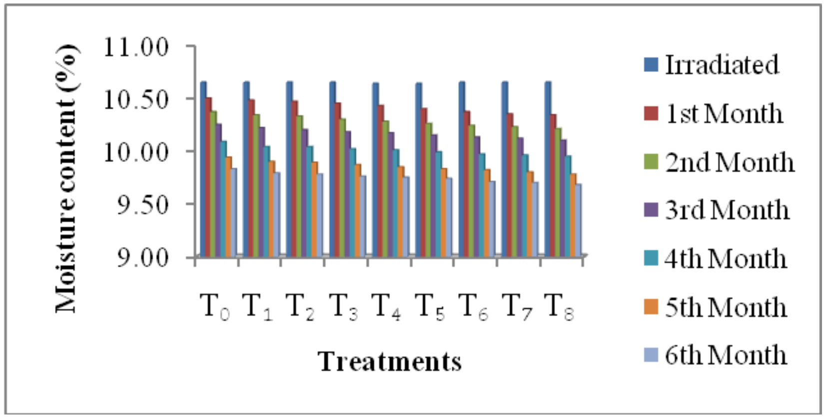


Fig.2 Effect of dosage of gamma irradiation on carbohydrates of foxtail millets during storage

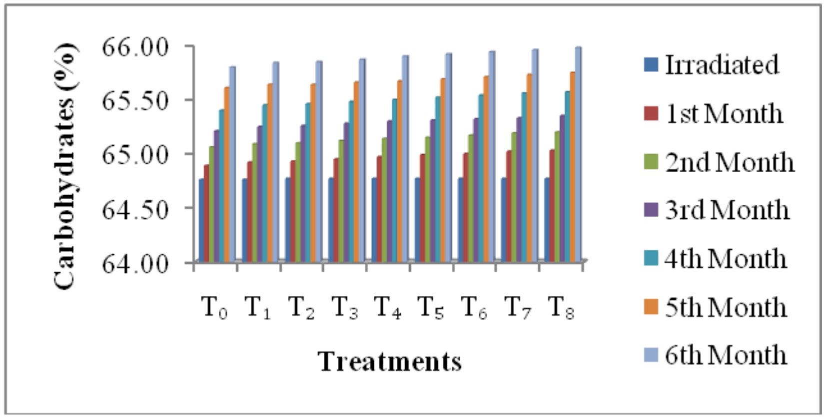


Fig.3 Effect of dosage gamma irradiation on crude protein of foxtail millets during storage

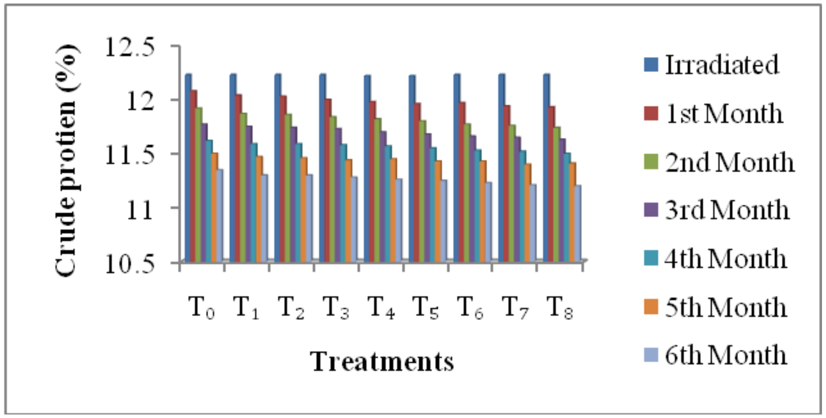


Fig.4 Effect of dosage gamma irradiation on crude fat content of foxtail millets during storages

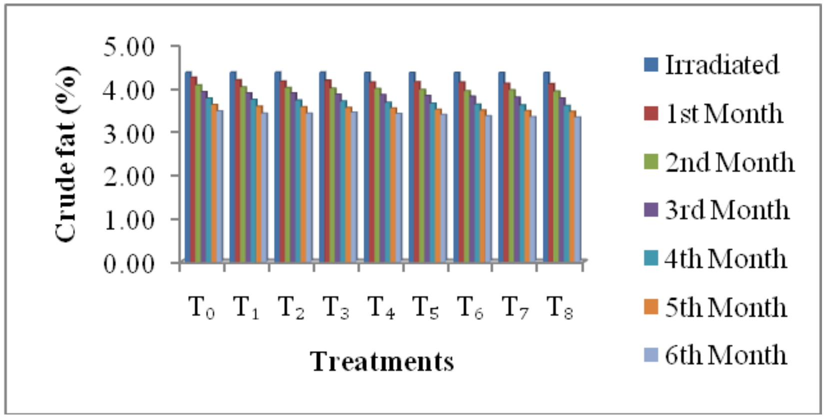


Fig.5 Effect of dosage of gamma irradiation on crude fibre of foxtail millets during storage

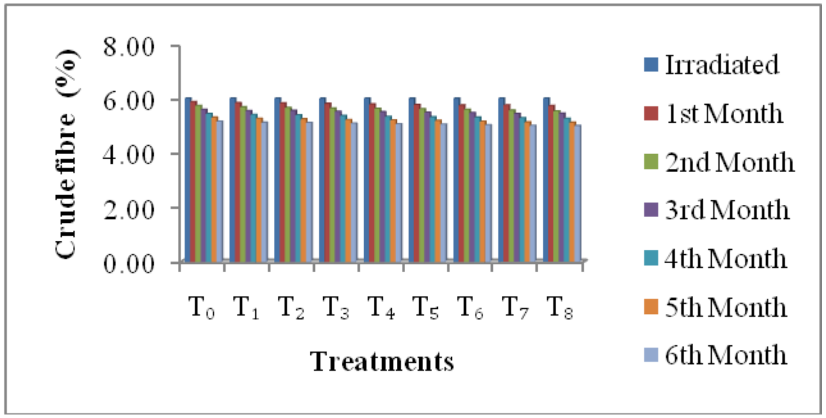


Fig.6 Effect of dosage of gamma irradiation on total ash of foxtail millets during storage

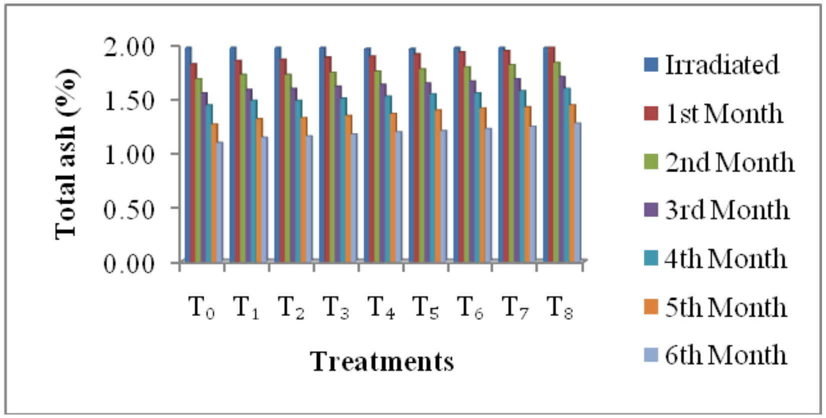


Fig.7 Effect of dosage of gamma irradiation on total phenols of foxtail millets during storage

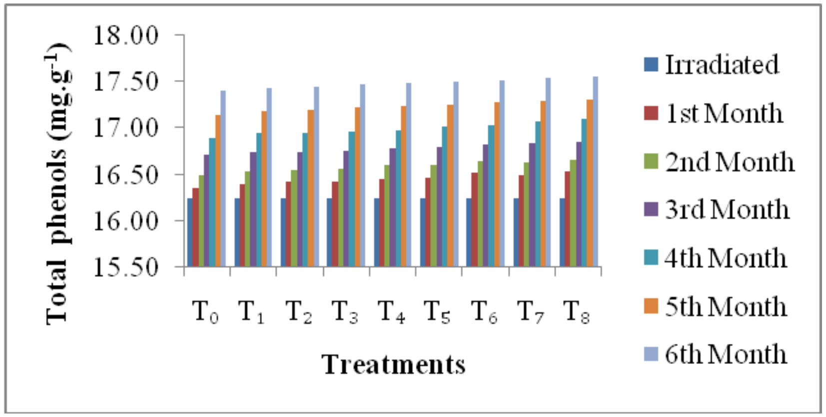


Fig.8 Effect of dosage of gamma irradiation on tannin content of foxtail millets during storage

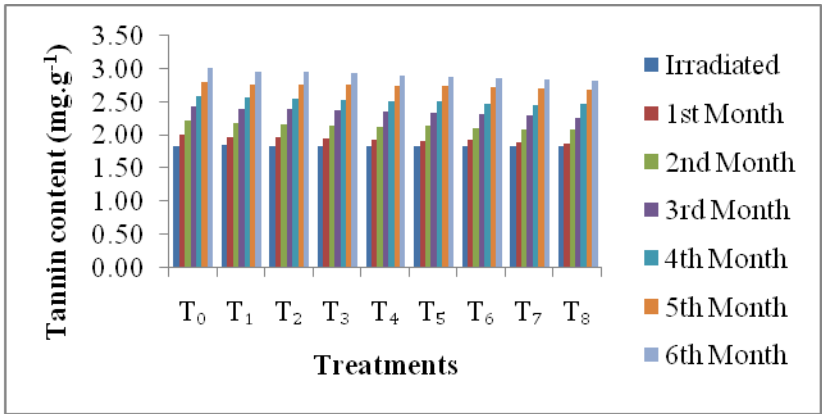
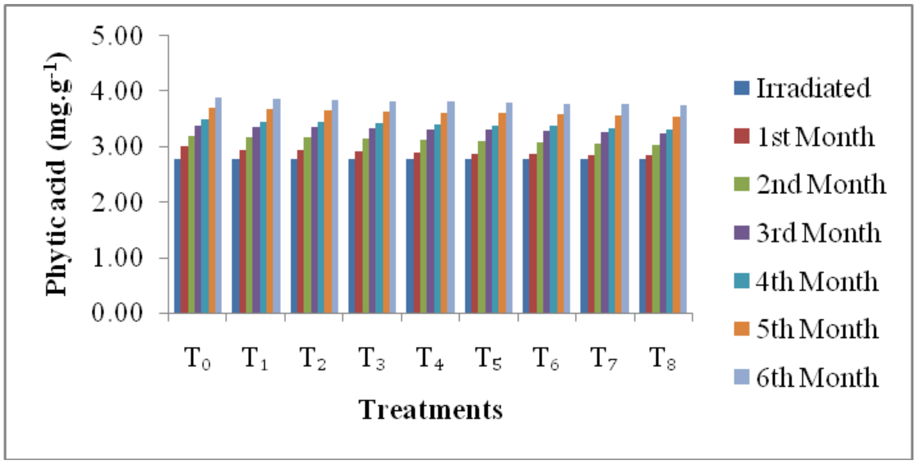


Fig.9 Effect of dosage of gamma irradiation on phytic acid of foxtail millets during storage



Effect on tannin

It was observed that the initial tannin content of dehusked foxtail millets was found to be 1.84 mg.g^{-1} and tannin content after first month of storage ranged from 1.97 to 1.88 mg.g^{-1}, whereas the highest was recorded in control as (2.01 mg.g^{-1}). It was observed that for all the treatments there was a increase in the tannin content with increase in storage period and decreased with increase in irradiation dosage as shown in Figure 8. The maximum tannin content after 6 months of storage was 3.01 mg.g^{-1} in control whereas minimum was 2.82 mg.g^{-1} which was statistically on par with treatment T_7 (2.84 mg.g^{-1}) and T_6 (2.86 mg.g^{-1}).

The decrease in tannin content as the dosage increased might be due to chemical degradation by the action of free radicals formed during the radiation (Nagat *et al.*, 2015). The results are in agreement with the findings of Rousta *et al.*, (2014) for sorghum grain, initially it was found to be 921 mg.100 g^{-1} but after irradiation it decreased to 191 mg.100 g^{-1} at 30 kGy dosage. Chamani *et al.*, (2014) reported that changes in tannin content of gamma irradiated sorghum grains. They found that the tannin content of unirradiated sorghum grain was found to be 82.50 mg.100 g^{-1} and after irradiation at 30 kGy it was reduced to 13.20 mg.100 g^{-1}.

Effect on phytic acid

It was observed that for all the treatments there was an increase in the phytic acid content with increase in storage period and decreased with increased dosage as shown in Figure 9. It was observed that the initial phytic acid content of foxtail millets was found to be initially 2.78 mg.g^{-1} and after first month of storage ranged from 2.95 to 2.85 mg.g^{-1}, whereas the highest was recorded in control as 3.00 mg.g^{-1}. The minimum phytic acid content after 6 months of storage was 3.75 mg.g^{-1} which was statistically on par with treatment T_7 (3.77 mg.g^{-1}) and T_6 (3.78 mg.g^{-1}) and the highest was recorded as 3.90 mg.g^{-1} in control. The reduction in phytic acid during radiation process might be due to chemical degradation of phytate to the lower inositol phosphates and inositol by the action of free radicals produced by radiation or might be due to cleavage of the phytate ring itself (Hania *et al.*, 2007). Results were comparable with the findings of Bamidele and Akanbi*et al.*, (2013) who reported the initial phytic acid content of pigeon pea flour was found to be 94.67 mg.g^{-1} in control but after irradiation treatment it decreased to 25 mg.g^{-1} at 20 kGy dosage.

This study investigated the effect of gamma irradiation on the quality parameters (moisture content, carbohydrates, crude protein, crude fat, crude fibre, total ash, total phenols, tannin and phytic acid) of dehusked foxtail millets. The proximate composition *viz*., moisture content, carbohydrates, crude fat and total ash of foxtail millets in treatment T_8 were found to be higher compared to other treatments followed by treatment $T_{7.}$ The anti-nutritional properties of the treated foxtail millets, the total phenols was found to be maximum, tannin content and phytic acid were found to be minimum in treatment T8. It was observed to be the best treatment as compared to other treatments

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