Mysore J. Agric. Sci., 57 (2) : 354-363 (2023)

Influence of Irradiation and Packaging on the Shelf Life of White Finger Millet (Ragi) [*Eleusine coracana* (L.)] Flour

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Received : September 2022
Accepted : January 2023

Abstract

The irradiation of food products as a measure of disinfestations against insects and microorganisms to extend its shelf life is a well established procedure worldwide. However, irradiation alone will not yield good results until and unless packed in suitable packaging material. Hence, the study was planned to irradiate the white finger millet flour at 1.5 kGy (IR) and stored in different packaging materials (LDPE, PP, PET and MPP) for a period of three months by taking flour stored without irradiation in steel box as control. Set of flour packed in different packaging material (LDPE, PP, PET and MPP) without irradiation served as non-irradiated sample (NIR). Every fortnight the samples in three different treatments were drawn for biochemical changes (moisture, alcoholic acidity and FFA), insect infestation and microbial growth. Significantly increase in moisture, alcoholic acidity and FFA content were noticed in control sample followed by non irradiated PP and LDPE packed flour. Insect infestation started after 30 and 60 days of storage in control and NIR-PP and NIR- LDPE covers respectively. Further, study indicated that acceptable level of biochemical changes, no fungal and insect growth was noticed in IR- MPP and IR-PET packed samples. Thus, white finger millet flour stored in MPP and PET pouches with irradiation dose of 1.5 kGy can be safely stored up to three months under room temperature.

Keywords : White finger millet, Irradiation, Insect infestation, Free fatty acids

Millets, considered as important food staples in human history. They have been in cultivation in East Asia for the last 10,000 years. Africa is the largest producer of millet (20.6 million metric tonnes), followed by Asia (12.4 million metric tonnes) and India (10.5 million metric tonnes). Millets including Pearl millet, Finger millet, Kodo millet, Proso millet, Foxtail millet, Little millet and Barnyard millet are important staples to millions of people world-wide.

Generally, these are rainfed crops grown in areas with low rainfall and thus resume greater importance for sustained agriculture and food security. Almost all the millets are used for human consumption in most of the developing countries but their use has been primarily restricted to animal feed in developed countries. Millets are nutritionally comparable to major cereals and serve as good source of protein, micronutrients and phytochemicals. Among the millets, finger millet (ragi) is a staple food in many African and South Asian countries. It is also considered as a helpful famine crop, as it is easily stored for lean years (FAO, 2012). The grain is readily digestible, highly nutritious and versatile and can be cooked like rice, ground to make porridge or flour used to make cakes (De Wet, 2006). Finger millet or ragi remains one of the main ingredients of the staple diet in Karnataka. Finger millet (Ragi) is an extremely nutritious cereal and is very beneficial for maintaining good health. Sprouted grains are recommended for infants and elderly people. In Karnataka, finger millet flour, popularly called as '*ragi hittu*' could be enjoyed in different forms and preparations such as *ragi roti*, *ragi dosa,* ragi porridge, *ragi upma*, ragi cakes, ragi biscuits, ragi malt, ragi vermicelli and ragi papad are few popular dishes of ragi.

Nutritionally, finger millet is a good source of nutrients especially calcium, phosphorus and fibre. Total carbohydrate content of finger millet has been reported to be in the range of 70 to 79.5 per cent depending upon the type of variety. The carbo hydrates include starch as the main constituent being 59.4 to 70.2 per cent (Bhatt *et al.,* 2003). Traditionally brown coloured grains are predominant and preferred by the consumers. Of late, white grains are preferred by the food processing industries because of their high protein, low tannins and increased consumer acceptability (Sharathbabu *et al.,* 2008). White coloured finger millet or ragi is mainly used in the form of flour in the preparation of bakery products such as bread, biscuit, sev, muruku vermicelli and many more. The white varieties have higher protein content than the brown varieties of the finger millet. Finger millet contains 44.7 per cent essential amino acids of the total amino acids which is higher than the 33.9 per cent essential amino acids. Since ragi does not contain gluten, it is a wonderful grain alternative for people who are gluten-sensitive (Dayakar *et al.,* 2017).

Due to increasing awareness of consumers regarding advantages of consumption of finger millet based staple foods, convenience foods, health mixes, infant foods, the production, availability and access plays a key role towards increasing consumption. The major drawback of finger millet consumption can be attributed to its dark brown or dark red colour has led to decrease its acceptability among children and urbanites. Even the availability of preferred cereals such as rice and wheat at subsidized prices also contributes for lesser usage. However, in the recent past with the support of governments, the cultivated area under this millet is increasing constantly, mean while, finger millet consumption also increased among health conscious consumers of urban areas. In the recent past, with the constant effort of plant breeders, the white coloured finger millet varieties with the same or superior nutritional quality are available, which serve as a boon to bakery and confectionery industries as well as appearance loving people. Modern home makers finds it difficult to cook many of our traditional recipes due to non availability of white finger millet flour in ready-to-usable form like wheat flour or rice flour. Whole finger millet grain as such having excellent keeping quality, once it is milled into flour, it readily deteriorates due to rancidity and attack of insects and micro organisms. The deterioration in storage due to the infestation by red flour beetle (*Tribolium castaneum*) and other microorganisms lead to losses which in turn has adverse effects on the economy of the nation and health of the people. Once the grains are ground into flour, it will intensify the activity of secondary pests during storage. The infestation by *Tribolium castaneum* could directly result in weight loss (hallow grains) and the beetle indirectly imparts a brownish tinge and pungent smell to infested flour by secretion of benzequinones (Hodges *et al.,* 1996).

It is therefore necessary that such losses after milling or during storage can be reduced through the use of technology so as to provide adequate information that will guarantee food security and food safety to the population. Food irradiation is already recognized as a technically feasible method for reducing postharvest food losses, ensuring the hygienic quality of food and facilitating wider food trade (Jyoti *et al.,* 2009). A food is irradiated to utilize the destructive power of ionization radiation on the microorganisms with minimum changes in food constituents (Zenthen and Sorensen, 2003). The use of irradiation alone as a preservation technique will not solve the problems of post-harvest food losses which are severe but it will definitely play an important role in cutting post harvest losses in many cases. Extensive research work done at the Bhabha Atomic Research Center (BARC) Mumbai had shown that low dose gamma irradiation (0.2-0.3 KGy) is effective in controlling insect infestation in rawa or semolina (Rao *et al.,* 1994) and many other food products. As per the literature cited, wheat and soya flours are normally irradiated at the rate of 1.0 kGy and health mix containing ragi is irradiated at the rate of 0.5 kGy. However, FSSAI proposed standards for irradiation of foods under class 3 (cereals, pulses and their milled products) provided the range is 0.25-1.0 kGy for insect disinfestations and 1.5 to 5.0 kGy for reduction of microbial load. Results of innumerous studies assure that the intake of irradiated food is absolutely safe for the consumers (Farkas, 2006). Regular brown colored finger millet flour or ragi flour in aesthetic designs is already available in the market in good number of packages; however, white finger millet flour in suitable packing material with good shelf life is very essential for bakery, confectionary people or regular consumers to meet their daily needs. Flour packed and stored in right conditions can prevent the loss or gain of moisture, entry of microorganisms, changes in fatty acid profile. Good packaging of any product will serve two purposes which are essentially technical and presentational. Technical aspects in packaging aim to extend the shelf life by providing better protection from all the hazards (physical, chemical and biological) during storage. The temperature variation in flour products could result in either hydrolytic or oxidative rancidity, triggering destabilization of flour quality. Hence, good and shelf stable package under sealed condition could prevent moisture absorption, free radical build up, prolong keeping quality and prevent microbial proliferations.

Hence, Shelf life of any flour is very important from the point of producer as well as the consumer. Studies on storage of millets in different conditions and different packaging materials are available a plenty (Chaturvedi *et al.,* 2013; Bunkar *et al.,* 2014; Thilagavathi *et al.,* 2015; Sindhu *et al.,* 2016 and Bhatt *et al.,* 2017), however, systematic studies on storage of white finger millet flour (white ragi flour) which is the basic raw material for the preparation of conventional as well as bakery products is available in very less numbers. Moreover, studies on combined effect of radiation as well as packaging on quality of white finger millet flour are not available. Hence, the study entitled 'Influence of Irradiation and Packaging on the shelf life of white finger millet flour' was taken up to assess the effect of different packaging and radiation treatment on the shelf life of white finger millet flour under room temperature.

Material and Methods

The White finger millet (KMR-340) was procured from AICRP (Small millets), ZARS, V.C. Farm, Mandya and were cleaned and milled into flour using domestic flour mill and packed in different packaging material [Low density polyethylene LDPE)-250gauge, Polypropylene (PP)-250 gauge, Metallised Polyester Polyethylene (MPP)-400 gauge and Polyethylene Teraphthalate (PET)-420 gauge as per the experimental design. One set of white finger millet flour samples immediately after milling packed into above packaging material were sent to BARC (Bhabha Atomic Research Centre) Mumbai for irradiation. Another set of flour samples packaged in different packaging material (LDPE, PP, PET and MPP) were kept under refrigeration until the arrival of irradiated samples. The irradiation process was carried out by exposing the packed milled flour samples to gamma radiation at the rate of 1.5 kGy (IR). Another set of millet flours packed in different packaging material (LDPE, PP, PET and MPP) without irradiation treatment (NIR). The white finger millet flour samples stored in stainless steel boxes (normal house hold practice) was served as Control.

Storage Study : Control, irradiated (IR) and non radiation (NIR) samples stored in different packaging material under normal room temperature ($30 \pm 2\ ^0C$) with a relative humidity of 75 ± 5 per cent for a period of three months. The stored millet flour samples were analyzed every fortnight for various flour quality parameters.

Nutritional Composition : Nutritional composition of the white finger millet flour (Moisture, protein, fat, ash, crude fiber, calcium, iron, magnesium, phosphorus and potassium) immediately after milling were analyzed according to standard AOAC (2005) procedure.

Functional Parameters : Water Absorption Index (WAI), Water Solubility Index (WSI), Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) of white finger millet flour was analyzed immediately after milling as per Thilagavathi *et al.* (2015).

Bio-Chemical Changes : Bio-chemical changes of stored white finger millet flour such as moisture, alcoholic acidity and free fatty acids were analyzed every fortnight as per standard AOAC (2005) protocol.

The alcoholic acidity of stored white ragi flour was determined by using the formula given below (AOAC, 2005).

$$\text{Alcoholic acidity (as } H_2SO_4) = 24.25AN / W$$

Where,

N = Normality of standard sodium hydroxide solution

W = Weight of the material taken for test

A = Volume in ml of the std sodium hydroxide used in titration

Insect Infestation : Visual observation for dead or alive insects (including larvae and adults) was done using sieve method. Data on insect infestation was recorded on the total number of larvae and adults as insect population from each replication by taking 20 grams of flour into 90 cm diameter Petri dish and counting the same using magnifying glass and converting into per cent age (Mali and Satyavir, 2005).

Microbial Analysis : Microbial load of the stored flour including Total Bacterial Count (TBC), Fungal Count (FC) and Escherichia coli (E.coli) were assessed every fortnight as per Chaturvedi *et al.* (2013). For microbial analysis, nutrient agar (Bacteria), Potato Dextrose Agar (Fungi) and MacConkey-Sorbitol Agar (E.coli) were procured from Himedia and enumeration was done using serial dilution technique using appropriate dilutions.

Statistical Analysis : Data obtained in triplicates was statistically analyzed using three factor ANOVA to assess the significant difference (0.05 %) between the treatments, between the time intervals and between the packaging material on the shelf life of millet flour.

Results and Discussion

Nutritional and Functional Quality of Milled White Finger Millet (Ragi) Flour

The nutritional and functional properties of white finger millet flour immediately after milling is depicted in Table 1. The white ragi variety (KMR-340) contained protein (8.90%), crude fiber (3.76%), calcium (343.20 mg%), phosphorus (283.73 mg%) and iron (3.80 mg%). The values reported in this work are in line with Gopalan *et al.* (2004) for most of the nutrients for brown finger millet except in protein and crude fiber. The functional properties such as bulk density (1.62 g/ ml), water and oil absorption capacity (76.78, 70.68.30 ml/ 100 g) reported for white finger millet flour in this work are in line with the values reported for selected millet and pulse flour by Thilagavathi *et al.* (2015) and Shobha *et al.* (2012) for maize flour.

TABLE 1

Nutritional composition of white finger millet flour (per 100 g)

Nutrients	White finger millet (KMR- 340)
Moisture (%)	10.20 ± 0.10
Ash (%)	2.69 ± 0.01
Fat (%)	4.20 ± 0.10
Protein (%)	8. 90 ± 0.10
Crude fiber (%)	3.76 ± 0.10
Carbohydrate (%)	70.95 ± 0.55
Energy (K. Cal)	357.2 ±10.56
Calcium (mg)	343.20 ± 0.80
Phosphorus (mg)	283.73 ± 0.64
Iron (mg)	3.80 ± 0.12
Functional quality of white finger millet flour :	
Bulk density (g/ ml)	1.62 ± 030
Water absorption capacity(ml/100 g)	76.78 ± 0.50
Oil absorption capacity (ml / 100 g)	70.68 ± 0.19
Water absorption Index (%)	4.23 ± 0.04
Water solubility Index (%)	7.34 ± 0.61

Values are mean of three replications ± SD

Effect of Storage on the Biochemical Parameters

Free Fatty Acids (FFA) : Free Fatty Acid (FFA) is a key feature linked with the quality and commercial value of fat and free fatty acids are indicators of deterioration of fat. Free Fatty Acids (FFA) are produced by the hydrolysis of oils and fats, since FFA's are less stable than neutral oil, they are more prone to oxidation thus turning to rancid. The FFA in this study increased significantly from 0 to 90 days and the increase was more pronounced in control (steel box) as it was neither irradiated nor packed in specific packaging, followed by non irradiated LDPE and PP (Table 2), however the changes in FFA content at the end of storage period were significantly less in irradiated PET (0.79%) and MPP (0.85%) covers as compared to non-irradiated samples in different packaging types. The changes between the treatments, between the packaging as well as between the storage duration were found to be significant (Table 2). Significantly higher FFA content of white finger millet flour stored in steel boxes followed by non irradiated PP and LDPE covers is probably because of higher moisture absorption of these samples which leads to rapid hydrolytic action of lipases at higher moisture level leading to increased FFA content. Research work carried out by Panjin *et al.,* (2006) and Monika and Mridula (2015) on the effect of storage period on the dragge based sunflower kernel and nutritious bar respectively indicated a significant increase in free fatty acid content and which was within the acceptable limit for three months of storage. Free fatty acid is an important parameter for storage of bajra flour and FFA was found significant after 16 days of storage in the cotton bag as compared to other packaging material such as Tin and HDPE container (Bhatt *et al.,* 2017). The FFA level should not exceed 1.5 per cent for noticeable rancidity (Shobha *et al.,* 2012). In this study the irradiated MPP and PET packed white finger millet flour have better retention of freshness compared to other packages. Similar result was also noticed in foxtail millet flour FFA content during strong (Shobha *et al.,* 2021)

Alcoholic Acidity : Flours when stored for long undergoes various types of deterioration, which in turn gives high value for alcoholic acidity, is an index of deterioration of flour during storage. Alcoholic acidity refers to combined acidity as we get by hydrolysis of fats by lipases into free fatty acids, hydrolysis of proteins into amino acids by proteolytic enzymes as well as acidity due to presence of certain acids, salts *etc.* The fresh white finger millet flour had alcoholic acidity of 0.08 per cent which

TABLE 2

Effect of storage on Free fatty acid content of white finger millet flour

Storage days	Irradiated sample (IR)					Non irradiated (NIR)				
	B1	B2	B3	B4	B5	B1	B2	B3	B4	B5
0	0. 21	0. 21	0. 21	0. 21	0. 21	0.21	0.21	0.21	0.21	0.21
15	0.49	0.43	0.15	0.27	0.34	0.36	0.23	0.27	0.43	0.40
30	0.52	0.81	0.17	0.23	0.38	0.48	0.32	0.36	0.81	0.42
45	0.80	1.03	0.24	0.35	0.42	0.61	0.33	0.53	1.03	0.46
60	0.95	1.12	0.33	0.52	0.61	0.71	0.46	0.55	1.12	0.67
75	1.24	1.18	0.48	0.64	1.13	1.23	0.72	0.72	1.18	1.23
90	1.35	0.85	0.79	0.82	1.32	1.33	0.87	1.13	1.36	1.38

Parameter		F-Value	SEm±	CD@5%
Free fatty acid (% oleic acid)	Between treatment	197.89	0.005	0.013
	Between packaging	646.45	0.007	0.021
	Between days	1670.4	0.009	0.024
	Treatment X packaging X days	1.927	0.027	0.077

Note : B1- Control, B_2-MPP , B_3- PET, B_4- LDPE , B_5-PP increased significantly in control (Table 3) followed by PP and LDPE covers irrespective of irradiation. However, the white finger millet flour stored in irradiated MPP and PET covers showed significantly less changes in alcoholic acidity compared to other treatments.

Moisture Content : The moisture content plays a vital role in enhancing the shelf life of any product. Generally moisture content decreases or increases during storage depending upon the storage conditions and packaging material. The effect of storage on the moisture content of white finger millet flour is depicted in Table 4.

Significant increase in moisture content of white finger millet flour from initial value of 7.30 to > 15.00 per cent was recorded in Control followed by non irradiated PP covers. While in case of irradiated sample, moisture increase was significantly less in MPP (10.00%), PET (10.10%), LDPE (12.40%) and PP (12.50%). Among different treatments and packages, the irradiated MPP and PET packed flour exhibited significantly minimal changes in moisture content as compared to others. The flour stored in steel box (control) absorbed highest moisture from the atmosphere, as it was obvious that during sampling, the lid of the box was widely exposed to the atmosphere leading to higher absorption of atmospheric moisture content. In case of PP and LDPE covers, the permeability for moisture transmission was quite high in these packages irrespective of irradiation treatment, however, the moisture content in all the packages was within the value prescribed by the Codex Alimentarius, where in the upper acceptable limit is 15.5 per cent for safe storage (Saad *et al.* 2014). Similar kind of work carried out by Bhatt, *et al.* (2017), indicated that the moisture content of bajra flour was found significant after 16 days of storage and the increasing trend was found in treatment of all the varieties of bajra flour kept in cotton bag at room temperature. Even the results of Veena *et al,* (2012) also reports higher moisture gain in papad samples during storage period of 90 days. The increase of moisture content in pearl millet grain over 12 months storage was reported by Mali and Satyavir (2005) where in initial

TABLE 3

Effect of storage on Alcoholic acidity of white finger millet flour during storage

Storage days	Irradiated sample (IR)					Non irradiated (NIR)				
	B1	B2	B3	B4	B5	B1	B2	B3	B4	B5
0	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
15	0.41	0.13	0.22	0.28	0.30	0.81	0.55	0.64	0.74	0.41
30	1.05	0.22	0.34	0.42	0.53	0.93	0.72	0.82	0.92	1.05
45	1.14	0.36	0.46	0.57	0.62	1.23	0.92	1.04	1.13	1.14
60	1.24	0.43	0.55	0.64	0.74	1.36	1.04	1.24	1.23	1.24
75	1.43	0.53	0.63	0.76	1.22	1.43	1.13	1.33	1.36	1.33
90	1.56	0.74	0.71	0.81	1.34	1.55	1.31	1.41	1.42	1.41

Parameter		F-Value	SEm±	CD@5%
Alcoholic acidity	Between treatment	4059.2	0.004	0.010
(% H_2SO_4)	Between packaging	697.3	0.006	0.016
	Between days	3721.3	0.007	0.019
	Treatment X packaging X days	14.21	0.021	0.059

Note : B_1-control B_2- PET B_3- MPP B_4-LDPE, B_5-PP

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TABLE 4
Effect of storage on Moisture content of white finger millet flour during storage

Storage days	Irradiated sample (IR)					Non irradiated (NIR)				
	B1	B2	B3	B4	B5	B1	B2	B3	B4	B5
0	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.300
15	10.30	6.50	6.70	7.400	9.00	10.30	7.50	7.66	9.90	10.30
30	11.20	7.00	7.10	8.200	9.50	11.20	8.53	9.23	10.30	11.20
45	12.40	7.30	7.60	9.500	9.90	12.40	9.33	10.23	11.70	12.90
60	13.26	8.00	8.10	10.200	10.20	13.26	10.40	11.46	12.20	13.90
75	14.36	8.50	9.00	11.433	11.43	14.36	11.46	12.46	13.30	14.26
90	15.40	10.00	10.10	12.400	12.50	15.40	12.46	13.56	14.46	15.33

Parameter		F-Value	SEm±	CD@5%
Moisture (%)	Between treatment	2362.7	0.026	0.073
	Between packaging	1069.6	0.042	0.116
	Between days	2247.5	0.049	0.164
	Treatment X packaging X days	5.438	0.155	0.137

Note : B_1- Control, B_2-MPP, B_3- PET, B_4- LDPE, B_5-PP

moisture content (5.15%) of the grain increased to 13.7 per cent after 12 months of storage at 25 °C.

Effect of Storage on Insect Infestation

The effect of storage on the insect infestation of white finger millet flour is depicted in figure 1. Significantly more number of insects (larvae and adults) was noticed in Control sample. Insects appeared after 30th day of storage in control, while after 60 days in PP and LDPE packed flours irrespective of irradiation. Number of insects (larvae and adults) was increased significantly in steel boxes from 30 days to till the end of storage

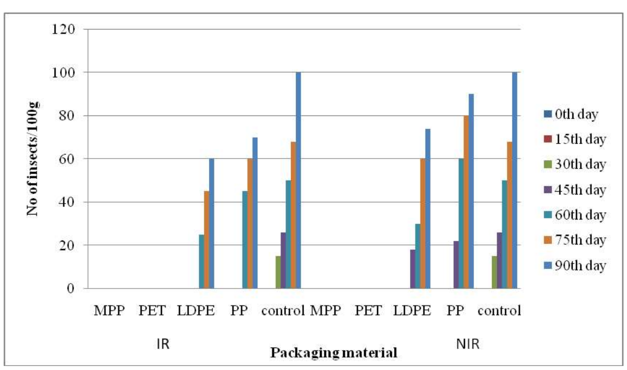

Fig. 1: Insect infestation in white finger millet flour

period (> 80 numbers). There was no insect infestation in MPP and PET covers irrespective of irradiation treatment (Fig. 1). The increase in insect infestation in steel boxes as compared to other materials was due to retention of higher moisture inside steel boxes that resulted in faster multiplication of the insect. The present study revealed that the increase of insect population in LDPE and PP packaged flour implies that it is not only the moisture content of the outer environment but also the insect population that created more humidity in the air by their metabolic activity which further increased grain moisture and insect population, has also been reported by Mali and Satyavir (2000).

The type of insects noticed in this study were majorly red coloured Red flour beetle (*Tribolium castaneum*) followed by black coloured Rice weevil (*Sitophilus oryzae*) and few creamish lavae of Rice moth (*Corcyra cephalonica*). Bran of millet contains some essential nutrients and has been implicated in supporting higher population of T. *castaneum* in whole finger millet flour. Similarly, study conducted by Mali and Satyavir (2005) on the storage of pearl millet found that grains were majorly infested with the larvae and adults of lesser grain borer (*Rhizopertha dominica*) and red flour beetle (*Tribolium castaneum*). Since T. *castaneum* is a secondary pest which preferes fine flour than grits or semolina for its growth. In this study, as the finger millet is milled into flour has enhanced the development and survival of T. *castaneum* in some packages. The less or no insects in MPP and PET packages in this study was due to the fact that the tightly packed flour reduce the development of eggs laid by T. *castaneum* in these packages irrespective of irradiation treatment

Effect of Storage on Microbial Quality

The microbial load of white finger millet flour stored in different packaging material is depicted in Fig. 2. More number of bacterial and fungal population was reported in non irradiated PP (14.01, 4.0 cfu/g) and control (10.04, 4.44 cfu/g) samples. The perusal of figure 2 indicated that there was no E. *coli* infestation in any of the samples, indicating that the method followed during flour making and storage was hygienically safe. In case of irradiated MPP and PET

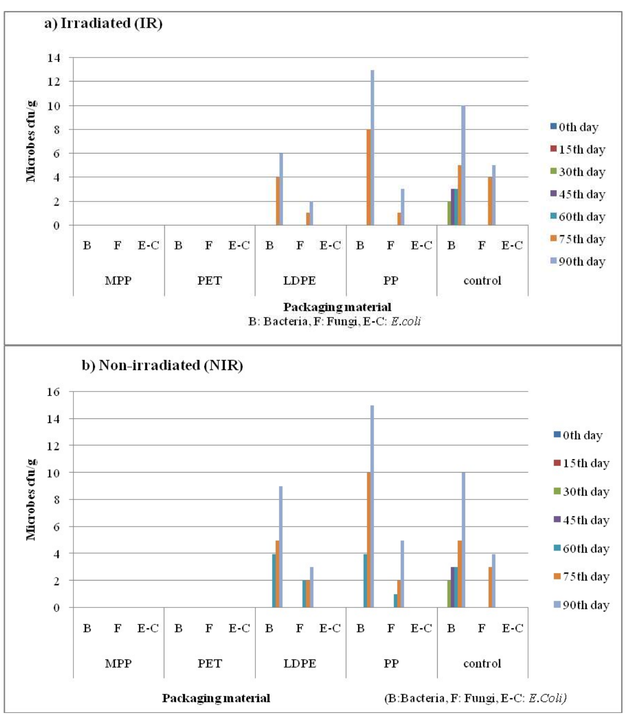

Fig. 2: Microbial quality of white finger millet flour a) Irradiated, b) Non-irradiated

covers less than five numbers of bacteria (1.0 and 1.5 log cfu/ g) were noticed and which did not increase throughout the storage period (Fig. 2).

No fungal colonies were noticed in irradiated MPP and PET packed flour. More number of bacterial and fungal counts in PP package irrespective of irradiation treatment (Fig. 2) might be due to damage caused to PP covers while handling, transportation and storage. Similar results were reported in irradiated processed ragi and barly by Chaturvedi, *et al.* (2013). Even the results of Ramasri *et al.* (2014) concluded that irradiation treatment (0.5kGy up to 3kGy) of health mix reduced the bacterial count and increased the shelf life. Our results are in line with the findings of Singh *et al.* (2006) and Mallesi *et al.* (1996) where in they found that there was no mould growth in irradiated formulation at the dosage of 0.5 kGy. A given radiation dose will kill a certain proportion of the microbial population exposed to it, regardless of the number of microorganisms present.

This property or result of radiation treatment implies that the higher the pretreatment population of bacteria, then higher will be the population after the food has been irradiated. If spoilage has already begun, radiation can do nothing to reverse it. Consequently, as with any other method of food preservation, irradiation is not a substitute for good hygienic practice in food production and processing. Exactly what portion of a given population of microorganisms will be destroyed by irradiation depends on several factors such as temperature at which the radiation treatment is carried out, time of irradiation and commodity which get irradiated.

In this study, the MPP and PET packages served as better packaging material for safe storage of white finger millet flour. Further, irradiation along with good packaging led to control of insect and bacterial population. Similar kind of study conducted by Panjin *et al.* (2006) reported that metalized polyester/ polyethylene; labeled metalized PET/ PE containers were most suitable for storage of dragee product. The packaging materials such as metalized polyester/ polyethylene; labeled metalized PET/ PE containers had lowest oxygen permeability (8.0mLm-2/dan 'p1bar) which had strong influence in the prevention of hydrolytic and oxidative changes in the final product. Even results of Bhatt *et al.* (2017) demonstrates that Tin and HDPE container are suitable for storage of bajra flour under room temperature for a short period of 16 days but with irradiation the storage period can be extended significantly. Even the shelf life of foxtail millet flour was found to be superior with irradation (1.5 kGy) when packed in MPP and PET packages (Shobha *et al.,* 2021)

Thus, the study demonstrates that the irradiation alone will not provide lasting disinfestations effect, therefore, it is also important to select the suitable packaging materials that cannot be penetrated by insects or beetles should be used to avoid post irradiation infestation. The use of irradiation alone as a preservation technique will not solve the problems of post-harvest food losses but definitely it will play an important role in cutting losses in many ways when used judiciously along with good packaging. Hence, the present study revealed that the white finger millet flour stored in MPP and PET pouches with irradiation dose of 1.5 kGy found suitable for safe storage up to three months under room temperature.

Acknowledgement : The authors gratefully acknowledge the financial support of University of Agricultural Sciences, Bengaluru under the research project entitled 'Effect of irradiation and packaging on nutritional, shelf life and acceptability of selected millet flours'.

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