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Effect of radiation on nutritional quality, shelf life and and acceptability of Ragi (*Eleusine coracana*) and Barley (*Hordeum vulgare*)

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ABSTRACT

Freshly harvested grains contain loads of thousand to million bacteria and mold spore per gram and the microbial contribution of cereal grains and flours to convenience foods is an important consideration from public health aspects and as a source of possible spoilage agents. Although the microbial load of cereal grains, meals, and flours may not constitute a spoilage problem by itself, the numbers and types of microorganisms in such products is of concern since these products are used in the formation of many other foods. Radiation processing technology can be used for disinfestation of food grains and certain pre-packed cereal products like atta (flour), suji (semolina) and premixes. The present study was conducted to establish radiation processing protocols to improve the shelf life with optimum retention of quality of selected grains namely ragi and barley. Grain samples were taken in triplicates in a polythene bag(100 gauge) of 500gms each , heat sealed and subject to radiation doses 0.25,0.50,0.75 and 1.00kGy using Gamma chamber and stored for a period of one year. Grains were assessed for Moisture, Total Bacterial Count (TBC) and Total Mould Count (TMC),Diastase activity and for organoleptic attributes. The results showed that moisture, TBC and TMC and Diastase activity (DA) increased significantly with increase in the radiation dose used. Millets being very susceptible to infestation can be radiation processed at 0.50 kGy and was found to be better than fumigation in preserving the grain with no adverse effects on nutritional and organoleptic quality and to reduce the post harvest loss.

INTRODUCTION

Millets can substantially contribute to food and nutritional security. They also constitute a major component of feed and fodder for livestock and offer raw material for agro based industries. In Andhra Pradesh, the important millets cultivated are sorghum, maize, pearl millet (bajra), finger millet (ragi) and foxtail millet (korra).

Improving the productivity of cereals, millets, pulses and oilseeds , reducing post harvest losses, value addition and popularization of the use of value added products could ensure food and nutrition security The additional requirement for food, therefore, has to come from the currently cultivated areas and shrinking land and water resources. Although the microbial load of cereal grains, meals, and flours may not constitute a spoilage problem by itself, the numbers and types of microorganisms in such products is of concern since these products are used in the formation of many other foods. The microbial contribution of cereal grains and flours to convenience foods is an important consideration from public health aspects and as a source of possible spoilage agents. Conservative estimates put post-harvest losses in food and agricultural commodities in India between 20-50 percent, which are worth thousands of crores of rupees. These losses are primarily due to insect infestation, microbiological contamination, and physiological changes due to sprouting, ripening, and senescence.

Extensive research work done at the Bhabha Atomic Research Center, Mumbai have shown that low dose gamma irradiation (0.2 – 0.3 KGy) is effective in controlling insect infestation in wheat (Rao V.S. et al 1976), Basmati rice (Rao V.S. et al 1994), rawa (Rao V.S. et al 1994) and whole wheat flour (Rao V.S. et al 1997).

Food irradiation for the insect and microorganisms decontamination has been studied for more than 40 years. Doses lower than 1.0 kGy effectively control a large number of insects (Patil et al., 2004) and have already been used in many countries. 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).

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).

Objective of the study:
To identify the optimum irradiation dose and disinfestation of grains to improve the shelf life and to study the physical,microbiological and sensory quality of radiation processed ragi and barley before, during and after storage.

MATERIALS AND METHODS

Methodology
Procurement of the sample : Ragi and Barley samples were procured from the local market and cleaned to remove extraneous matter. The samples obtained were of the best quality and completely free of infestation.

Fumigation : Five kg of Ragi and Barley were tied in the muslin cloth separately and placed in an air tight metallic bin. An ampoule of EDB without being taken out of the packaging, was broken and placed a little below the surface of the grain. The opening was then immediately sealed with mud plaster and polythene sheet. The storage structure thus sealed was left undisturbed for a period of seven days. After that it was aerated well for a few hours until there was no smell of the fumigant. Then the fumigated sample was packed in polythene bags in triplicate weighing around 800 grams for further study .

Radiation processing
Ragi and barley samples were taken in triplicate in a polythene bag of 100 gauge, heat sealed and subject to radiation. Gamma chamber 5000 supplied and installed by BRIT, DAE, Mumbai at the Food radiation Unit at Quality Control lab, Acharya N.G.Ranga Agricultural University (ANGRAU),Hyderabad was used for giving the radiation treatments.

Treatments followed:
Radiation dose: Kilo Gray (kGy).
T1: Control
T2:Fumigated
T3: Irradiation at 0.25kGy
T4: Irradiation at 0.50kGy
T5:Irradiation at 0.75kGy
T6:Irradiation at 1.00kGy

Number of treatments	:	Six
Levels of storage temperature	:	one (Ambient)
Number of replications	:	Three
Experiment design	:	Factorial CRD

Unprocessed samples of ragi and barley were packed in polythene bags in triplicate and used as the control.

Storage
Radiation processed, fumigated and control samples in triplicates were stored at room temperature in a well ventilated room at 29.0-38.3^{o}C with mean temperature of 25.90 ^{o}C and at RH 47.4-82.7% with mean RH of 65.00% for a period of one year.

Frequency of analysis: Control ,fumigated and radiation treated samples were analyzed initially and every three months thereafter in triplicates.

Parameters analyzed
Physical : Insect infestation : Visual observation for dead or live insects (either larvae or adults) was done by using the sieve method as described by Hill (1990).

Chemical: Moisture was determined using AOAC 2005

Diastase activity: Diastase activity was estimated using the method of Novellie, L. (1959). Diastase enzyme comprises alpha- and beta-amylases bringing about the breakdown of starch into maltose and dextrin. The liberated maltose was determined quantitatively by iodometric method.

Microbiological: Total bacterial Count (TBC), Total Mould Count (TMC) and E.coli by the method of Cruikshank et al 1975.

Organoleptic evaluation: Assessment of Appearance, flavor, and overall acceptability in control and experimental samples using four point hedonic scale.

Data obtained was statistically analyzed by ANOVA single factor and two factor with replications to assess the significant difference at 0.05 % level of significance (Snedecor and Cochran 1994) between treatments and within time intervals to see the effect of irradiation

RESULTS

Results pertaining to the effect of irradiation on quality parameters during storage of ragi and barley were as follows:

- Moisture content increased in Ragi samples (table no.1) from 6.22-7.43 to 7.97- 10.97 (%) and in Barley from 5.44-7.44 to 8.34-9.32 (%).The increase in moisture of the packed commodity indicates that the packaging was not impervious to moisture and need to be improved.
- Diastase activity (DA) expressed as "mg maltose per 10 gm of flour" increased significantly in radiation processed samples compared to control samples. In ragi DA increased from 334 - 418 to 498-542 and in barley from 351-453 to 534-588 (table 2). Maltose value is an indicator of damaged starch and due to radiation processing it increased during storage in a dose responsive manner.
- Significant difference between treatments and storage period was observed at both 0.05 and at 0.01% for both moisture and diastase activity in ragi and barley grains.
- TBC and TMC were high in control sample (3-5 log cfu per gm) (table no.3) and lower (0.5 to 1.5 log cfu per gm) in the radiation processed samples.
- No insect infestation was observed in any samples stored up to 6 months. After 6 months infestation was seen in both control and fumigated samples (table No.4) of ragi and 0.25 kGy irradiated barley sample. Insect infestation and spoilage was high in control followed by fumigated and samples radiated with 0.25 kGy.
- Acceptability of radiation processed samples, 0.25 and 0.5 kGy (table no.5) was comparable to control. With higher doses (0.75 and 1.00 kGy) acceptability was observed lower than control sample
- Overall acceptability as judged by trained taste panel showed no change initially in samples irradiated at 0.25 KGy while at higher doses (1 KGy) it was slightly lowered. However, on 3 months storage at room temperature, control samples showed significantly lower acceptability, whereas in irradiated samples, acceptability improved significantly.
- It could be presumed that radiation treatment of 0.5 kGy is better than fumigation in preserving the grain with no adverse effects on nutritional and organoleptic quality. Also, radiation treatment needs to be combined with other hurdles like adequate packaging. Since ragi is commonly used as a malted food in Andhra Pradesh, irradiation technology can be used to increase malt content of ragi.

Irradiation at the doses used for disinfestation does not affect product quality or the quality of processed foods made from grains and cereals. Some grains or cereals show dose related starch changes at higher doses. Higher doses (2-3 kGy*)* can result in death of more resistant pests within 24 hours, but at this dose there may be starch changes that affect later food processing applications.

So, care should be taken to ensure minimum to maximum dose uniformity is not excessively large (e.g. <3: 1). The irradiation of wheat flour at dose ranges higher than I kGy is likely to result in undesirable flavor changes. Malting losses could also be reduced 1-2% by irradiating dry barley with doses of 0.5 to 8 kGy (50 to 800 krad). Maltose values of irradiated wheat have been reported to increase substantially by radiation processing with dosages greater than 0.5 Mrad (Linko and Milner,1960) .This has been attributed to de-polymerization of polysaccharides due to increased susceptibility of starch to enzymes. The final break down of starch by irradiation is not one of acid hydrolysis, but due to the splitting of the pyranose structure (Kertesz, et al., 1959;Korotchenko et al.,1973).The ultimate products of starch breakdown by irradiation include glucose, maltose, malto-triose, gluconic acid and other lower molecular weight organic acids (Berger et al., 1973).

Table 1: Effect of Radiation processing on Moisture content in Ragi and Barley

Treatment	Moisture content in Ragi (g%)			Moisture content in Barley (g%)		
	0Month	12th month	Mean ± S.D	0Month	12th Month	Mean ± S.D
T1:Control	7.43 ± 0.14	10.97 ± 0.06 (47.68)	9.78 ± 0.10	5.70 ± 0.11	9.10 ± 0.02 (59.69)	7.07±0.01
T2:Fumigated	7.36 ± 0.10	10.01 ± 0.089 (36.01)	9.12 ± 0.09	7.44 ± 0.04	9.32 ± 0.05 (25.27)	8.36±0.05
T3:0.25kGy	6.22 ± 0.12	9.78 ± 0.05 (57.27)	8.69 ± 0.09	5.64 ± 0.08	8.34 ± 0.03 (47.89)	6.93±0.05
T4:0.50kGy	7.31 ± 0.14	9.64 ± 0.07 (31.89)	9.02 ± 0.08	5.44 ± 0.08	8.83 ± 0.06 (62.32)	7.21 ±0.06
T5:0.75kGy	7.79 ± 0.05	9.82 ± 0.05 (26.06)	9.22 ± 0.05	5.84 ± 0.05	9.29 ± 0.02 (59.08)	7.66±0.03
T6:1.00kGy	7.97 ± 0.14	9.98 ± 0.08 (25.23)	9.28 ± 0.07	5.47 ± 0.03	8.92 ± 0.04 (63.07)	7.50±0.02
Mean ± S.D	7.35±1.78	10.03 ± 0.63		5.92 ± 0.71	8.97 ± 0.34	
CV	6.112	cd at 5%	cd at 1%	4.51	CD at 5 %	CD at 1 %
Sed(T)	0.038	0.076	0.101	0.02	0.04	0.054
Sed(P)	0.035	0.069	0.092	0.018	0.037	0.049
Sed(TxP)	0.085	0.17	0.226	0.045	0.09	0.12

Values represented are the Mean ± S.D of three independent determinations
Figures in parenthesis represent percent change over initial value
Cv-Coefficient of Variation ; CD-Critical difference
Sed(T)-Standard error deviation between treatments;
Sed(P) – Stanard error deviation between periods; Sed(TxP) Standard error deviation between treatments and periods;

The quantity of radiation to be used depends on the food type and targeted results .Healthiness of irradiated food (toxicological, nutritive and microbiological) has been carefully evaluated and tested for over 50 years. Results of innumerous studies assure that the intake of irradiated food is absolutely safe for the consumers. (Farkas, 2006).

Marathe et al. (2002) performed storage studies on irradiated (0.25–1 kGy) whole-wheat flour packaged in polyethylene pouches and found that there was no adverse effect of irradiation and storage up to 6 months for whole-wheat flour treated at doses up to 1 kGy on total proteins, fat, carbohydrates, vitamin B1 and B2 content, sedimentation value, dough properties,and total bacterial and mold count. Moreover, irradiation as such had no effect onmoisture, free fatty acids, starch, sugars, and gelatinization viscosity. Irradiation at 0.25 kGywas sufficient to extend the shelf life of whole-wheat flour up to 6 months.

Thus, Gamma ray irradiation is a food preservation technique with the potential to protect cereal grains from insect infestation and microbial contamination during storage.To conclude, it needs to be emphasized that irradiation offers no protection from re-infestation . It is therefore, imperative that the time gap between irradiation and storage should be minimal to reduce the probable insect attack. Grains may be handled as bulk products, without any form of packaging. In some circumstances, however, the grains may be packed in containers such as bags (sacks). Such packaging should be done prior to irradiation. Irradiation provides no lasting disinfestation effect; therefore, where possible, packaging materials that cannot be penetrated by insects should be used to avoid post irradiation infestation. The use of irradiation alone as a preservation technique will not solve problems of post-harvest food losses, which are severe, but it can play an important role in cutting losses in many cases.Irradiation can also serve as an effective process for dis-infestation of certain pre-packed cereal products like atta (flour), suji (semolina) and premixes.

Table 2: Effect of Radiation processing on Diastase activity in Ragi and Barley

Treatments	Ragi			Barley		
	Diastase activity (mg maltose per 10 gm of flour)					
	initial	Final	Mean ± SD	Initial	Final	Mean ± S.D
T1:Control	334.33 ± 6.51	351.33 ± 9.61 (5.07)	342.83±12.02	498.67 ± 6.51	534.33 ± 6.25 (7.02)	516.50 ± 6.08
T2:Fumigated	347.00 ± 6.00	366.67 ± 6.51 (5.68)	356.83 ±13.90	505.33 ± 13.50	542.00 ± 8.00 (7.33)	523.67 ± 2.75
T3:0.25kGy	360 ± 7.00	382.33 ± 8.33 (6.20)	371.17 ± 15.79	512.67 ± 14.01	550.00 ± 8.00 (7.43)	531.33 ± 6.25
T4:0.50kGy	383.67 ± 9.24	410.00 ± 3.46 (6.91)	396.83 ± 18.62	519.33 ± 7.50	558.67 ± 9.02 (7.52)	539.00 ± 8.26
T5:0.75kGy	394.00± 3.46	431.33 ± (6.51) (9.47)	412.67±26.40	527.00 ± 15.00	568.00 ± 10.00 (7.80)	547.50 ± 12.50
T6:1.00kGy	418.33 ± 6.51	453.33 ± 4.04 (8.39)	435.83 ± 24.75	542.00 ± 8.00	588.00 ± 10.00 (8.49)	565.00 ± 4.58
Mean ± S.D	372.88 ± 31.46	399.17 ± 39.28		517.50 ± 17.48	556.83 ± 19.63	
CV	1.74	cd at 5%	cd at 1%	1.87	CD at 5%	CD at 1%
Sed(T)	3.879	8.006	10.849	5.85	12.074	16.362
Sed(P)	2.239	4.622	6.264	3.377	6.971	9.447
Sed(TxP)	5.486	11.322	15.343	8.273	NS	NS

Values represented are the Mean ± S.D of three independent determinations
Figures in parenthesis represent percent change over initial value
Cv-Coefficient of Variation ; CD-Critical difference
Sed(T)-Standard error deviation between treatments;
Sed(P) – Stanard error deviation between periods; Sed(TxP) Standard error deviation between treatments and periods;

Table 3: Effect of Radiation processing on Total Bacterial Count (TBC) and Total Mould Count (TMC) in Ragi and Barley

Treatment	TBC (log cfu/gm)				TMC(log cfu/gm)			
	Ragi		Barley		Ragi		Barley	
	0 Month	12th Month	0 Month	12th Month	0 Month	12th Month	0 Month	12th Month
T1:Control	4.03	4.47	4.19	4.40	3.88	4.34	4.04	4.36
T2:Fumigated	3.90	4.47	4.00	4.40	3.65	4.39	3.65	4.19
T3:0.25kGy	3.28	3.51	3.34	3.52	3.04	3.34	3.06	3.36
T4:0.50kGy	3.06	3.39	3.12	3.41	2.70	3.25	2.85	3.30
T5:0.75kGy	2.78	3.17	2.88	3.27	2.54	3.00	2.65	3.06
T6:1.00kGy	2.28	2.50	2.38	2.55	2.04	2.29	2.08	2.32

Table 4: Effect of Radiation processing on Insect count and Spoilage in Ragi and Barley

	Total No of Insects per 100 gms				Spoilage (%)			
Treatment	Ragi		Barley		Ragi		Barley	
	0Month	12th Month	0Month	12th Month	0Month	12th Month	0Month	12th Month
T1:Control	0	9	0	26	0	8.01	0	33.64
T2:Fumigated	0	10	0	21	0	4.9	0	32.65
T3:0.25kGy	0	0	0	4	0	0	0	22
T4:0.50kGy	0	0	0	0	0	0	0	0
T5:0.75kGy	0	0	0	0	0	0	0	0
T6:1.00kGy	0	0	0	0	0	0	0	0

In closing, it can be stated that food irradiation is not a miracle process that can convert spoiled food into high-quality food. It is equally true that not all foods are suitable for radiation treatment, just as not all foods are suitable for canning, freezing, drying, etc.

Food irradiation has two main benefits to the health and well-being of humans: the destruction of certain food borne pathogens, thus making the food safer; and prolongation of the shelf life of food by killing pests and delaying the deterioration process, thus increasing food supply.

Table 5: Effect of Radiation processing on Overall aceeptability in Ragi and Barley

Treatment	Overall acceptability							
	0 month	12 month	Mean ± S.D		0Month	12th Month	Mean ± S.D	
T1:Control	3.80±0.42	3.70±0.48	3.72± 0.45		3.90±0.32	3.70± 0.67	3.80± 0.51	
T2:Fumigated	3.60±0.52	3.40±0.70	3.46± 0.60		3.80±0.42	3.30± 0.67	3.60± 0.48	
T3:0.25kGy	3.70±0.48	3.50±0.71	3.58± 0.54		3.90±0.32	3.50± 0.53	3.74± 0.36	
T4:0.50kGy	3.60±0.52	3.30±0.67	3.42± 0.52		3.90±0.32	3.30± 0.67	3.62± 0.44	
T5:0.75kGy	3.50±0.53	3.10±0.74	3.28± 0.53		3.70±0.48	3.20± 0.92	3.50± 0.58	
T6:1.00kGy	3.20±0.79	2.90±0.74	3.10± 0.72		3.60±0.52	3.10± 0.99	3.34± 0.72	
Mean± S.D	3.57±0.56	3.32±0.70	3.43± 0.58		3.80±0.40	3.35± 0.75	3.60± 0.53	
Cv	17.94	CD-5%	CD 1%	F	16.79	CD-5%	CD 1%	F
Sed(T)	0.123	0.241	0.317	**	0.121	0.237	0.311	**
Sed(P)	0.112	0.22	0.289	NS	0.11	0.216	0.284	**
Sed(TxP)	0.275	0.539	0.709	NS	0.27	0.53	0.696	NS

Values represented are the Mean Scores ± S.D of ten panelists.
Cv-Coefficient of Variation ; CD-Critical difference
Sed(T)-Standard error deviation between treatments;
Sed(P) – Stanard error deviation between periods;
Sed(TxP) Standard error deviation between treatments and periods;

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