EFFECT OF RADIATION PROCESSING ON DEHUSKING AND MICROBIAL LOAD OF KODO AND KUTKI MILLETS

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***Abstract*:**

The present study deals with the effect of gamma irradiation by cobalt 60 as the radioactive source on dehusking of two varieties of Millets: Kodo (Paspalum scrobiculatum) and Kutki (Panicum sumatrense). Our aim is to find out: a) if irradiation can make de-husking easier since this is one of the major challenges faced by farmers b) what radiation dose would be good to ensure that grains are de-husked easily. Grains were irradiated at doses: zero to 10 kGy. De-husking behaviour and microbial load of the grains was evaluated. Dose of 2.5 to 5 kGy was the most suitable for the desired effects. It was possible to reduce time and efforts involved in de-husking of grains of both varieties, and its effect was more pronounced in Kodo than in Kutki. Microbial load was also eliminated on irradiation at these doses.

***Index terms*:** De-husking, Kodo, Kutki, Radiation Processing, Shelf-life.

I. INTRODUCTION

Radiation Processing refers to the use of energy of short-wavelength radiations from the electro-magnetic spectrum for processing of materials for their valorization (Technical Document, Department of Atomic Energy, Government of India, 2014). There are two main types of radiations: ionising and non-ionising. Ionising radiations are of high energy, enough to detach electrons from atoms. On exposure to ionising radiations, changes in materials happen at the electronic level causing ionisation. On the other hand, when subjected to the non-ionising radiations having much lesser energy, changes happen only at the molecular and atomic level. High Ultra-violet rays, X-rays and gamma rays are all ionising radiations whereas radio-waves, micro-waves, infra-red, ultra-violet, and visible rays are all non-ionisation radiations. Depending upon changes, desired radiations, and their doses are chosen for the purpose. Almost every industry including food has exploited the potential of radiation processing (WHO, 1994).

Mostly, they are perishable foods that are irradiated to increase their shelf-life (Marathe et al., 2002; Maity et al., 2009). The process of irradiation has been widely used for preventing a large number of food products from insect infestation, thereby making them fit for human consumption (Rees, 2004; Kabbashi et al., 2012). Fresh fruits and vegetables are irradiated again for several benefits like delayed ripening, reducing the microbial load, prevention from sprouting etc. (Melki and Marouani, 2009). Studies have also been conducted not only for stopping the growth of moulds like *Aspergillus flavus*, which is the cause for aflatoxins (Aziz and Moussa, 2004) in oil seeds but also to de-contaminate oil seeds contaminated with aflatoxins. Although, WHO (WHO, 1994) recommends irradiation by gamma rays as an acceptable technique for preserving foods, the world is divided on this matter. While on one hand, the USA allows foods to be irradiated by gamma rays to make them free from deadly pathogens and, in fact, there the consumers prefer gamma irradiated foods, even if they are priced more than the un-irradiated foods, but on the other hand, EU countries don't allow irradiation of food using gamma radiations. Besides, then, there are countries like India where an approach of caution is adopted in this regard, i.e., allow foods that have been established to be safe after irradiation with gamma rays (Stewart, 2001). Here, the data, based on research studies and validated by scientific evidences is essential to get permission for approval from the regulatory authorities. Thus, wherever there is a need felt for irradiating any food product using gamma irradiation, all those products are studied to optimize the dose for the purpose of irradiation and also demonstrate that irradiation will have no adverse effect on food quality and safety (Stewart, 2001). Different irradiation doses are being used to produce different desired effects in various foods. Thus, an appropriate dose is always specified while permitting the product for gamma irradiation. Several food products have been listed as allowed by the regulatory authorities for gamma irradiation at an allowed dose.

This study has been targeted to provide sufficient data for the decision-support system for irradiation of two varieties of millets, Kodo and Kutki, using gamma irradiation. It is that irradiation for the first time as a technology intervention has been studied to resolve challenges pertaining to the process of de-husking of grains.

There are two fundamental facts that must be understood about millets before irradiation by gamma rays as a technological intervention is taken up as an option!

Firstly, it is to be noted that, till a century ago, millets had always been a major crop, used for staple food across India. But with time, farmers started opting for wheat as a preferred crop (Marathe et al., 2002) in spite of the fact that millets have a long shelf-life, which means they can be stored for longer time duration (McDonough and Rooney, 2000). One of the reasons for that can be attributed to the challenges involved in the process of de-husking of millets, which is cumbersome and highly time-consuming since the outer seed coat is profusely attached to the grain, whereas, it is easy to de-husk wheat or the paddy grains (Perten, 1983). Therefore, slowly, wheat started becoming a household name and consumers started using it as their staple food. This trend was further driven by the fact that it was possible to prepare different types of food products with wheat flour as compared with millet flour which was not that easy to process for preparation of various products (McDonough and Rooney, 2000; Perten, 1983; Rao and Basavaraj, 2015; FAO, 1995). This resulted in demand for wheat more than for millets. In fact, today, millets are being grown only in selected areas in the country. Thus, with time, wheat started becoming a symbol of prosperity and affluence. Farmers, thus, started growing wheat as a cash crop.

But the story is not completed here unless the second fact is understood. During the last two decades, the scenario about millets has been fast changing. A general perception that millets are food for the poor is no more valid. In fact, it's now the consumer from the affluent class who is demanding for millets. Thanks to the knowledge about nutritional aspects of different grains, the millets are being considered as superior grains of all! Trends have started changing in favour of millets (Rao and Basavaraj, 2015). Now, millet has suddenly become the grain of choice for the rich and not just for the poor. This all means that the demand for millets has started rising. Farmers would like to grow millets as a cash crop in the future. But then, that can become a reality only if the challenges involved in the processing of millets are resolved (Rao and Basavaraj, 2015; FAO, 1995). This is a matter of concern for the policy makers as well. Technology interventions required to meet this challenge will have to be developed and rendered to farmers for the purpose.

The present paper aims to find if irradiation can make de-husking easier. At present, in most of the cases, de-husking is either done manually by pounding the grains or soaking the grains before removal of the husk. Hence, once the benefits of irradiation for the purpose of de-husking the grains are established, that will be a boon for the farmers to exploit this cost-effective technique of using the gamma rays to de-husk grains easily. Here, it may also be mentioned that there are reported studies to show that gamma radiations may also enhance certain functional properties of the flours (Balasubramanian and Viswanathan, 2010); Chaturvedi et al., 2013; Pankaj et al., 2013; Irfaq and Nawab, 2001) produced from the irradiated grains.

Let us first discuss the de-husking of millets. Several studies that have been carried out to resolve this issue have resulted into different processing machines which can reduce the time of de-husking. However, each design developed for the purpose suffers from one flaw or the other. None is found to be perfect to achieve the desired results. The need for further research and innovation still remains to be explored. In the present paper, an attempt has been made to process the millet grains of two important varieties, i.e., Kodo and Kutki, by irradiation using gamma rays from Cobalt 60 as the radioactive source. Since radiation processing of foods is allowed only after it is established that the chosen dose of radiation is safe for food as well as for consumers, hence, taking this into consideration, grains were evaluated for different characteristic parameters to arrive at the appropriate dose. The main aim, of course, was to make the de-husking of millets easy and efficient. Besides, attempts have also been made to evaluate the effect of gamma irradiation for decontamination of the millets under study from microbial load and increasing their shelf-life.

II. Materials and Methods

2.1 Procurement of millet grains

The grains of the local variety of Kodo and Kutki grown in the season of 2019/2020 were procured from the Krishi Vigyan Kendra, Dindori, Madhya Pradesh. The grains were cleaned of all foreign material before using them for the studies. About 500 grams of the cleaned grains were packed hygienically in food grade laminated LDPE (low density poly ethylene) bags, purchased from the certified distributor. The packed grains were then stored under ambient conditions of temperature and humidity. All experimental work was performed at the National Institute of Food Technology Entrepreneurship & Management (NIFTEM), Sonepat, Haryana, India.

2.2 Gamma Irradiation of millets

Packed samples, each of both Kodo and Kutki millets were gamma irradiated at different doses of 0.5, 2.5, 5.0, 7.5 and 10 kGy respectively. The irradiation process was carried out at room temperature using Cobalt 60 as an irradiation source and following the standard operating procedure of dosimetry as per the guidelines of Atomic Energy Regulatory Board (AERB), Govt of India. The samples were irradiated using the facilities available at Shriram Institute for Industrial Research, Delhi, India. The unirradiated samples were treated as control.

2.3 De-husking of Millets and determination of De-husking Efficiency

Since millets are small in size and enclosed by a sturdy outer aleurone layer, followed by the bran layer and cellulose rich husk, hence the procedure of separating the outer husk along with the aleurone layer which is called de-husking or dehulling is quite tedious (Perten, 1983). Conventionally, removal of husk is normally done using a wooden pestle and mortar, which is a difficult and time-consuming task and in this case the roll sheller is being used, that requires passing of the grains several number of times through it for complete de-husking (Pradhan et al., 2010). In the present study, a laboratory de-husker Rubber Roll Sheller was used that had the following units (i) feeding unit, (ii) de-husking unit and (iii) the separating unit. The grains (containing moisture content of 11 % w/w) were passed through a rubber roller where it gets abraded by the two knurled shafts and is de-husked by rotation of the de-husking drum in the de-husking unit. A fixed speed motor having a capacity of 5 hp was used for operating the dehusker at fixed rpm.

The complete process was optimized to get maximum de-husking efficiency (Dixit et al., 2011; Singh et al., 2011; Meghashyam et al., 2014; Tippeswamy, 2006; Ravindra et al., 2008).

Data was recorded for assessment of (a) the number of times the grains had to be passed through the roll sheller for complete de-husking, (b) the time taken for each individual cycle and (c) the total time required, i.e. the sum total of the time taken for all the individual cycles. The de-husking efficiency was evaluated in terms of total yield (%) of the de-husked grains, the head grain yield (%) and the broken grain yield (%). The experimentation was carried out with 1 kilogram of both, i.e., unirradiated and the gamma irradiated grains at different doses. The calculations were done as per the following indices:

a) De-husking Efficiency (%) = Weight of Milled Grain (Head grains and Broken (g) / Weight of Grains fed to machine (g) x 100
b) Head Grain Yield (%) = Weight of Head Grain (Round and clean Dehusked grain (g)/ Weight of Milled Grain (Head grains and Broken (g) x 100
c) Broken (%) = Weight of Broken grain (g) / Weight of Milled Grain (g) x 100

2.4 Determination of Microbial Load

The microbial load of the grains of Kodo and Kutki millets was determined on the basis of total bacterial count and the total yeast and mould count or the total fungal count.

2.5 Total Bacterial Count

The total bacterial count,(log cfu/g i.e. colony formation unit per gram) of both unirradiated and irradiated grains of Kodo and Kutki was carried out respectively using Plate Count Agar method as per the Indian Standard (IS) specifications 5402.

2.6 Total Yeast and Mould Count

The Total Yeast and Mould count, (log cfu/g) of both unirradiated and irradiated grains of Kodo and Kutki at different doses was carried out respectively using Potato Dextrose Agar as per the Indian Standard (IS) specifications 5403.

2.7 Statistical Analysis

All analytical determinations were carried out in triplicate and statistically analyzed using ANOVA (One-Way Analysis of Variance) to evaluate significant differences between irradiated and unirradiated flours (Snedecor and Cochran, 1983).

III. Results and Discussion

3.1 Effect of Gamma irradiation on de-husking of millets

The effect of gamma irradiation on de-husking of millets was studied for the following objectives:

a) How much total time it takes to de-husk the grains when irradiated at different doses as compared to the unirradiated grains? Hence, the total time taken was noted down.

b) How many times the grains were to be put for processing into the machine for complete de-husking, or, in other words, how many cycles were needed to de-husk the grains irradiated with different doses as compared to unirradiated grains and also how much is the time taken during each cycle. Therefore, the number of cycles was noted and c) time taken for each cycle for grains irradiated at different doses was noted and compared with that of the unirradiated grains.

The results obtained for de-husking of both irradiated samples of kodo and kutki with respect to the above-mentioned objectives are presented graphically in Figures 1- 4.

From figure 1, indicating irradiation doses versus total time taken for de-husking, it can be seen that there is a considerable reduction in time taken for de-husking of both the grains, i.e., Kodo and Kutki with increase in radiation dose. The effect is more prominent in the case of kodo than in the case of kutki. This can be attributed to the fact that forces of adhesion get loosened between the outer layer and the surface of the grain by irradiation. As the dose is increased, the process of de-husking becomes easier. Total time taken for de-husking of kodo reduced considerably from approximate 15 minutes for un-irradiated grains to approximately 6.5 minutes for grains irradiated at 5.0 kGy

and thereafter, to 4.1 minutes for the grains irradiated at 10 kGy. In the case of kutki, un-irradiated grains could be de-husked in a total time of approximately 8 minutes while the same could get de-husked in approx. 2 minutes when irradiated at dose of 5.0 to 7.5 kGy and approx. one minute when irradiated at 10 kGy.

This is one observation which must bring relief to farmers for whom de-husking has always been a challenge! Even if the grains are irradiated at dose of 5.0 to 7.5 kGy, one can notice the reduction in total time of de-husking; since irradiation above 7.5 kGy may lead to initiation of certain changes in rheological properties (oil absorption or water absorption capacities as reported in the literature for other grains (Lorenz et al., 1979), though there would be no changes in the nutritional properties (Chaturvedi et al., 2013; Pankaj et al., 2013).

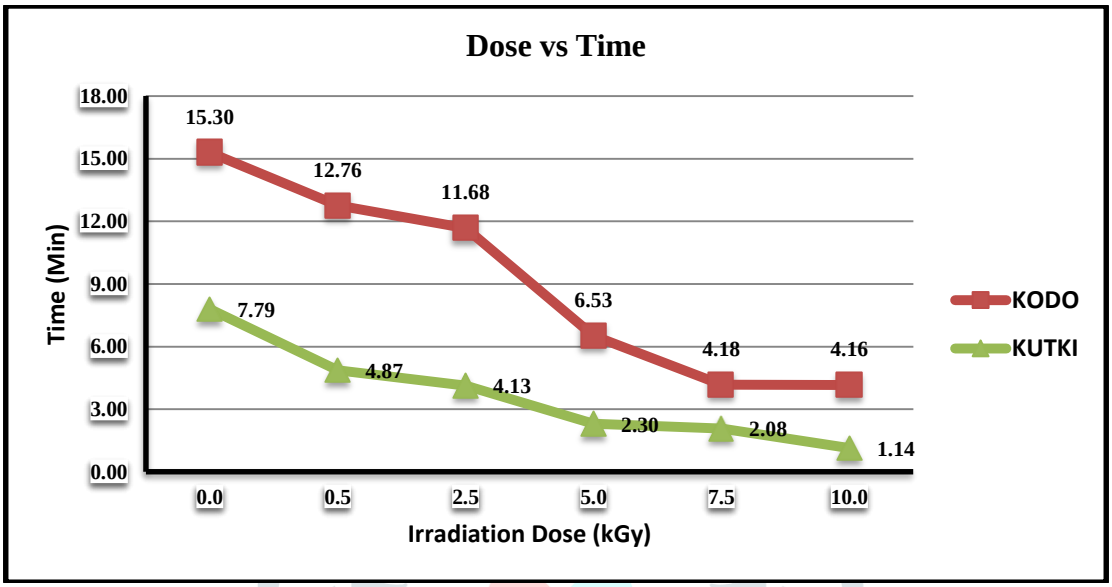

Figure 1: Effect of Irradiation on De-husking of Kodo and Kutki millets (Irradiation dose versus Total time taken). Results are the mean of 3 replicates.

It may be noted here that while it required 12 processing cycles to completely dehusk the control un-irradiated samples of kodo millets, the same result could be achieved in 7 processing cycles for the samples irradiated at 10 kGy for the complete de-husking process. This shows that not only total time taken for de-husking was reduced when subjected to irradiation as seen above, but the number of cycles needed for this purpose was also reduced as seen in Figure 2. In the case of Kutki, the similar results were found; with the increase of the dose, there was a reduction of the number of processing cycles required for completely de-husking from 6 cycles to 3 cycles at 0 kGy and 10 kGy respectively. These observations are in line with results of total time for de-husking, as presented above.

The results for time taken for each processing cycle for de-husking of kodo and kutki are presented in Figure 3 & 4 respectively. It may be noted (Figure 3) that the time required for subsequent cycles gets reduced. For example, in the case of kodo millet irradiated at 2.5 kGy, it can be seen that while the first processing cycle took approx. 2.05 minutes, the 12th cycle took less than 30 seconds. The same was observed for all samples of kodo as the radiation dose was increased from 0 to 10 kGy. Similar trends were observed for Kutki millet as well (Figure 4). From the results, it can be concluded easily that the de-husking of both Kodo and Kutki millet can be achieved by radiation processing using Gamma rays. The effect of irradiation is more evident in the case of Kodo in comparison to Kutki.

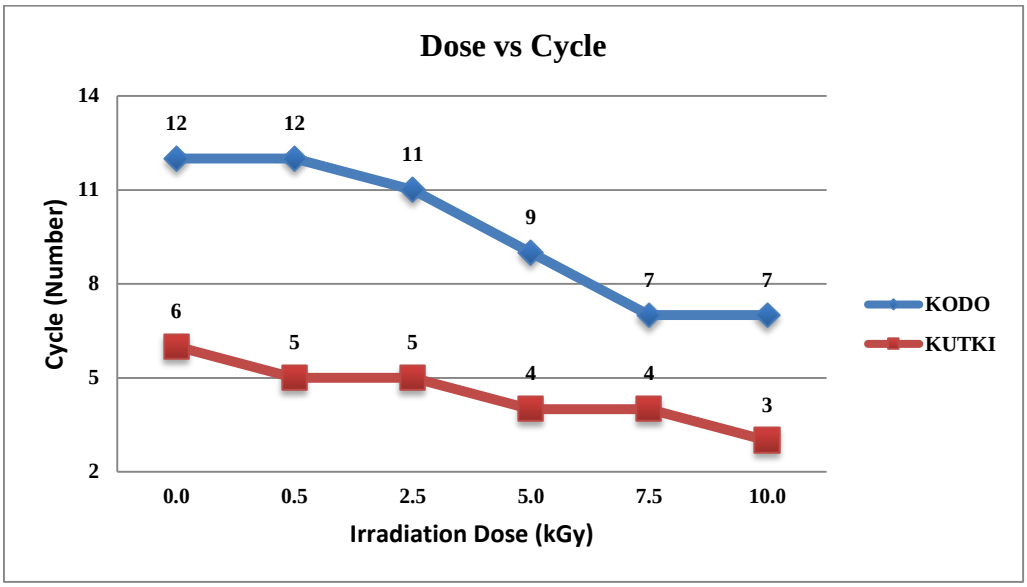

Figure 2: Effect of Irradiation on De-husking of Kodo & Kutki millets (Irradiation dose versus Cycles). Results are the mean of 3 replicates.

This shows that the degree of adhesion of the top cover with the grain surface is of different degrees in these two types of millet. Further even though the radiation dose of 2.5 to 5.0 kGy was found effective for de-husking, there is always some fraction of grains that remain unaffected by irradiation at 0.5 to 10 kGy. The results of these studies, therefore, demonstrated that irradiation can be an option to facilitate de-husking. Irradiated grains are much easier to de-husk than the unirradiated ones.

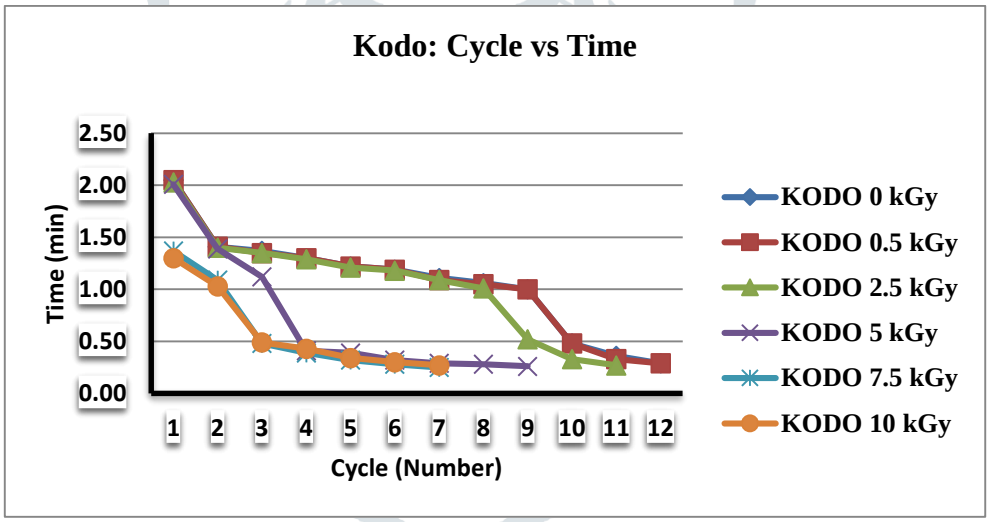

Figure 3: Effect of Irradiation on De-husking of Kodo millet (Time taken for each processing cycle). Results are the mean of 3 replicates.

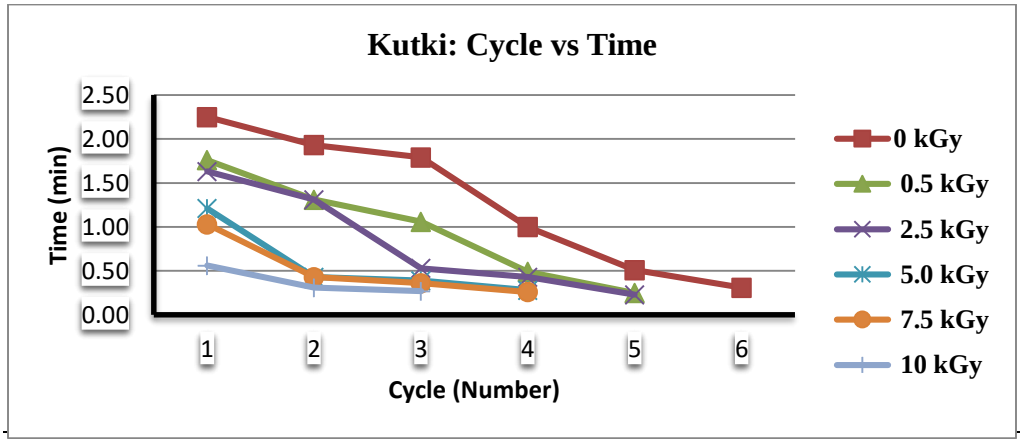

Figure 4: Effect of Irradiation on De-husking of Kutki millet (Time taken for each processing cycle). Results are the mean of 3 replicates.

3.2 Effect of irradiation on De-husking Efficiency of Kodo and Kutki millets

The effect of Irradiation on de-husking efficiency of the millets was measured in terms of total yield (%), head grain yield (%) and broken grains (%). From Table 1, it may be noted that there was a significant effect of gamma radiation on de-husking efficiency of Kodo and Kutki millets. In case of Kodo millet, total yield was found to have increased from 68.94% to 72.59 % in all the samples irradiated at dose levels between 0.5 kGy to 10 kGy as compared to control where total yield obtained was 68.58% after de-husking. Similarly, broken yield percentage decreased from 6.4-5.9% at 0.5 to 10 kGy, whereas in control it was 6.5%. The head Grain yield of control was 93.5% whereas it ranged from 93.6-94.1% at 0.5 to 10 kGy respectively.

Similar observations were made in Kutki millet also where there was an overall increase in the de-husking efficiency. The total percentage yield in the controlled unirradiated control was found to be 79.10 whereas it was found in the range of 79.41-79.99% in the samples irradiated at different dose levels between 0.5 to 10 kGy. The percentage broken grain was found to get decreased from 6.0 to 5.4 in the samples irradiated at doses in the range of 0.5 to 10 kGy respectively as against 6.1% in the controlled unirradiated sample. The percentage of Head Grain yield in the unirradiated samples of Kutki was 93.9% whereas it was in the range of 94.0-94.6% at 0.5-10 kGy resp. Hence, the dose from 0.5 to 10 kGy was found to have a significant effect on de-husking Efficiency (%) as compared to Control. The parameters like size, shape, outer layer and toughness of grains play a key role in milling efficiency (Pradhan et al., 2010; Dixit et al., 2011; Singh et al., 2011; Meghashyam et al., 2014; Tippeswamy, 2006; Ravindra et al., 2008). Hence, there was significant change observed in the de-husking efficiency of Kodo and Kutki millet due to gamma irradiation processing at different doses.

Table 1: Effect of Gamma Irradiation in Processing of Kodo Millet and Kutki Millet

Gamma Dose (kGy)	Total Yield (%)	Broken Yield (%)	Head Grain Yield (%)
KODO MILLET			
Kodo Control	68.58	6.5	93.5
Kodo 0.5	*68.94	6.4	93.6
Kodo 2.5	*70.61	*6.3	*93.7
Kodo 5.0	*71.13	*6.3	*93.7
Kodo 7.5	*71.89	*6.1	*93.9
Kodo 10	*72.59	*5.9	*94.1
KUTKI MILLET			
Kutki Control	79.10	6.1	93.9
Kutki 0.5	*79.41	6.0	94.0
Kutki 2.5	*79.84	*5.8	*94.2
Kutki 5.0	*79.93	*5.6	*94.4
Kutki 7.5	*79.97	*5.5	*94.5
Kutki 10.0	*79.99	*5.4	*94.6

Values expressed are mean. Mean value in the columns with superscripts are significantly different ($p \leq 0.05$)

3.3 Determination of Microbial Load

The results of microbial studies of Kodo and Kutki irradiated at different doses immediately after irradiation are presented in Table 2. It may be noted that specimens irradiated at 0.5 kGy and above did not show any microbial load in Total Bacterial Count as well as Total Yeast and Mould Count. The un-irradiated specimens were found to be contaminated with microbial load.

It may be noted as represented in Table 2 that in unirradiated flour the total bacterial count in log cfu/g of Kodo millet was 3.47 log cfu/g. However, in the case of irradiated flour there was significant reduction of total bacterial count from 3.47 log CFU/g in unirradiated flour to 0 CFU/g at 0.5, 2.5, 5, 7.5 & 10 kGy. Similarly before irradiation total yeast and mould count of Kodo was 2.20 log cfu/g. As reported in Table 2 for Kutki millet, in unirradiated flour the total bacterial count in log (cfu/g) was 3.32 log cfu/g. Similarly, it may be noted for Kutki millet that the total yeast and mould count was 2.17 log cfu/g in unirradiated flour. Our results are in agreement with (Kabbashi et al, 2012; El-Naggar and Mikhaiel (2011); Hitoshi & Islam (1994); Nagat et al., 2016; Gupta et al., 2009) that with increase of dose there was significant reduction of microbial load. Hence, it was found that there was enhancement of shelf-life of Kodo and Kutki millet by the treatment of gamma irradiation.

Table 2: Effect of Gamma Irradiation on Total bacterial Count (TBC) and Total Yeast and Mould Count (TYMC) in Kodo millet and Kutki millet

Treatment	TBC (log count cfu/g)		TYMC (log count cfu/g)	
	Kodo	Kutki	Kodo	Kutki
	Immediately after Irradiation	Immediately after Irradiation	Immediately after Irradiation	Immediately after Irradiation
Control	3.47 ± 0.14	3.32 ± 0.10	2.20 ± 0.14	2.17 ± 0.32
0.5 kGy	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2.5 kGy	0.00 ± 0.00	0.00 ± 0.06	0.00 ± 0.00	0.00 ± 0.00
5.0 kGy	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7.5 kGy	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
10 kGy	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Values expressed are means ± SD (n = 3).

IV. CONCLUSION

From the studies the following conclusions could be drawn:

a) The process of Gamma Irradiation is evidently a promising technique to detach husk from the grains, especially in the case of those grains where the outermost layer is very tough to remove as in the case of Kodo and the Kutki millets.

b) De-husking in the case of Kodo millets was found to be affected more by the gamma irradiation process than in the case of Kutki millets which can be attributed to the difference in their structure.

c) Not only time but even the efforts required for de-husking was found to be much lesser for the irradiated grains

d) Irradiation was found to be more effective for dose of 2.5 kGy and 5 kGy and hence gamma irradiation at less than 5 kGy can be adopted as a technology option not just for de-husking but also for eliminating microbial load including pathogens, thereby increasing the shelf-life and at the same time not affecting the other quality parameters either of the grains or the flours extracted from the grains.

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CONFLICT OF INTEREST

None

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