

**RESEARCH ARTICLE****Impact of irradiation on nutritional quality and functional properties of soy flour and sprouted soy flour****Nawab Mahae Jabeen, Manjula Kola and K. Jalarama reddy**Department of Homescience, Sri Venkateshwara University,
Tirupati, India.**Manuscript Info****Manuscript History:**Received: 25 January 2015
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Published Online: March 2015**Key words:**Irradiation, Soybean, antioxidant,
protein, functional properties***Corresponding Author****Nawab Mahae Jabeen****Abstract**

Irradiation is recommended as a safe and effective food processing method that can be used to preserve foods and reduce the risk of food poisoning and contamination without any deterioration of health with minimum effect on nutritional quality of food. Soy protein is the only vegetable whose protein is complete. Recently the popularity of soy protein is increasing mainly because it contains soy-isoflavones which are antioxidants. Soybean also contains some anti-nutritional factors like Trypsin inhibitors, phytates which can be reduced by sprouting, roasting process. The present investigation was carried out to study the effect of radiation processing nutritional quality, functional properties like absorption capacity and acceptability of soy flour and sprouted soy flour and compared with non-Irradiated soy and sprouted soy flours. Protein, fibre, and total antioxidants content found to be statistically not significant between irradiated and non-Irradiated soy flours. The increase content was found to be statistically significant ($p < 0.05$) between irradiated and non-Irradiated sprouted soy flours at 1 month of storage period. It can be concluded from the findings of the whole study that both radiation and sprouting processing does not affect the quality of foods. In addition improves the protein content, antioxidant content and absorption capacities at 1kgy radiation dose and also decreases the anti-nutritional factors to great extents.

*Copy Right, IJAR, 2015,. All rights reserved***INTRODUCTION**

Numerous processing techniques have been developed to control food spoilage and raise safety. The traditional methods have been supplemented with pasteurization (by heat), canning, freezing, refrigeration and chemical preservatives (Agrios, 2005). Another technology that can be added to this list is irradiation. Ionizing radiation produces chemical changes by primary and secondary radiolysis effects. The effect of chemical reactions depends on the absorbed dose, dose rate and facility type, presence or absence of oxygen and temperature. Generally, most food micronutrients (mainly water-soluble and fat-soluble vitamins) and macronutrients (carbohydrates, proteins, and lipids) are not affected by 10 kGy range ionizing dose with regard to their nutrient contents. Whereas, radiation doses above 10 kGy, the properties of fibrous carbohydrates can be degraded structurally and lipids can become some what rancid (Miller, 2005; Brewer, 2009).

Food irradiation has been approved by authorities like FDA, USDA, WHO, FAO, etc. and also various scientific societies based on extensive research (Tritsch, 2000; Morehouse, 2002). Radiation processing of foods at low radiation doses does not cause any significant changes in flavor, texture and sensory properties (Farkas, 2006). Irradiation also eliminates problems associated with other food safety treatments such as nutrient degradation or changing the produce's color, texture and flavor. However, market success of irradiated foods has not been at desired level. This is probably due to consumers' erroneous fear that irradiated foods become radioactive and irradiation could form harmful compounds in food (Oliveira & Sabato, 2002). Food irradiation has been recognized as a reliable and safe method for preservation of food, improve hygienic quality of foods and improve the nutritional quality of foods (Al-Kaisey et al., 2003; Diehl, 2002). The chemical structure of irradiated food is less modified than heat-treated food and this technique avoids the use of potentially harmful chemicals.

Soybean (*Glycine max* L. Merrill) plays an important role in human's diet as the richest and least expensive sources of vegetable protein and has been appreciated for many centuries in Asia (Winarno and Muchtadi, 1984). Soy protein and its associated phytochemicals seem to reduce heart disease, osteoporosis and risk of cancer. The soy protein has a high biological value and contains all essential amino acids. Soy isoflavones act as anti-cancer agents because they are antioxidant, inhibit the growth of blood vessels required to feed tumors and inhibit the protein production in cancer cell. Soy isoflavones are also beneficial for menopausal symptoms and help to maintain strong bones. Soybean also contains anti-nutritional factors like protease inhibitor, phytate was thought to be harmful as it binds with other minerals and prevents their absorption in the intestines. Sprouting of such soybean will reduce anti-nutritional factors up to 80% and enhance nutrients and mineral availability. Such sprouted soybean can be consumed directly but it has off odour. Now days sprouted flours are also available in markets, which is good for health and also rich in nutrients.

Sprouting is the practice of soaking, then germinating seed growing sprouts under controlled conditions. Uniform and quick germination increases yield and enhances the quality of sprouts (Khattak, Zeb, Khan, Bidi, Isanullah, & Khattak, 2007). Germination improves the nutritive value of legumes by causing desirable changes in nutrient availability, texture and organoleptic characteristics (Frias, Miranda, Doblado, & Vidal-Valverde, 2005; Granito, Torres, Frias, Guerra, & Vidal-Vilverd, 2005) and decreases anti-nutritional factors and increases antioxidant effects (Doblado, Frias, Vidal-Valverde 2007). Anti-nutritional factors (ANF) are compounds which reduce the nutrient utilization and/or food intake of plants or plant products used as human foods or animal feeds and they play a vital role in determining the use of plants for humans and animals. The anti-nutritional factors (ANFS) may be defined as those substances generated in natural food stuffs by the normal metabolism of species and by different mechanisms (e.g. inactivation of some nutrients, diminution of the digestive process, or metabolic utilization of feed) which exert effects contrary to optimum nutrition (Kumar, 1992.) Food irradiation is a process of exposing food to ionizing radiations, such as gamma rays emitted from radioisotopes ^{60}Co and ^{137}Cs , or high energy electrons and X-rays produced by machine sources (Diehl, 2002). Gamma irradiation has been recognized as a reliable and safe method for improving the nutritional value and inactivation or removal of certain anti-nutritional factors in foods and feeds (Siddhuraju et al., 2002; Farkas, 2006). In order to inactivate or reduce the above mentioned anti-nutrients, various conventional, simple processing methods have been used such as dry heating, roasting, boiling, soaking in water, alkali and acid, solvent extraction, germination and fermentation (Siddhuraju & Becker 2001). However, none of these methods is able to completely remove all the detected antinutrients that are present in seeds, grains or feed materials. A combination of processing methods is generally more effective than a single method.

The present investigation was carried out to study the effect of radiation processing on the functional properties, acceptability and shelf life of soy flour and sprouted soy flours.

Materials and Methods

Raw materials

A good quality soybean was purchased from local supermarket Tirupati. Cleaning is crucial to obtain high quality and product soybeans were cleaned to separate out dust, pebbles, stones or coarse materials. Soybeans were washed properly to remove the surface dirt and also loosen the husk.

Processing of raw material

Measured quantity of soybeans were taken and soaked in water. During soaking the volume of water used for soaking, time of soaking, water drained after soaking was noted down. Soybeans were soaked for 12 hours at ambient temperature. After soaking the soybeans are drained from water and tied in a muslin cloth tightly and moistened, then left at room temperature in dark place. Sprouts are rinsed as little as twice a day, but possibly three or four times a day in hotter climates, to prevent them from souring. To retard mould growth during sprouting the sprouts are immersed in 0.05% hypochloride solution for 15min, then rinsed with water. Each seed has its own ideal sprouting time. A long white sprout grows out from cotyledons. The duration of sprouting was 12 hours and sprout length was noted down. These sprouted soybeans were dried in sunlight for two days to remove moisture content, uniform drying of the soy sprouts is very important during sun drying. These sprouts are spread uniformly on a cloth before exposure to sunlight.

Dried sprouts were roasted for 5 minutes because most off flavours are formed during the initial processing. Soy off flavor is mainly due to the lipoxygenase activities. High temperature and acid treatments are commonly used to denature lipoxygenases. During roasting the duration of roasting is important to obtain results with least protein denaturing. Roasting of soybeans will reduce raw-flavour and also minimizes heat-labile anti-nutritional factors. Roasted soy sprouts were milled into flours of the desired particle size. The flour obtained was sieved to remove the husk or coarse particles to get fine powder.

Preparation of samples

Two packs of Soy flour and two packs of sprouted Soy flour which constitutes 250gm in each pack were prepared for the study. One sample of Soy flour and one sample of sprouted soy flour irradiated at a dosage of 1kGy which were treated as experimental samples. The other two samples were treated as control samples (non-irradiated).

Radiation processing

Samples were packed and subjected for irradiation dose of 1 kGy. The irradiated samples and Non-irradiated samples were further used for chemical analysis.

Chemical analysis

Parameters like percentage of protein (microjeldhal method), crude fiber content (sulphuric acid method), anti-nutritional factors (by using TCA method) and total antioxidant activity (TBARS method) were studied for the irradiated and non irradiated samples.

Determination of water and oil absorption for samples

For water and oil absorption capacity of flours samples the method of scathe et al., 1982.

Formulation of Chapathi mix

The chapathi mix was formulated with the combination of wheat flour (70%) and soy flour (30%) and the ingredients are shown in table 1. The chapathi mix was formulated for Soy and sprouted soy flour of both irradiated & non irradiated samples with composition given in Table 1. The formulated chapathi were prepared by using all the formulated chapathi mixes and individually were subjected to sensory evaluation.

Sensory evaluation

Sensory evaluation of chapathi were carried out by 13 semi-trained panellists on a 5 point hedonic scale as per Murray et al., (2001) to establish the overall acceptability of the product.

Shelf life studies

Irradiated and non-Irradiated soy and sprouted soy flours were kept for 1 month of storage period to analyze the chemical changes in radiated flours and compared it with non-irradiated flours.

Statistical Analysis

All the data is recorded tabulated and subjected to appropriate statistical analysis. Independent sample student's t-test was used to observe whether there is significant difference between irradiated and non-irradiated samples and also the acceptability of irradiated and non-Irradiated flours were measured by using one way ANOVA.

Results and Discussion

Effect of radiation on the nutrient contents of flours

The impact of radiation on the sprouted soy flour and normally processed soy flours are examined through the assessment of changes that are observed in the nutrient factors like soy protein, crude fibre content and total antioxidant activity and compared with non irradiated flours.

Protein content of irradiated and non-Irradiated Soy flour and sprouted Soy flour

The protein content of irradiated and non-Irradiated samples were analysed with standard procedure and the values obtained are depicted in Table 2. The data (table 2) shows that that the values of Soy protein content in Irradiated and non-Irradiated Soy flours were 24.459 ± 0.231 , 24.085 ± 0.363 respectively with their t-value was 1.313 where as in irradiated and non-Irradiated sprouted Soy flours were 26.008 ± 0.495 , 25.844 ± 0.302 with their t-value was 0.489. These result indicates that soy protein content was found to be statistically not significant ($p > 0.05$) between irradiated and Non-Irradiated soy and sprouted soy flours. After irradiation the soy protein levels was found to be increased slightly in both Soy flour and sprouted soy flour as there is little increase in protein levels, but significant difference was not observed. The reason for increase in protein levels after irradiation might be due to gamma radiation leads to the disruption of the ordered structure of soy protein molecules by degradation, cross linking and aggregating of the polypeptide chains which decreases the viscosity due to cleavage of polypeptides chains and water vapour permeability by 13%. But mean tensile strength of the soy protein increased two times by γ -irradiation. Myoung Lee et al (2004) studied the effect of γ -irradiation on the physic-chemical properties of soy protein isolate films reveals the above trend. Studies conducted by Shawrang et al (2007) reveals that treatment of soybean meal and canola meal with gamma irradiation was successful in reducing degradation of protein by rumen microorganisms and increasing protein intestinal digestibility.

The result shows that soy protein content found to be statistically not significant between irradiated and non-Irradiated soy flours. The increase in soy protein content was found to be statistically significant ($p < 0.05$) between irradiated and non-Irradiated sprouted soy flours at 1 month of storage period.

Crude fibre content of irradiated and non-Irradiated Soy flour and sprouted Soy flour.

Values of Crude fibre content of irradiated and non-Irradiated samples are depicted in Figure 1. From the Fig 1 it shows that the mean values of soy crude fibre content in irradiated and non-Irradiated soy flour were 5.117 ± 0.095 , 5.307 ± 0.135 respectively their t-value was -1.993 and in Irradiated and non-Irradiated sprouted Soy flours were 4.580 ± 0.310 , 5.283 ± 0.045 respectively with their t-value was -3.889. Crude fibre content was found to be statistically not significant ($p > 0.05$) between irradiated and Non-irradiated soy flours. The decrease in crude fibre content between irradiated and non-Irradiated sprouted soy flours were found to be statistically significant ($P < 0.05$). The reason for decrease in crude fibre content after sprouting might be due to depolymerization of fibre which dissociates in to small stands of a glycones. The results of present study coincides with the results of Dipika Agrohar Murukar et al (2009) states that Soy bean were examined for their germination ability as well as changes in

nutritional and functional quality on germination. Results shown that decrease in fibre content was found to be significant ($p < 0.05$) after germination.

The result states that after irradiation the crude fibre content was found to be statistically not significant ($p < 0.01$) between irradiated and non-Irradiated soy and sprouted soy flours at one month of storage period. Kovacs et al (1986) studied the effect of irradiation on carbohydrate content of wheat flour. In a dose range at 0.8 kGY. The results shown that carbohydrate content of wheat bran (water soluble carbohydrates, content, crude fibre content) did not change at all after irradiation.

Total antioxidant property of Irradiated and non-Irradiated Soy flour and sprouted Soy flour

Total antioxidant values of Irradiated and non-Irradiated samples are presented in Table 3. From the data it is found that after irradiation the total antioxidant activity was increased in both in soy flour and sprouted soy flours. The increase in the total antioxidant activity between irradiated and non-Irradiated samples were statistically significant ($p < 0.01$). The reason might be due to the effect of irradiation on Soy antioxidants leads to increase in aglycones, radiolytic degradation and increments of anti radical activity. Antioxidant potential increased with radiation dose. In vitro studies of soy bean samples were treated with γ -radiation doses between 0.5 and 5kGY for achieving insect disinfestation and microbial decontamination. Nutritional quality of Soy beans with respect to antioxidant isoflavone content was tested in radiation – treated and un treated samples. Antioxidant potential measured as percent 1, 1-diphenyl-2-picrylhydrazyl scavenging activity showed an increasing trend with dose indicating that radiation processing as a method of food preservation has a positive nutritional implication (Prasad S. Variyar et al., 2004). The results of present study coincides with the Hyun-Joo Ahn et al (2004), studied the comparison of Irradiated phytic acid and other antioxidants for antioxidant activity. The results shows that phytic acid irradiated at 20kGY, showed significantly higher DPPH radical – scavenging capacity ferric reducing / antioxidant power (FRAP) of phytic acid was significantly increased by irradiation. The results shows that after irradiation the total antioxidant activity was increased in both soy and sprouted soy flours at 1 month of storage period. The increase in total antioxidant activity between irradiated and non-Irradiated samples were statistically significant ($p < 0.01$) at one month of storage period. In vitro studies of evaluation of the antioxidant activities of irradiated phytic acid at 0.10, 20 kgy. Results shows that the antioxidant activity of phytic acid in the lipid models showed the highest antioxidant ability at 20kGY among the antioxidants tested at 3 weeks of storage (Cherun JO et al., 2004).

Impact of radiation on Non-Nutrient factors of flours

The impact of radiation on the sprouted flour and normally processed soy flours were examined through the assessment of changes that are observed in the non-nutrient factors like anti-nutritional status after radiation and compared with non-Irradiated samples.

Anti-nutritional status was measured by trypsin-inhibitor activity (TIB). The data in Table 4 reveals that after irradiation the Trypsin-inhibitor activity was decreased in both soy flour and sprouted soy flours. The decrease in Trypsin-inhibitor activity between irradiated and non-Irradiated samples were statistically significant ($p < 0.01$). The reason might be due to inactivation of trypsin-inhibitor activity in irradiated samples could be attributed to the destruction of disulphate (S-S) groups. The sulfhydryl (S-H) and disulphide groups (-S-S) are highly susceptible to irradiation. The results of present study coincides with the earlier studies conducted by Hamza. M et al (1998). Radiation processing as an effective means of food preservation, has been shown to decrease anti nutritional components in some proteinaceous leguminous seeds, thereby helps to provide food security (Bhat et al., 2007; Alothman et al., 2009). The results states that after radiation the decrease in Trypsin-inhibitor activity in both soy and sprouted soy flours at one month of storage period. The decrease in Trypsin-inhibitor between irradiated and non-Irradiated samples were statistically significant ($p < 0.01$). It is clearly shown that Irradiation does not shows any chemical changes in protein, fibre, antioxidant content and in addition, it improves the quality and quantity of nutrients and reduces anti-nutritional factors like Trypsin-inhibitor to great extent during the storage period of flours.

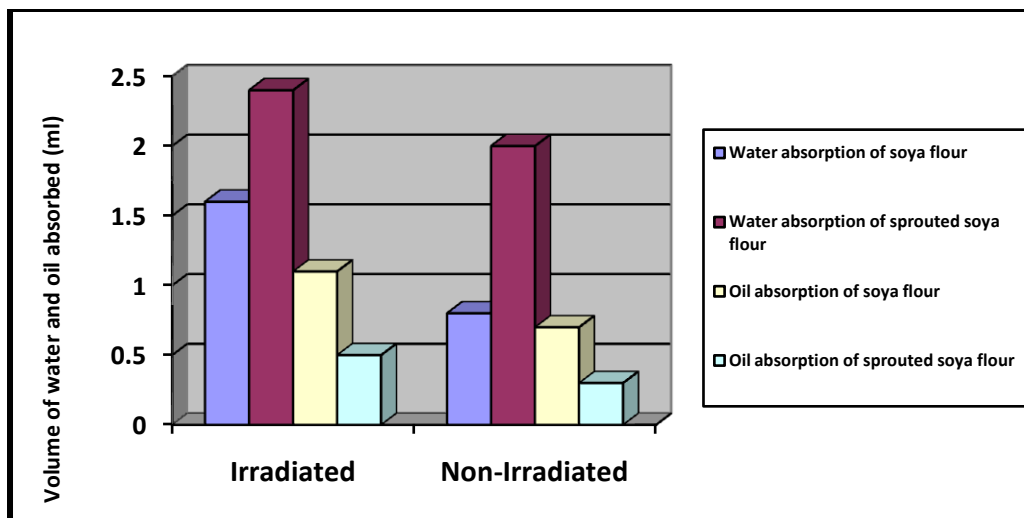


Figure 1. Volume of water and oil absorbed by flours before and after irradiation.

Table 1. The composition of chapathi mix

Ingredients	Amount
Wheat flour	70%
Irradiated / Non Irradiated Soy flours	30%

Table 2. Impact of radiation on shelf life of Soy protein content of irradiated and non-Irradiated samples

S.No.	Sample	Irradiated				Non-Irradiated			
		0 th day	1month	t-value	Significant difference	0 th day	1month	t-value	Significant difference
1.	Soy flour	24.45±0.23	25.21±0.54	-2.20	0.093 ^{ns}	24.08±0.36	25.05±0.45	-3.17	0.034*
2.	Sprouted soy flour	26.00±0.49	27.42±0.09	-4.85	0.008**	25.84±0.30	26.65±0.49	-2.43	0.072 ^{ns}

Table 3. Impact of radiation on shelf life of crude fibre content of soy flours

S.No.	Sample	Irradiated				Non-Irradiated			
		0 th day	1 month	t-value	Significant difference	0 th day	1 month	t-value	Significant difference
1.	Soy flour	5.11±0.09	5.04±0.03	1.21	0.291 ^{ns}	5.30±0.13	5.25±0.02	0.63	0.56 ^{ns}
2.	Sprouted soy flour	4.58±0.31	4.43±0.09	0.74	0.487 ^{ns}	5.28±0.04	5.24±0.09	0.76	0.74 ^{ns}

Table 4. Impact of radiation on shelf life of total antioxidant activity of soy flours

S.No.	Sample	Irradiated				Non-Irradiated			
		0 th day	1 month	t-value	Significant difference	0 th day	1 month	t-value	Significant difference
1.	Soy flour	172.30±1.53	183.07±1.53	-8.57	0.001**	152.30±1.53	161.53±1.53	-7.34	0.002**
2.	Sprouted soy flour (TBARS %)	163.07±1.53	173.84±1.53	-8.57	0.001**	146.15±1.53	155.38±1.53	-7.34	0.002**

Table 5. Impact of radiation on shelf life of anti-nutritional status of flours

S.No.	Parameters	Irradiated				Non-Irradiated			
		0 th Day	One month	t-value	Significant difference	0 th day	Month	t-value	Significant difference
1.	Soy flour	4.8±0.05	4.3±0.02	10.49	0.000**	5.6±0.04	5.0±0.05	15.17	0.000**
2.	Sprouted soy flour	4.7±0.5	4.4±0.02	9.29	0.001**	5.1±0.02	4.6±0.01	6.00	0.004**

Table 6. Impact of radiation processing on sensory attributes of soy flours.

S. No.	Sensory attributes	Chapathi with				F-value	Significant difference
		Irradiated soy flour	Irradiated Sprouted soy flour	Non- Irradiated soy flour	Non-Irradiated Sprouted soy flour		
1.	Appearance	4.1±0.30	4.7±0.47	4.0±0.00	4.6±0.50	17.35	0.000**
2.	Flavour	4.250±0.44	4.80±0.41	3.350±0.48	3.350±0.48	47.80	0.000**
3.	Taste	4.30±0.47	4.750±0.44	3.550±0.51	4.150±0.36	24.16	0.000**
4.	Texture	4.250±0.44	4.7±0.47	3.350±0.48	4.00±0.000	15.62	0.000**
5.	Colour	4.050±0.22	4.6±0.50	4.00±0.00	4.00±0.00	47.80	0.000**
6.	Overall acceptability	4.050±0.22	4.750±0.44	3.450±0.51	4.00±0.00	44.72	0.000**

Water and oil absorption capacities of irradiated and non irradiated soy and sprouted soy flours.

The water and oil absorption capacities of Irradiated and non-Irradiated flours were depicted in Figure 2. The data reveals the water and oil absorption capacities of irradiated and non-Irradiated Soy flour and sprouted Soy flour. The irradiated Soy flour and sprouted Soy flour absorbed 1.6ml, 2.4ml of water and 1.092ml, 0.546 ml of oil respectively where as Non-Irradiated Soy flour and sprouted Soy flour absorbed 0.8ml, 2ml of water and 0.7ml, 0.3ml of oil respectively. The result states that the radiation processing significantly increases the oil and water absorption capacities of Soy flour and sprouted Soy flour. Research study conducted by Mrinal Pendnekar et al (2004) on the effect of radiation processing and functional properties of soy bean found to show that radiation processing increases the oil absorption capacity and it also improves the functional properties like solubility, emulsification activity and foam stability of soy bean protein.

Acceptability studies of irradiated and non-Irradiated Soy and sprouted Soy flours.

Sensory evaluation is the best method of evaluating the food sensory evaluation was a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste and touch. (Anomynous, 1975).

The chapathi mix was formulated by using irradiated and non irradiated soy and sprouted soy flours. The chapathies were prepared and subjected to sensory evaluation to know the acceptance and difference between the irradiated and non irradiated chapathies. Addition of 15 to 25% soy flour to ordinary roti improves the nutritive quantity, and also improves digestibility. The chapathies were subjected to sensory evaluation by using 5 point headonic rating scale. The results obtained by sensory evaluation were shown in table 5.

The appearance of chapathies prepared with Irradiated flours shown higher mean values than non-Irradiated flours. They were smooth in texture, the reason might be due to radiation processing leads to soft and smooth texture. The flavor of chapathies made with Irradiated flours shows higher mean values than non-Irradiated flours. The reason is might be due to radiation processing in which reduces the soy off-flavour by inactivating lipoxygenase activity.

The mean values for taste of chapathies prepared with Irradiated soy and sprouted Soy flours were 4.30 ± 0.470 , 4.750 ± 0.44 and in non-Irradiated soy flour and sprouted soy flours were 3.550 ± 0.510 , 4.150 ± 0.366 respectively and their f-value was 24.165. The taste of chapathies prepared with Irradiated flours shows higher mean values than the non-Irradiated flours. The reason was radiation improves the nutritional qualities by improving functional properties of flours which adds taste to chapathies. The texture of chapathies prepared with irradiated flours shows higher mean values than non-Irradiated flours. The reason was due to radiation processing which change the functional properties of soy flours, leads to smooth texture which adds to chapathies. The chapathies prepared with irradiated flours shows higher mean values than non-irradiated flours. The functional properties was improved, may be the reason for browning of chapathies. The data reveals that the mean values for overall acceptability of chapathies prepared with irradiated and Non-Irradiated Soy flour and sprouted Soy flour. The overall acceptability of chapathies showed statistically significant difference ($p < 0.01$) between irradiated and Non-Irradiated samples. The reason was that both radiation and sprouting activity increases nutritional quality, improves functional properties, reduces off flavor of soy.

Conclusion

Radiation and sprouting process does not affect the organoleptic qualities of food and does not show any chemical changes during storage period and improves keeping quality of foods. Thus it can be concluded from the findings of the whole study that both radiation and sprouting processing does not affect the quality of foods, organoleptic qualities. In addition improves the protein content, total antioxidant activity, absorption capacities of oil, water at 1kGy radiation dose and also decreases the anti-nutritional factors to great extent and not shown any chemical changes during storage period and improves keeping quality of foods.

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