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Nutritional quality of tofu (Soy paneer) as affecting by gamma irradiation during storage

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Abstract
The shelf life of tofu is very less therefore to extend it, effect of gamma radiation and packaging in BOPP, HDPE and LDPE at 0, 5, 10, 15, 20 days have been studied. The Soybean (*Glycine max* L.) variety JS-9752 was used for tofu preparation.

The effect of different doses of gamma radiation on weight of tofu packed in various packaging materials and stored for varying storage period shows. Non significant difference among the different treatment contribution of treatment during storage period for moisture (20 days), protein (0-20days), fat (0day), and ash (0days) respectively, however for remaining period the effect on the content of above constituents was significant. The significant effect was also seen only in case of carbohydrate content throughout storage period.

LDPE shows non significant contribution of treatment during storage period for moisture (20 days), Protein (0-20days), fat (0day), and ash (0days) respectively, however for remaining period the effect on the content of above constituents was significant. The significant effect was also seen only in case of carbohydrate content throughout storage period. The treatment effect was non signifcant for the moisture (20 days), protein (15,20days) respectively.

In a nutshell it is deduced from the findings of present investigation and their justification that 1.25 kGy Gamma radiation treatments in combination with LDPE can be successfully utilized for extension of shelf life up to 15 days without sacrificing the quality of product. The gamma radiation treatment and effective packaging system has great potential for value addition in soymilk product industry for production of tofu (soy paneer).

Keywords: Tofu, soy paneer, gamma radiation, BOPP, HDPE, LDPE, nutrition

Introduction
Soybean (*Glycine max*) belongs to the legume family and is native to East Asia. The United States is the world leader in soybean production. In India, Madhya Pradesh and Maharashtra are the major producers of soybeans. Approximately 85% of the world's soybean crop is processed into soybean meal and vegetable oil (Dahlquist, 2013) [6]. Soybean is considered to be a source of complete protein. It contains significant amounts of all the essential amino acids that must be provided to the human body because of the body's inability to synthesize them. Soy protein products can be good substitutes for animal products because, unlike some other beans, soy offers a 'complete' protein profile.

Soybeans can be processed to produce many dairy product substitutes e.g., soy milk, margarine, soy ice cream, soy yogurt, soy cheese, and soy cream cheese. Soymilk and tofu producers prefer the higher protein cultivars. Essentially, Soymilk is an aqueous extract that is prepared by grinding soya beans that have been soaked in water. In India about 60% of soymilk is converted into tofu. Tofu is widely accepted all over the globe. Tofu is made by coagulating hot soymilk in tofu machine. Tofu has bland flavour it absorbs the flavour of the food with which it is cooked.

It is sold in loose, vacuum packed and water filled pouches and is increasingly available in shops. It has a mild flavor, very smooth and soft texture, creamy white appearance and a pleasant mouth feel. Tofu is very porous in nature and blends well with the Indian cuisine (Singh et.al. 2016) [13]. Regular use reduces the cholesterol level. Helps avoid osteoporosis (bone eakness) some of the nutrients (sphingolipids) found in soy protein are anticancer agents. It is a complete vegetable protein containing all nine essential amino acids. It is an excellent food for children, elderly people and pregnant and lactating woman as this protein is very nutritious and easy to digest.

The shelf life of tofu is very poor (5-7 days) at ambient temperature. The prepared fresh tofu is placed in cold water for preservation and storage. It is sold in loose, vacuum packed and water filled pouches and is increasingly available in shops. At room temperature the physical, nutritional and sensory quality of tofu often influenced by microorganism and bio molecules like lipoxygenase isozymes. Lipoxygenase (Linoleate: oxygen oxidoreductase, EC 1.13.11.12) which is major culprit responsible for production of off-flavour-producing aldehyde and ketone compounds**,** that limits the acceptability of soy products. In the last couple of years several research attempts have been done to check the microbial growth and remove off flavour of tofu during storage using conventional chemical control measures etc. However these methods were not found effective due to end uses in domestic products. It has been observed that higher temperature cause nutritional loss, vitamins, colors, etc. Use of chemical preservation is also hazardous to health damaging kidney and other parts of organ. Therefore it calls for investigation for development of modern method for long-term storage of tofu.

Among modern methods recently, radiation processing of food have been adopted and accepted as safe, effective and economical method to treat the food commodities (Taghinejad *et al*. 2009) [14]. In this technology, the gamma irradiation with its unique properties of high penetration power is used. Less than one kGy irradiation can be used to inhibit sprouting of potatoes, control insects in fruits and grains, and delay ripening. 1-10 kGy treatments can kill pathogenic microorganisms, whereas 30kGy to 67 kGy can be used to sterilize foods (meats, dried spices, etc.) (Bennion and Scheule, 2004 [4]; Potter and Hotchkiss, 1995 [12]). The Packaging material should be resistant to gamma radiation, i.e., the amount of migration of packaging material to food should be insignificant after gamma radiation also irradiation should not affect the organoleptic, nutritional properties & toxicological safety of the food (Asha et. al. 2011) [3].

As the information on application of low dose of gamma radiation along with the effect on chemical & nutritional composition and consumer acceptability of radiated food (tofu) are quite meager, therefore the present investigation entitled "nutritional quality of tofu (Soy paneer) as affecting by gamma irradiation during storage" has been undertaken.

Materials and methods

1. Collection of material

The Soybean (*Glycine max* L.) variety JS-9752 was collected from Department of plant breeding & Genetics, College of Agriculture, Jabalpur (M.P.). Different type of packaging materials were purchased from the Priya Darshani Cooperative Store, Adhartal, Jabalpur (M.P.). All the chemicals used were of standard analytical grades from BDH (India), E-Merck Sarabhai, M. (Guaranteed) and glassware's were of Qualigens and Borosil respectively.

2. Experimental Plan and Design

This was carried out in the Department of Food Science and Technology, College of Agriculture, JNKVV, Jabalpur (M.P.). To study the effect of gamma radiation on nutritional quality attributes during storage period of twenty days in various packaging material i.e., BOPP, LDPE and HDPE. The experimental plan was consisted of five variables doses of gamma radiation (Control, 0.25kGy, 0.50kGy, 0.75kGy, 1.0kGy and 1.25kGy), three different packaging material (BOPP, LDPE, HDPE) and storage period up to 20 days (0, 5, 10, 15 and 20 days). Storage period (days) & Radiation doses (kGy) with packaging materials are given in below table 1.

Table 1: Different storage periods & Radiation doses with packaging materials used.

Packaging material	Storage period (days)	Radiation doses (kGy)					
BOPP	0	Control	0.25	0.50	0.75	1.0	1.25
	5	Control	0.25	0.50	0.75	1.0	1.25
	10	Control	0.25	0.50	0.75	1.0	1.25
	15	Control	0.25	0.50	0.75	1.0	1.25
	20	Control	0.25	0.50	0.75	1.0	1.25
LDPE	0	Control	0.25	0.50	0.75	1.0	1.25
	5	Control	0.25	0.50	0.75	1.0	1.25
	10	Control	0.25	0.50	0.75	1.0	1.25
	15	Control	0.25	0.50	0.75	1.0	1.25
	20	Control	0.25	0.50	0.75	1.0	1.25
HDPE	0	Control	0.25	0.50	0.75	1.0	1.25
	5	Control	0.25	0.50	0.75	1.0	1.25
	10	Control	0.25	0.50	0.75	1.0	1.25
	15	Control	0.25	0.50	0.75	1.0	1.25
	20	Control	0.25	0.50	0.75	1.0	1.25

3. Evaluation of nutritional properties of *tofu*

a. Protein

The protein content in sample was determined by using conventional micro-Kjeldahl digestion and distillation procedure as given in AOAC (1984) [1]. The following formula used for calculation.

$$N\ (\%) = \frac{\text{Normality of } H_2SO_4 \text{ X Volume of 0.1N } H_2SO_4 \text{ X 14}}{\text{Weight of sample X 1000}} \text{ x 100}$$

Crude protein (%) = N % X 6.25

b. Fat

The fat content of the sample was determined by the procedure as described in AOAC (1984) [1]. The fat content was determined as below:

$$\text{Crude fat (\%)} = \frac{\text{Weight of flask (B)-Weight of flask (A)}}{\text{Weight of sample}} \text{ X 100}$$

c. Carbohydrates

Total carbohydrate in the samples was estimated by hydrolysis method as described in AOAC (1984)[1] and total carbohydrate content was calculated as under.

$$\text{Dextrose \%} = \frac{\text{Factor x 250}}{\text{Titrated value X Weight of sample}} \text{ X 100}$$

Total carbohydrates (%) = Dextrose % X 0.9

d. Estimation of total ash

The ash content in tofu was estimated according to the procedure as described in AOAC (1984) [1].

Result

In this context utilization of soya milk and soymilk products i.e tofu as an ingredient of daily diet is an area of current interest because of nutritional awareness of consumer and changing demographics. Therefore to extend nutritional value and effect of gamma radiation has been studied packed in BOPP, HDPE and LDPE.

1. Protein

The range of protein content of tofu packed in BOPP, HDPE and LDPE during storage period of 20 days varied from 13-14.37, 13.6-14.37 and 13.6-14.37 percent respectively.

In case of gamma radiated tofu packed in BOPP it was found to varied from 13.25-14.17, 13-15, 13-14.7, 13.7-14.37 and 13.7-14.37, percent at 0, 5, 10, 15 and 20 days of storage period (Table 2). The analysis of variance indicates that the F-ratio of the model was higher as compared with the table value of at 5 % level of significance. The significant difference among the different treatment combination has been observed during the storage of tofu up to 10 days however a non significant difference has been seen at 15 and 20 days of storage.

The protein content of gamma radiated tofu packed in LDPE varied from 13.6-14.3 and 13.17-14.37 for 0 and 5 days while 13.7-14.37 percent were observed at 10, 15 and 20 days of storage period (Table 2). During the storage period the protein content varied from 13.6-14.37. The F-ratio indicates no significant variation among the treatment combination for protein content of at 0 to 20 days of storage period.

The results of protein content of gamma radiated tofu packed in HDPE. The protein content varied from 13.6-14.3, 13.57-14.7, 13.32-14.7, 13.57-14 and 13.24-14.37 percent at 0, 5, 10, 15 and 20 days of storage period. The significant difference among the treatment combination has been observed in protein content at 5 and 10 days of storage however it was no significant in case of 0, 15 and 20 days of storage period.

2. Fat

The fat content of tofu packed in BOPP, HDPE and LDPE during storage period of 20 day varied from 2.19-3.7, 3.17-3.7 and 3.17-3.5 percent respectively.

The fat content of tofu packed in BOPP after treating with gamma radiation varied from 2.19-3.23, 2.65-5.17, 2.65-5.17 and 2.57-3.7 percent at 0, 5, 10 while same range was also seen at 15 and 20 days of storage period (Table 3). The analysis of variance shows that treatment combinations have got significant effect on fat content of tofu up to 20 days.

The fat content of tofu packed in LDPE varied from 3.17-3.3, 2.57-5.30, 2.57-3.7, 2.65-3.7 and 2.26-3.7 percent at 0, 5, 10, 15 and 20 days of storage period (Table 3) respectively. During the storage period the fat content varied from 2.5-3.7. The analysis of variance table indicates that the F-ratio of the model was significant which results significant difference among the different treatment combination on fat content of tofu packed in LDPE for 0, 5, 10 and 15 days however a non significant difference has been seen at 0 day of storage.

The findings presented in Table 3 indicates that fat content of tofu packed in HDPE and treated with gamma radiation varied from 3.17-3.3, 2.7-5.25, 2.7-3.57, 2.65-3.7 and 2.33-3.5 percent at 0, 5, 10, 15 and 20 days of storage period. In general during the storage period fat content varied from 2.33-5.25. The ANOVA table indicates that the F-ratio was significant for 5 and 15 days of storage however it was no significant in case of 0, 10 and 20 days of storage period.

3. Carbohydrate

The minimum and maximum carbohydrate content was found to be 4.63-5.25, 2.19-3.5 and 2.19-2.83 percent in tofu packed in BOPP, LDPE and HDPE respectively. Specifically during 0, 5, 10, 15 and 20 days of storage period in BOPP, it varied from 4.63-5.25, 1.59-5.23, 1.69-3.5, 2.29-5.1 and 2.29-5.1 percent respectively. The significant difference among the all treatment combination has been observed during the storage of tofu up to 20 days however except at zero days.

In case of product packed in LDPE the carbohydrate content of tofu varied from 2.19-3.23, 2.39-5.1, 2.29-5.1, 1.59-3.5 and 2.2-4.86 percent at 0,5,10,15 and 20 days of storage period (Table 4.) respectively. The analysis of variance table indicates that the F-ratio of the model was significant which results significant difference among the all treatment combination.

A cursory view of Table number 4 indicates that carbohydrate content of tofu packed in HDPE varied from 2.19-3.23, 2.39-4.19, 2.39-3.43, 1.59-3.5 and 2.1-2.83 percent at 0, 5, 10, 15 and 20 days of storage period respectively. The ANOVA table indicates that the F-ratio was significant for 0, 5, 10 and 15 days of storage however it was no significant in case of 20 days of storage period.

4. Ash

It is evident from the data presented in Table 5 that during the storage period the overall ash content varied from 4.03-7.25 percent. The tofu packed in BOPP after treating with different doses of gamma radiation exhibits the range of ash content from 4.63-5.25, 4.2-7.25, 4.4-5.7, 4.03-5.2 and 4.03-5.2 percent at 0, 5, 10, 15 and 20 days of storage period respectively. The F-ratio was significant that shows significant treatment effect during 5, 10, 15 and 20 days of storage of tofu however it was also seen no significant in case of 0 day of storage period.

Tofu packed in LDPE exhibits the data of ash content to be 4.63-5.25, 4.65-6.43, 4.03-5.2, 4.2-5.56 and 4.75-5.2 percent at 0,5,10,15 and 20 days of storage period (Table 5) respectively. The analysis of variance table indicates that the F-ratio of the model was higher as compared with the table value of at 5 % level of significance. The ANOVA table indicates that the F-ratio was significant for 5, 10, 15 and 20 days of storage however it was no significant in case of 0 day.

The ash content of tofu packed in HDPE shows the range from 4.63-5.25, 4.03-6.8, 4.03-5.45, 4.03-5.65 and 4.03-5.2 percent at 0,5,10,15 and 20 days of storage period (Table 5) respectively. During the storage period the overall ash content varied from 4.03-6.8. The analysis of variance table indicates that the F-ratio of the model was significant which gives significant difference result among all treatment combination on ash content.

Table 2: Protein content (%) in gamma radiated tofu packed in BOPP, LDPE and HDPE at varying storage period.

Gamma radiation doses	BOPP					LDPE					HDPE				
	Storage period					Storage period					Storage period				
	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days
Control	13.3	14.5	14.5	14	14	14.3	13.9	14	14	14	14.3	14.7	14.5	13.9	13.84
0.25 kGy	14.17	13	13	13.8	13.8	13.6	13.8	13.8	13.8	13.8	13.6	13.6	13.8	13.8	13.8
0.5 kGy	13.25	14.57	14.57	14.37	14.37	14.17	14.37	14.37	14.37	14.37	14.17	13.77	13.57	13.57	14.37
0.75 kGy	13.3	15	14.7	13.7	13.7	14.3	13.7	13.7	13.7	13.7	14.3	14.5	14.7	13.8	13.7
1.00 kGy	14.17	13.2	13.2	14	14	13.6	14	14	14	14	13.6	13.8	13.2	14	13.96
1.25 kGy	13.25	14.37	14.37	14.37	14.37	14.17	13.17	14.37	14.37	14.37	14.17	13.57	14.37	13.9	13.24
CD at 5%	0.65	0.49	0.55	NS	NS	NS	NS	NS	NS	NS	NS	0.56	0.62	NS	NS
SEm±	0.14	0.078	0.12	0.13	0.1	0.11	0.15	0.14	0.08	0.11	0.09	0.1	0.12	0.08	0.09

Table 3: Fat content (%) in gamma radiated tofu packed in BOPP, LDPE and HDPE at varying storage period.

Gamma radiation Doses	BOPP					LDPE					HDPE				
	Storage period					Storage period					Storage period				
	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days
Control	2.19	3.7	3.4	3.5	3.5	3.3	3.5	3.5	3.5	3.5	3.3	2.9	3	3.5	3.5
0.25 kGy	3.1	5.17	5.17	2.57	2.57	3.17	2.57	2.57	3.37	2.26	3.17	3.37	3.37	3.37	2.57
0.5 kGy	3.23	2.85	2.85	3.65	3.45	3.25	3.65	3.65	2.65	3.65	3.25	3.45	3.45	2.65	3.21
0.75 kGy	2.19	3.5	3.5	3.7	3.7	3.3	5.3	3.7	3.7	3.7	3.3	2.7	2.7	3.7	2.33
1.00 kGy	3.1	3.37	3.17	2.77	2.77	3.17	2.77	2.77	2.77	2.77	3.17	3.57	3.57	2.77	2.77
1.25 kGy	3.23	2.65	2.65	3.45	3.45	3.25	3.45	3.45	3.45	3.45	3.25	5.25	3.45	3.5	2.84
CD at 5%	0.65	0.5	0.59	0.62	0.56	NS	0.7	0.64	0.52	0.56	NS	0.56	NS	0.48	NS
SEm±	0.14	0.079	0.11	0.12	0.1	0.12	0.16	0.13	0.08	0.11	0.1	0.1	0.13	0.07	0.79

Table 4: Carbohydrate content (%) in gamma radiated tofu packed in BOPP, LDPE and HDPE at varying storage period.

Gamma radiation Doses	BOPP					LDPE					HDPE				
	Storage period					Storage period					Storage period				
	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days
Control	5.25	1.79	1.79	2.29	2.29	2.19	2.59	2.29	1.89	2.29	2.19	2.39	2.39	1.89	2.29
0.25 kGy	4.8	3.3	3.3	5.1	5.1	3.1	5.1	5.1	3.3	3.27	3.1	2.5	2.5	3.3	2.1
0.5 kGy	4.63	3.43	2.63	2.83	2.83	3.23	2.83	2.83	3.43	4.86	3.23	3.63	2.65	3.43	2.83
0.75 kGy	5.25	1.59	1.69	2.39	2.39	2.19	2.39	2.39	1.59	2.39	2.19	4.19	2.59	1.59	2.39
1.00 kGy	4.8	3.5	3.5	3.1	2.3	3.1	3.3	3.1	3.5	2.2	3.1	2.7	2.7	3.5	2.1
1.25 kGy	4.63	5.23	3.43	2.63	2.63	3.23	2.63	2.63	3.43	2.63	3.23	3.43	3.43	1.89	2.31
CD at 5%	NS	0.4	0.59	0.63	0.56	0.6	0.53	0.65	0.52	0.56	0.54	0.55	0.62	0.47	NS
SEm±	0.13	0.7	0.11	0.13	0.1	0.11	0.09	0.13	0.08	0.1	0.09	0.1	0.12	0.072	0.09

Table 5: Ash content (%) in gamma radiated tofu packed in BOPP, LDPE and HDPE at varying storage period.

Gamma radiation Doses	BOPP					LDPE					HDPE				
	Storage period					Storage period					Storage period				
	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days	0 day	5 days	10 days	15 days	20 days
Control	5.25	5.45	5.65	4.85	4.85	5.25	4.85	4.85	5.45	4.85	5.25	5.65	5.35	5.45	4.85
0.25 kGy	4.8	4.2	4.8	5	5	4.8	5	5	4.2	5	4.8	6.8	5.08	5	5
0.5 kGy	4.63	5.03	5.03	4.03	4.03	4.63	4.83	4.03	5.03	5.09	4.63	4.23	4.23	4.03	4.03
0.75 kGy	5.25	7.25	5.75	4.75	4.75	5.25	4.65	4.75	5.65	4.75	5.25	5.45	5.45	5.65	4.75
1.00 kGy	4.8	4.4	4.4	5.2	5.2	4.8	5.2	5.2	4.4	5.2	4.8	5	4.8	4.4	5.2
1.25 kGy	4.63	4.83	4.73	4.83	4.83	4.63	6.43	4.83	4.83	4.83	4.63	4.03	4.03	5.45	4.83
CD at 5%	NS	0.53	0.59	0.519	0.55	NS	0.54	0.64	0.52	0.56	0.49	0.56	0.63	0.47	0.56
SEm±	0.14	0.09	0.12	0.08	0.1	0.12	0.1	0.13	0.09	0.11	0.07	0.11	0.13	0.072	0.1

Discussion

LDPE in the application of packaging are heat-resistant and retains flexibility over a wide range of temperature, it is chemically inert and has good resistance to acids and alkalis (Asha et. al., 2011) [3]. And she also resulted that HDPE in the application of packaging are higher chemical resistance, can withstand rather higher temperatures. We find better result with LDPE for nutritional content of tofu using gamma radiation.

The findings give critical direction that biochemical constituents of tofu has significant difference due to radiation treatment. The effect of radiation may be due to removal of water. The protein, carbohydrate, and fat biomolecules may also undergo for conformational changes due to radiation which may cause the variation in the concentration during storage. The present findings can be supported with the reported results of Pablo *et al.* (1971) [11], Ahmad *et al.*, (1972) [2], Cuevas-Ruiz *et al.*, (1972) [5], Nagvi and Moy (1985) [9], Thomas and Janave (1975) [15], Durbey *et al.*, (1984) [7] and Olsan *et al.*, (1989) [10].

Whereas, lower doses upto 10KGy did not produce any statistically significant changes in overall migration values of biochemicals (IAEA, 2005) [8]. It is deduced from the findings of this investigation that 1.25 kGy gamma radiation treatments in combination with LDPE can be successfully utilized for extension of shelf life up to 15 days (Figure.1) without sacrificing the nutritional quality of product which is genuinely supported by IAEA, 2005 [8].

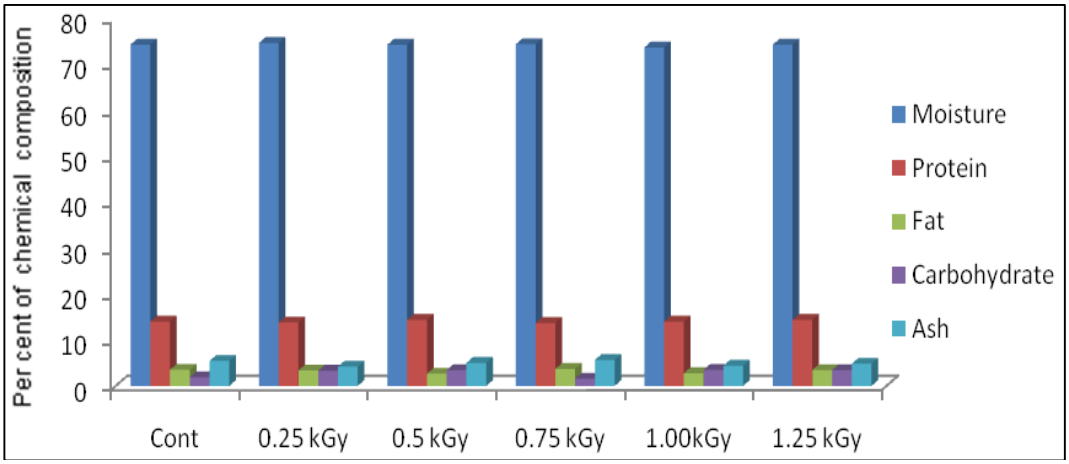

Fig 1: Effect of different dose of gamma radiation on proximate composition of tofu packed in LDPE during storage (15 days)

Conclusion

Intensified health problems of the society resulted in a change of human attitude to the quality of consumed products. Within the last few years the interest in "safe food" has increased significantly. The effect of different doses of gamma radiation on weight of tofu packed in various packaging materials and stored for varying storage period shows no significant difference among the different treatment. This effect is may be due to the fact that radiation doses do not add or withdraw any constituent to the product.

In a nutshell it is deduced from the findings of present investigation and their justification that 1.25 kGy Gamma radiation treatments in combination with LDPE can be successfully utilized for extension of shelf life up to 15 days (Figure.1) without sacrificing the nutritional quality of product. The gamma radiation treatment and effective packaging system has great potential for value addition in soymilk product industry for production of tofu (soy paneer). The standardized value of gamma radiation treatment and packaging can be successfully translated at commercial scale for domestic and commercial application.

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