QUALITY EVALUATION OF GAMMA-IRRADIATED FOOD LEGUMES

GAMMA-IŞINLAMA UYGULANMIŞ YEMEKLİK BAKLAGİLLERDE KALİTE DEĞERLENDİRMESİ

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ABSTRACT: Effects of gamma irradiation on the quality of food legumes was investigated. Two lentil, one kabuli chickpea and one bean sample were irradiated at the doses of 1.0, 2.5, 5.0, 10.0, 20.0 kGy using the ^{60}Co source. The samples were analyzed for hydration capacity and hydration index, swelling capacity and swelling index, dry and wet cooking times. Generally, at lower doses (1.0-2.5 kGy), irradiation treatment did not significantly affect the water absorption properties of the food legumes. Irradiation reduced both dry and wet cooking times significantly. At higher doses (10.0-20.0 kGy) irradiation treatment significantly affected the water absorption properties and cooking times of all food legumes. But, distinct off-flavor and odor were observed at these higher doses.

ÖZET: Gamma ışınlamanın yemeklik tane baklagillerin kalitesi üzerine etkileri araştırılmıştır. İki mercimek, bir kabuli tip nohut ve bir kuru fasulye örneği ^{60}Co kaynağı kullanılarak 1.0, 2.5, 5.0, 10.0, 20.0 kGy dozlarda ışınlanmıştır. Örneklerde su alma kapasitesi ve su alma indeksi, şişme kapasitesi ve şişme indeksi, yaş ve kuru pişme süreleri belirlenmiştir. Genellikle düşük dozlarda (1.0-2.5 kGy) ışınlama işlemi baklagil örneklerinin su alma özelliklerini önemli ölçüde etkilememiştir. Işınlama kuru ve yaş pişme süresini önemli düzeyde azaltmıştır. Yüksek dozlarda (10.0-20.0 kGy) ışınlama işlemi tüm baklagil örneklerinde su alma özelliklerini ve pişme süresini önemli ölçüde etkilemiştir. Fakat, yüksek dozlarda, istenmeyen koku saptanmıştır.

INTRODUCTION

Cereals and food legumes are important dietary components and stored as dry seeds. However, a great amount of cereal grains and food legumes are lost annually during storage. Gamma irradiation is a food preservation technique that offers potential to protect cereal grains and legumes from insect infestation and microbial contamination during storage. It has been reported that gamma irradiation in the range of 0.2-1.0 kGy doses is effective in controlling insect infestation in cereals (ANONYMOUS, 1991). Increasing the irradiation dose to 5 kGy totally kills the spores of many fungi and bacteria (MURRAY, 1990). A Joint Expert Committee convened by FAO, IAEA and WHO stated that irradiation of any food commodity up to 10 kGy presents no toxicological hazard (ANONYMOUS, 1981). Therefore, the effect of ionizing radiation upto this recommended dose level (and above) on the quality of food legumes needs to be investigated.

Besides its protective role against insects, gamma irradiation may also have important effects on the functionality and various quality criteria of cereal grains and food legumes (FIFIELD et al., 1967 MacARTHUR and D'APPOLONIA, 1983, RAO and VAKIL, 1985, SABULARSE et al., 1991, KÖKSEL et al., 1996, KÖKSEL et al., 1998-a, RAO et al. 2000). It is also known that gamma irradiation alters the physicochemical properties of macromolecules in cereals (KÖKSEL et al., 1998-b). REDDY et al. (1979) reported that nutritive value of beans was significantly improved by gamma-irradiation due to inactivation of anti-nutritional factors. The rates of digestibility of proteins and α-amylolysis of starch were shown to increase by gamma-irradiation in red gram samples (NENE et al. 1975a, b). The irradiation treatment is also shown to be effective for reduction of flatulence causing oligosaccharides in green gram samples (RAO and VAKIL 1983).

The main objective of this study was to examine the effects of gamma irradiation at different levels (upto 20 kGy) on water absorption properties and cooking quality of food legumes.

MATERIALS AND METHODS

Material

Two lentil samples (Lens esculenta), one kabuli chickpea sample *(Cicer arietinum)*, and one bean *(Phaseolus vulgaris)* sample were used in this study. The chickpea (cv. Canıtez) and lentil (cv. Erzurum: green-colored and Malazgirt:red-colored) samples were grown at Experimental Research Farm of Field Crops Improvement Center (Ankara, Turkey). The bean sample was purchased from a local market. The samples were cleaned, placed in polyethylene bags and irradiated with the doses of 1.0, 2.5, 5.0, 10.0, 20.0 kGy from the ^{60}Co source at Sarayköy Nuclear Research Institute. The dose rate was 6.0 kGy/h. The absorbed dose was checked by Fricke's dosimetry (CHADWICK et al. 1977). All food legume samples were stored in a refrigerator before laboratory analyses.

Methods

The quality criteria, dry and wet seed weights, dry and wet seed volumes, hydration capacity, hydration index, swelling capacity and swelling index, and the dry and wet cooking times were determined according to the methods of WILLIAMS et al. (1986). The seed weights and seed volumes were determined in mg and µl, respectively. Labconco crude fiber testing equipment was used for the determination of the cooking times. 600 ml Berzelius beakers were used for boiling the samples under continuous reflux.

Data related to hydration capacity, hydration index, swelling capacity, swelling index, dry and wet cooking time values were analyzed for variance using the MSTAT statistical package (ANONYMOUS 1988). When significant differences were found, the Least Significant Difference (LSD) test was used to determine the differences among means.

RESULTS AND DISCUSSION

Hydration capacity and hydration index, swelling capacity and swelling index values of the chickpea, lentil and bean samples irradiated at 1.0, 2.5, 5.0, 10.0, 20.0 kGy levels were determined and the results are presented in Tables 1, 2, 3. Dry and wet seed weights, dry and wet seed volumes were determined and used in the calculation of water absorption parameters, but they are not presented in the tables.

Average dry seed weights of lentil cultivars Erzurum and Malazgirt were 53.7 and 34.4 mg, respectively. Irradiation at the higher levels caused significant increases on the hydration capacity and hydration index values ($p<0.05$) of both lentil cultivars. Irradiation treatment significantly affected hydration capacity at 2.5 kGy and 5.0 kGy doses for Erzurum and Malazgirt cultivars respectively (Table 1). Hydration index of both cultivars was significantly affected at 5.0 kGy and higher irradiation levels. Similar increases were also observed in swelling capacity and swelling index values. However, the significant increases were observed at 2.5 kGy and 5.0 kGy doses for Malazgirt and Erzurum cultivars, respectively.

Average dry seed weight of chickpea cultivar, Canıtez was 50.9 mg. As shown in Table 2, hydration capacity and hydration index values of Canıtez sample irradiated at 10-20 kGy were significantly greater than those of the unirradiated control. No apparent changes were observed in the swelling capacity and swelling index values of Canıtez cultivar at 1 kGy level, but steady and significant ($p<0.05$) increases were observed above this level (Table 2).

Average dry seed weight of bean sample was 310 mg. Table 3 shows the effects of gamma irradiation on hydration capacity and hydration index, swelling capacity and swelling index values of the bean sample. Hydration capacity of bean sample was significantly affected ($p< 0.05$), above 2.5 kGy level. On the other hand, a significant increase in the hydration index value of the bean sample was observed at a lower irradiation dose (above 1 kGy) and a steady and significant increase was apparent above this level. Although swelling capacity and swelling index values of the bean sample have also increased with increasing irradiation doses, this was not statistically significant (Table 3). Generally, the water absorption properties of food legumes irradiated at 1.0-2.5 kGy showed no significant difference from the unirradiated control. Similar results were also reported by RAO and VAKIL (1985).

Table 1. Effects of Gamma- Irradiation on Water Absorption Properties and Cooking Times of Lentils[1,2]

Variety	Radiation Level (kGy)	Hydration Capacity	Hydration Index	Swelling Capacity	Swelling Index	Cooking Time Dry	Cooking Time Wet
	Control	50 a	0.943 a	49 a	1.116 a	53 a	23 a
	1.0	51 a	0.938 a	50 ab	1.123 a	49 ab	20 ab
ERZURUM	2.5	53 b	0.956 b	50 ab	1.111 a	45 bc	22 a
	5.0	53 b	0.992 bc	52 bc	1.223 b	41 c	18 bc
	10.0	54 b	1.012 c	53 c	1.233 b	35 d	16 c
	20.0	58 c	1.066 d	58 d	1.303 b	35 d	16 c
LSD	(p < 0.05)	1.3	0.0492	2.9	0.0984	4.1	3.2
	Control	33 a	0.945 a	35 a	1.302 a	40 a	12 a
	1.0	33 a	0.945 a	35 a	1.289 a	39 a	7 b
MALAZGİRT	2.5	34 a	0.988 a	37 b	1.410 b	37 ab	7 b
	5.0	37 b	1.050 b	41 c	1.533 c	34 bc	8 b
	10.0	37 b	1.076 b	41 c	1.577 cd	31 c	6 bc
	20.0	38 b	1.091 b	42 d	1.596 d	27 d	4 c
LSD	(p < 0.05)	1.9	0.0696	0.9	0.0492	3.1	2.3

1 Mean of duplicate determinations.
2 Means with the same letter within a column are not significantly different ($p < 0.05$) by LSD analysis.

Table 2. Effects of Gamma-Irradiation on Water Absorption Properties and Cooking Times of Chickpea[1,2]

Variety	Radiation Level (kGy)	Hydration Capacity	Hydration Index	Swelling Capacity	Swelling Index	Cooking Time Dry	Cooking Time Wet
	Control	500 a	0.985 a	490 a	1.289 a	178 a	42 a
	1.0	506 a	0.996 a	495 ab	1.296 ab	159 b	39 a
CANITEZ	2.5	509 a	0.999 a	505 c	1.329 c	149 c	33 b
	5.0	509 a	0.999 a	500 bc	1.316 bc	147 cd	20 c
	10.0	520 b	1.023 b	515 d	1.355 d	144 de	15 d
	20.0	525 b	1.030 b	520 d	1.368 d	142 e	15 d
LSD	(p < 0.05)	9.1	0.0221	7.2	0.0220	3.8	3.1

1 Mean of duplicate determinations.
2 Means with the same letter within a column are not significantly different ($p < 0.05$) by LSD analysis.

Table 3. Effects of Gamma-Irradiation On Water Absorption Properties And Cooking Times of Dry Bean[1, 2]

Variety	Radiation Level (kGy)	Hydration Capacity	Hydration Index	Swelling Capacity	Swelling Index	Cooking Time Dry	Cooking Time Wet
	Control	330 a	1.068 a	341	1.423	112 a	40 a
	1.0	333 a	1.092 ab	341	1.423	108 ab	28 b
BEAN	2.5	346 a	1.136 bc	348	1.451	107 b	24 b
	5.0	380 b	1.183 cd	344	1.378	107 b	15 c
	10.0	377 b	1.212 d	362	1.477	100 c	10 c
	20.0	395 b	1.285 e	368	1.532	86 d	10 c
LSD	(p < 0.05)	22.5	0.0696			4.8	6.5

1 Mean of duplicate determinations.
2 Means with the same letter within a column are not significantly different ($p < 0.05$) by LSD analysis.

Correlations of water absorption properties of lentil, chickpea and been samples with gamma-irradiation levels are listed in Table 4. The correlations cover a range of food legume samples. From the table it can be seen that the correlation coefficients calculated between water absorption properties and irradiation levels are significant at least at $p<0.05$ level.

Degradation of wheat starch structure with irradiation and its increasing effect on water absorption properties of wheat flour dough were reported by various investigators (LAI et al., 1959 ; LEE 1959 ; MacARTHUR and D'APPOLONIA 1983, 1984). In gamma-irradiated red gram, the rates of α-amylosis of starch was shown to increase significantly, indicating degradation of starch with irradiation (NENE et al. 1975b). In this study, the water absorption properties of the food legumes as measured both gravimetrically (hydration capacity and index) and volumetrically (swelling capacity and index) might also be related to the degradation of starch.

Dry and wet cooking times of the chickpea, lentil and bean samples irradiated at 1.0, 2.5, 5.0, 10.0, 20.0 kGy levels were determined and the results are presented in Tables 1-3. The dry cooking time for the irradiated samples was found to be reduced in all legume samples, when compared with their respective control. The reduction in the dry cooking time was significant ($p<0.05$) at 5 kGy level for Malazgirt sample. However, the significant reduction in dry cooking time was observed at lower irradiation levels for the other legume samples (e.g. 1 kGy level of Canıtez and 2.5 kGy level of Erzurum and the bean sample). The soaking process reduced the cooking time of the samples as expected. The studies by WILLIAMS et al (1986) have shown that soaking of food legumes before cooking, which is a very common practice, reduces cooking time significantly. The wet cooking time for the irradiated samples was found to be reduced in all legume samples, when compared with their respective control. The reduction in the wet cooking time was significant ($p<0.05$) starting from 1.0 kGy level for red lentil (cv. Malazgirt) and bean samples. The significant reduction in wet cooking time was first observed at 2.5 kGy level in Canıtez cultivar. RAO and VAKIL (1985) have also observed appreciable reduction in cooking time of the irradiated legumes. The correlations of dry and wet cooking times with gamma-irradiation levels were also high and generally significant ($p<0.05$) except the ones calculated for dry cooking time of Canıtez sample and wet cooking time of Malazgirt sample (Table 4).

Distinct off-flavor and odor were observed during dry and wet cooking of all legume samples irradiated at 10 and 20 kGy levels. This might be probably due to the degradation of protein molecules during irradiation. The formation of off-flavor and odor was also noted in doughs, breads and food legumes especially at high irradiation doses (LAI et al. 1959, MILLER et al 1965, FIFIELD et al. 1967, NENE et al. 1975-b).

Table 4. Correlations Of Water Absorption Properties and Cooking Times Of Food Legumes With Gamma-Irraditation Levels

Variety	Hydration		Swelling		Cooking Time	
	Capacity	Index	Capacity	Index	Dry	Wet
Erzurum	0.965**	0.980**	0.991**	0.927**	-0.858*	-0.822*
Malazgirt	0.855*	0.867*	0.827*	0.831*	-0.969**	-0.775
Canıtez	0.945**	0.937**	0.908**	0.903**	-0.686	-0.828*
Bean	0.873*	0.954**	0.941**	0.813*	-0.987**	-0.789*

* $p<0.05$
** $p<0.01$

Cooking time is considered to be a function of permeability of seed coat, followed by the rate at which the hot water causes the gelatinization of starch (WILLIAMS and NAKKOUL 1985). RAO and VAKIL (1985) reported that the hydration rate of irradiated food legumes was increased. Furthermore, in our recent study the loss of the external membrane integrity due to irradiation was reported (DADAYLI et al. 1997, SÜNNETÇİOĞLU et al. 1998). Therefore, the loss of membrane integrity due to irradiation might have caused water to enter through the cell walls of cotyledons easily, resulting in substantial increases in gelatinization, hence significant decreases in the cooking times.

Research on the changes in food legumes due to gamma-irradiation as related to the cooking quality must be well documented before the irradiation technique can be recommended for industrial applications and as a means of disinfestation of the legumes for storage.

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