NOTE

Effects of Gamma Irradiation on Durum Wheats and Spaghetti Quality

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The efficient control of insects in cereal grains has long been the main objective of processors who are always looking for safer and more economical methods. Gamma irradiation is a physical technique of food preservation that seems to have a potential to protect grains from insect infestation and microbial contamination during storage. It has been reported that gamma irradiation doses in the range of 0.2–1.0 kGy are effective in controlling insect infestation in cereals (IAEA 1991). Increasing the dose to 5 kGy totally kills the spores of many fungi surviving the lower doses (Murray 1990).

Besides its protective role from insects and microorganisms, gamma irradiation also has important effects on various quality criteria of cereal grains. Experiments have been performed to study the effects of gamma irradiation on various aspects of wheat quality such as milling characteristics, dough properties, and baking quality (Lai et al 1959, Lee 1959, Fifield et al 1967, Rao et al 1975, Paredes-Lopez and Covarrubias-Alvarez 1984, MacArthur and D'Appolonia 1983, Ng et al 1989). It was reported that amylograph peak viscosity and falling number values of the flour decreased significantly as radiation levels increased (MacArthur and D'Appolonia 1983, Ng et al 1989). Rao et al (1975) showed that as radiation dose increased, amylograph peak height and dough stability decreased. At 10 kGy, loaf volume and crumb grain were impaired. Paredes-Lopez and Covarrubias-Alvarez (1984) found that the overall bread quality of wheat was greatly reduced at medium doses of radiation (1–10 kGy). At doses >5 kGy, irrespective of the baking formula used, loaf volume and baking quality deteriorated (Lai et al 1959). Irradiation of grain has also caused problems in noodle quality. Japanese noodles (*udon*) show increased cooking losses and inferior scores in sensory analysis when the bread wheats have been irradiated in the range of 0.2–1.0 kGy (Shibata et al 1974, Urbain 1986). However, no detailed study on the effects of gamma irradiation on the properties of durum wheat, semolina, and the spaghetti cooking quality has been found.

A Joint Expert Committee on the Wholesomeness of Irradiated Food 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 on the quality of cereal grains needs to be investigated within this recommended dose level but below the tolerance of the final product.

The objective of this study was to examine the effects of gamma irradiation on various wheat and semolina properties and the spaghetti cooking quality of two durum wheat cultivars.

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MATERIALS AND METHODS

Material

The two durum wheat samples (cv. Kunduru and Çakmak) used in this study were from the Experimental Research Farm of Field Crops Improvement Center, Ankara, Turkey, harvested in 1992. They are the predominant durum wheat cultivars grown in Turkey. Kunduru has strong gluten characteristics while Çakmak is a medium quality durum wheat with weaker gluten properties. The wheat samples were cleaned on a Carter Dockage Tester, placed in polyethylene bags (2 × 1,500 g) and irradiated with the doses of 1.0, 2.5, and 5.0 kGy using the ^{60}Co source at Hacettepe University, Department of Chemistry. The dose rate was 0.03 kGy/min.

Tests on Grain Samples

All of the tests on the grain samples were performed in triplicate and the average values reported. The hectoliter weight was determined using an Ohaus test weight apparatus and reported on an as is moisture basis. The 1,000 kernel weight was determined by counting the number of seeds in 20 g of grain and reported on a dry basis. Moisture, protein (N × 5.7), ash content, and falling number values were determined according to standard methods (AACC 1995). Sodium dodecyl sulfate (SDS) sedimentation tests were performed on a 3.0-g sample (ground using a Udy cyclone mill and sifted through a 100-mesh sieve) as described by Williams et al (1986).

Milling

The durum wheat samples were tempered at two stages, initially to a water content of 14.5%, left overnight, and then the moisture content increased to 16.5% and left standing for 90 min. The samples were milled into semolina on a Bühler pneumatic laboratory mill (model MLU 202) with three break and three sizing passages. The semolina was purified using a Namad laboratory purifier. The mill environment was controlled at 20°C and 65% rh. Milling was performed in duplicate.

Tests on Semolina Samples

A portion of each semolina sample obtained from duplicate millings was combined to obtain a composite semolina sample to use in rheological and other semolina tests. Moisture and ash contents of semolina samples were determined in triplicate according to standard methods (AACC 1995). Mixograms were obtained according to standard methods (AACC 1995) on a 35-g mixograph (National Manufacturing Co., Lincoln, NE) using 35 g of semolina, 20 ml of distilled water, and a spring setting of 8. Mixing tolerance index is defined as the difference between the center of the graph at peak and the center of graph 3 min after peak. Band width was measured 3 min after the peak.

Pasta Processing and Drying

The semolina samples obtained from each duplicate milling were processed into spaghetti separately using the micro-method of D'Egidio et al (1982). The semolina samples were mixed in a premixer (Namad, Italy), water was added to obtain a total water content of 30–32%, and the dough was extruded in an extruder (Namad, Italy) under vacuum at a pressure of ≈500 mm Hg. Spaghetti (1.7 mm thick) was dried at 40°C in a ventilated static system decreasing gradually from 90% rh to 60% rh over 20 hr. The final dried spaghetti contained a maximum of 12% moisture.

Cooked Spaghetti Analysis

Total organic matter (TOM) in the washing water of spaghetti after cooking was determined according to the method of D'Egidio et al (1982, 1993). The cooking test was performed twice on each duplicate spaghetti sample.

The sensory characteristics of the cooked spaghetti samples were evaluated by a panel of three experts according to the methods of D'Egidio et al (1982, 1993) under test conditions of the International Standard 7304 (ISO 1985). Final judgment was obtained by averaging the values of all the experts. The textural properties evaluated were: stickiness (material adhering to surface of cooked pasta), bulkiness (degree to which the cooked spaghetti strands adhere to each other), and firmness (resistance to bite through the cooked spaghetti strand with the incisors). The first two attributes are assessed visually and manually. All of these parameters were evaluated by a score of 10–100 (D'Egidio et al 1993). Judgment scores for bulkiness and stickiness were assigned as: <20 = very high, 40 = high, 60 = average, 80 = almost absent, 100 = absent. Judgment scores for firmness were : <20 = very low, 40 = low, 60 = sufficient, 80 = good, 100 = very good.

To determine the amount of solid substance lost (SL) to cooking water, the cooking water was collected in a tarred beaker, placed into an air oven at 110°C and evaporated to dryness. The residue was weighed and reported as percentage of the starting material.

Statistical Analysis

The data were statistically evaluated by the one-way analysis of variance procedure (factor: irradiation level) using the MSTAT-C statistical analysis program (MSTAT 1988). The least significant difference test was applied to compare mean values.

RESULTS AND DISCUSSION

The effects of various dosages of gamma irradiation on the composition and the milling properties of the two durum wheat samples are presented in Table I. No apparent changes were observed in ash and protein contents of the wheat samples irradiated at various levels. The 1,000 kernel weight, test weight, and semolina yield (Table I) were not affected by the irradiation in the range of treatments examined. Also, semolina ash and protein contents were not affected by the irradiation (results not presented).

Falling number (FN) values of the meal samples obtained from irradiated wheat samples (Table I) showed a steady and significant ($P < 0.05$) decrease in both cultivars as the radiation level was increased. The high FN values of the control samples indicated that the two durum wheat samples were sound. Previous studies indicated that α-amylase activity was not affected by irradiation (MacArthur and D'Appolonia 1983, Ng et al 1989). Therefore, it can be concluded that the FN values decreased because of an alteration in the starch component. Similar results have been reported for bread wheat (Rao et al 1975). Apparently, susceptibility of starch to amylolytic activity is increased by irradiation.

SDS-sedimentation values decreased significantly ($P < 0.05$) with increasing dosages of radiation (Table I). The values of 34 and 26 ml for the control samples were reduced even by the lowest dosage of 1 kGy and fell progressively to 23 and 16 ml with 5 kGy for Kunduru and Çakmak cultivars, respectively. The observed decrease in sedimentation value with increasing radiation dosage indicates damage to gluten and is in general agreement with results for the sedimentation values reported by Fifield et al (1967) and Ng et al (1989).

Previous researchers have reported that some changes occur in the rheological properties of doughs when bread wheat or flour is irradiated (Rao et al 1975, Paredes-Lopez and Covarrubias-Alvarez 1984). In general, irradiation causes the doughs to lose strength, especially at high levels of treatment. In this study effects of irradiation on the rheological properties of the doughs obtained from the semolinas of the two durum wheat cultivars were studied using the mixograph (Table II). Peak height and the bandwidth values of both cultivars decreased slightly with increasing radiation exposure. However, mixing tolerance index increased for both cultivars investigated. No apparent change was observed in mixing time of the various irradiated samples of the two cultivars.

Relatively little information is available on the cooking quality and sensory properties of noodles produced from irradiated wheats. Irradiation of bread wheats in the range of 0.2–1.0 kGy resulted in increased cooking losses and inferior sensory scores of Japanese noodles (*udon*), which are consumed fresh (Shibata et al 1974). The authors are not aware of any detailed study on the effects of gamma irradiation on spaghetti cooking quality. In the present study, the irradiation treatments produced important changes in the spaghetti cooking properties of both cultivars. TOM and SL values increased progressively and significantly ($P < 0.05$) with increasing irradiation levels (Table III). D'Egidio et al (1982) has suggested that the TOM values can be used for the classification of spaghetti products: TOM values <1.4 indicate very good quality spaghetti; TOM values between 1.4 and 2.1 indicate good quality spaghetti; TOM values >2.1 indicate poor quality spaghetti. The control sample of the stronger cultivar, Kunduru, had a TOM value of 1.34, indicating a very good quality

TABLE I
Various Properties of Durum Wheats Irradiated at Various Levels[a,b]

Sample	Radiation Level (kGy)	Ash (%)	Protein (%)	1,000-Kernel Weight (g)	Test Weight (g)	Semolina Yield (%)	Falling Number (sec)	SDSS (ml)[c]
Kunduru								
Control	0	1.63a	12.1a	45.1a	79.8a	66.1a	427a	34a
	1.0	1.64a	12.0a	45.3a	79.7a	66.6a	395b	30b
	2.5	1.63a	12.0a	45.0a	79.9a	66.7a	332c	26c
	5.0	1.62a	12.1a	45.2a	79.8a	65.7a	285d	23c
Çakmak								
Control	0	1.59a	11.0a	31.5a	77.2a	65.0a	408a	26a
	1.0	1.61a	10.9a	31.5a	77.3a	65.2a	389b	23a
	2.5	1.59a	11.0a	31.6a	77.0a	65.1a	323c	19b
	5.0	1.60a	10.9a	31.4a	77.2a	64.8a	278d	16b

[a] Values are the averages of triplicate determinations except semolina yield, which is the average of duplicate determinations.
[b] For each cultivar, means with the same letter within a column are not significantly different ($P < 0.05$) by least significant difference analysis.
[c] Sodium dodecyl sulfate (SDS) sedimentation.

spaghetti, and all of its irradiated samples had TOM values between 1.4 and 2.1, indicating good quality. The control sample of the weaker cultivar, Çakmak had a TOM value of 1.69, indicating good quality; however, irradiation resulted in a lower quality spaghetti in Çakmak starting from the 2.5 kGy level. The structure of spaghetti can be envisaged as starch and minor constituents enveloped by a three dimensional network of gluten. It is difficult to entrap starch in gluten network when starch has disintegrated. MacArthur and D'Appolonia (1983) reported that irradiated flour samples showed a decrease in amylograph peak height, whereas solubility and damaged starch values increased. Therefore, significant increase in TOM and SL values can be attributed to starch disintegration, which is also supported by FN findings. Furthermore, decreased SDS values indicated damage to gluten. Therefore, the increase in TOM and SL values is probably due to a combination of poorer gluten network development and starch granule breakdown.

Sensory evaluation by experienced panelists showed considerable differences in stickiness, firmness, and bulkiness with increased radiation dosage (Table III). The deterioration in sensory properties was not significant at 1 kGy irradiation level, which is the recommended dose for disinfestation of cereals. However, stickiness, firmness, and bulkiness scores of the samples irradiated at higher levels were significantly lower when compared to the respective control samples. The weak cultivar Çakmak exhibited lower scores for stickiness, firmness, and bulkiness at all irradiation levels when compared to the Kunduru samples. Values obtained by sensory analyses appear to be supported by increased TOM and SL values and decreased SDS sedimentation and FN results. Because damaged gluten would not provide as well-developed a protein matrix as the control samples to trap starch granules, and excessive swelling and subsequent rapture of starch granules will be more prominent during cooking if they are damaged.

TABLE II
Mixogram Properties of Semolinas Obtained from Wheats Irradiated at Various Levels

Sample	Radiation Levels (kGy)	Development Time (min)	Peak Height (MU)[a]	Mixing Tolerance (MU)	Bandwidth (MU)
Kunduru					
Control	0	2.25	550	100	45
	1.0	2.00	540	100	40
	2.5	2.00	510	105	40
	5.0	2.00	520	110	40
Çakmak					
Control	0	3.75	500	125	35
	1.0	3.50	500	125	35
	2.5	4.00	480	145	30
	5.0	3.50	490	160	30

[a] Mixograph unit.

TABLE III
Spaghetti Cooking Properties of Irradiated Samples[a,b]

Sample	Radiation Level (kGy)	TOM[c] (g/100 g)	SL[d] (%)	Stickiness[e]	Firmness[e]	Bulkiness[e]
Kunduru						
Control	0	1.34d	4.11d	69a	65a	60a
	1.0	1.44c	4.38c	64a	61a	57a
	2.5	1.76b	4.66b	53b	54b	51b
	5.0	1.85a	4.99a	50b	48c	44c
Çakmak						
Control	0	1.69d	4.67d	60a	50a	56a
	1.0	1.88c	5.07c	55a	45a	51a
	2.5	2.25b	5.55b	49b	36b	41b
	5.0	2.45a	6.03a	44b	33b	38b

[a] Values are the averages of two separate spaghetti samples each cooked twice.
[b] For each cultivar, means with the same letter within a column are not significantly different ($P < 0.05$) by least significant difference analysis.
[c] Total organic matter.
[d] Amount of solid substance lost to cooking water.
[e] Evaluated by a panel of three experts on each cooked sample.

CONCLUSIONS

The effects of gamma irradiation on durum wheat and semolina properties and spaghetti cooking quality were reported. The falling number and sedimentation values of the wheat meals obtained from irradiated wheat samples decreased significantly as radiation levels increased, indicating alterations in both starch and gluten components. Irradiation also caused important changes in the spaghetti cooking properties. TOM and SL values of both cultivars increased significantly with irradiation. From the data presented here, it appears that irradiation may be useful at 1 kGy levels for treatment of grain for insect control without adversely affecting quality. Above 1 kGy level, irradiated samples exhibited significantly lower scores for stickiness, firmness, and bulkiness when compared with control samples, probably because of deterioration in both starch and gluten. However, further investigations are required to support the conclusions derived from our study. Research on the changes in durum wheat due to irradiation as related to the end-products must be well documented before the gamma irradiation technique can be recommended for industrial applications.

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