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EFFECT OF GAMMA RADIATION ON THE PHYSICOCHEMICAL COOKING AND ORGANOLEPTIC CHARACTERISTICS OF RICE

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Abstract. Gamma irradiation (10–1000 krad) of Basmati-370 and IR-8 varieties of rice did not cause any change in any physicochemical parameters except sugars which increased at higher doses of radiation. Swelling number (98°C), elongation ratio and starch–iodine blue value were decreased by irradiation while water uptake (77°C) and loss of total solids in the residual liquid were increased. Organoleptic evaluation of cooked rice clearly demonstrated that irradiation up to 50 krad dose level had no adverse effect on the sensory characteristics of rice but higher doses caused browning of rice kernels, off-flavour and texture deterioration.

The use of radiation to control insect infestation of cereals has been investigated by various workers.[1] Some work has also been carried out on the irradiation of rice but the available information is too inconsistent and contradictory. Roseman *et al.*[2] and Hogan and Roseman[3] found that rice treated with gas-plasma irradiation absorbed more water, gave swollen appearance and cooked faster than untreated rice. Some workers observed adverse changes in the sensory characteristics of irradiated cooked rice at ten,[4] twenty[5] and fourty[6] krad while others did not find any change in the general acceptability at sixteen,[7] twenty,[8] fourty[9] and sixty[10] krad dose levels.

The present study was initiated to investigate the effect of gamma radiation (10–1000 krad) on the physicochemical, cooking and organoleptic qualities of Basmati-370 (fine) and IR-8 (coarse) varieties of rice. Higher radiation doses than are recommended for control infestation were used to see the type and extent of change in the quality characteristics of these Pakistani rice varieties.

Experimental

Two varieties of milled rice, i.e. Basmati-370 and IR-8, were procured from the local market and irradiation was carried out in a gamma cell-220 (Atomic Energy of Canada Limited). Dose rate at the time of irradiation was 3.5 krad/min as determined by $FeSO_4$ dosimetery.[11] Levels of radiation applied were 0, 10, 25, 50, 100,250,500 and 1000 krad. After irradiation, rice samples of each treatment were packed separately in polyethylene bags and stored at room temperature for analytical work.

Rice was ground in a Wiley mill equipped with a 60-mesh screen. Moisture, ash, fat, protein, sugars and fat acidity in the flour were determined according to *Cereal Laboratory Methods.*[12] The method of Halick and Keneaster[13] was used for the determination of starch–iodine blue values. The intensity of blue was determined in a Spectronic-20 (Baush and Lomb) at 600 nm. The water uptake values were calculated in grams of water absorbed by 100 g of whole rice kernels when cooked at 77°C for 45 min.[14] The amount of water in grams imbibed by 100 g of whole kernels cooked for 30 min in boiling water was reported as swelling number.[13] Total solids from the residual liquid (cooking gruel from swelling number determination) were determined according to the method of Batcher *et al.*[15] The results were reported as percentage dry matter (solids) loss during cooking of rice kernels.

The rice were cooked according to the following indigenous method.[5] Twenty-five g rice was soaked in 50 ml water for 15 ± 2 min and then the water was drained off. The rice was then cooked for 10 min in another 50 ml water. Elongation ratio was calculated by dividing the length of presoaked cooked rice by that of raw rice. The control and irradiated cooked rice were examined by a panel of 10 trained judges for colour, flavour and texture using a scoring method in which 0–10 rating was used.[16]

All the data was statistically analysed by the analysis of variance technique.[17]

Results and Discussion

Physicochemical Characteristics. Data pertaining to the effect of irradiation on physicochemical parameters of Basmati-370 and IR-8 varieties of rice are given in Table 1. It is clear from results that irradiation did not cause any change in moisture, ash, fat, protein and fat acidity contents of any of the two varieties of rice. Similarly radiation doses less than 250 krad had no effect on sugars but higher doses caused significant ($P < 0.01$) increase in reducing, non-reducing and total sugar contents of rice. Similar effect of low doses of irradiation on rice sugars has been reported by Hamid *et al.*[5] High radiation doses produce changes in the carbohydrate complex of cereals resulting in an increase in sugars at the expense of starch.[18]

Cooking Properties. Measurement of water absorption by rice kernels during cooking has been used to account for differences in cooking quality and grain type.[13,14,19–21] The swelling numbers show the hydration characteristics of rice kernels and a high value is indication of good cooking quality. Some workers have reported a relationship between high amylose content (inversely related

to starch–iodine blue value) and certain preferred cooking qualities (fluffy and nonsticky) of rice varieties.[13,19,22] But others have criticized this test[23,24] and have reported that amylopectin, instead of amylose of rice starch, may be more influential in controlling the cooking quality of rice.[14] Rice varieties which elongate more during cooking are also considered superior in our country. Results regarding irradiation-induced changes in cooking quality of rice are given in Table 2. Irradiation of both the varieties of rice caused significant ($P<0.01$) decrease in swelling number, elongation ratio and starch–iodine blue value but significantly ($P < 0.01$) increased water uptake at 77°C and the % loss of total solids in the cooking gruel.

The cooking quality of rice is mainly dependent on quantity and quality of its starch, i.e. granule size, micellar organization of the granules, amylose–amylopectin ratio and molecular weight of its components. IR-8 is higher in amylose contents and lower in gelatinization temperature than Basmati-370.[25] Hence the former variety has lower starch–iodine blue value and higher water uptake at 77°C than the latter. Higher water uptake of rice kernels at 77°C due to irradiation reflects a lowering of gelatinization temperature of rice starch as observed by Chaudhry and Glew.[25,26] Irradiation induced decrease in the starch–iodine blue values indicates leaching of more dissolved solids in the heating medium as this test is based on the fact that amylose is leached out of the starch granules which is responsible for the blue colour of iodine. Results clearly indicate that the lower swelling numbers of irradiated samples were mainly due to greater loss of total solids in the cooking gruel rather than an actual decrease in the water uptake capacity of rice kernels. Chaudhry and Glew[26] also reported that starch and amylose showed a progressive decrease in blue value due to irradiation, indicating depolymerization to the extent that iodine binding capacity and starch density were reduced. Degradation of rice starch by irradiation has also been reported by other workers.[10]

Organoleptic Attributes. The results of the effect of irradiation on the organoleptic attributes of both varieties of cooked rice are presented in Table 3. The judges almost gave equal scores to all the samples irradiated up to 50 krad dose levels as gamma radiation did not cause any change in the sensory characteristics of cooked rice of both the varieties. The judges gave less scores ($P < 0.01$) to rice which were cooked from samples irradiated at 100 krad and above dose levels. Above 50 krad dose the judges detected a progressive change in colour from white to yellow, off-flavour development and texture deterioration (Sticky and shrivelled kernels) of cooked rice. At higher radiation intensities, Hogan and Roseman[2] also reported browning of rice kernels off-flavour and off-odour in cooked samples.

As reported earlier, the results on the organoleptic evaluation of irradiated cooked rice are very contradictory. Reports on Burmese rice indicate changes in colour, flavour and taste at 10 and 40 krad.[46] This variation might be due to varietal differences and also different experimental conditions as Okakoua *et al.*[6] irradiated rice in nitrogen atmosphere. Hamid *et al.*[5] detected adverse changes in the colour, flavour and texture of cooked irradiated

TABLE 1. EFFECT OF GAMMA RADIATION ON THE PHYSICOCHEMICAL CHARACTERISTICS OF RICE.

Radiation dose(krad)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Reducing sugars (%)	Nonreducing sugars (%)	Total sugar (%)	Fat acidity (mg KOH 100 g)
Basmati—370								
0	10.7	0.65	0.49	7.6	0.70	0.53	1.22	8.40
10	10.9	0.65	0.49	7.6	0.70	0.52	1.21	8.40
20	10.7	0.64	0.50	7.4	0.70	0.51	1.22	8.58
50	10.7	0.66	0.49	7.6	0.71	0.53	1.23	8.40
100	10.4	0.65	0.50	7.2	0.72	0.54	1.25	8.58
250	10.7	0.65	0.50	7.6	0.73	0.56	1.29	8.40
500	10.4	0.66	0.49	7.4	0.74	0.58	1.32	8.58
1000	10–4	0.64	0.49	7.4	0.76	0.59	1.35	8.58
L.S.D. (1%)	N.S.	N.S.	N.S.	N.S.	0.03†	0.06†	0.06†	N.S.
IR—8								
0	10.9	0.50	0.38	6.4	0.70	0.55	1.26	15.56
10	10.7	0.50	0.40	6.8	0.70	0.55	1.25	14.28
20	10.9	0.48	0.39	6.4	0.69	0.55	1.24	14.28
50	10.4	0.50	0.38	6.4	0.70	0.54	1.24	14.56
100	10.7	0.49	0.40	6.4	0.72	0.53	1.25	14.56
250	10.7	0.50	0.40	6.4	0.73	0.57	1.30	14.20
500	10.4	0.48	0.39	6.8	0.74	0.59	1.34	14.56
1000	10.4	0.48	0.38	6.4	0.76	0.61	1.37	14.56
L.S.D. (1%)	N.S.	N.S.	N.S.	N.S.	0.04†	0.05†	0.06†	N.S.

*All the values are mean of 5 determinations. N.S. Nonsignificant. †Highly significant.

TABLE 2. EFFECT OF GAMMA RADIATION ON THE COOKING PROPERTIES OF RICE.*

Radiation dose (krad)	Elongation ratio	Starch–iodine blue value (% transmittance)	Water uptake (77°C) (%)	Swelling number (98°C) (%)	Solids loss (%)
Basmati—370					
0	1.71	49	162	341	7.53
10	1.70	47	171	343	8.07
20	1.64	43	178	325	8.60
50	1.61	41	185	313	9.83
100	1.61	37	189	264	14.47
250	1.41	18	196	256	18.47
500	1.34	13	201	205	21.50
1000	1.30	8	209	111	43.57
L.S.D. (1%)	0.12†	1.92†	5.48†	7.59†	0.17†
IR—8					
0	1.41	25	203	317	6.53
10	1.41	22	203	300	8.60
20	1.39	18	214	285	9.13
50	1.38	17	215	281	9.27
100	1.37	13	218	268	10.40
250	1.29	9	225	230	10.70
500	1.25	6	231	210	17.03
1000	1.16	3	241	143	26.70
L.S.D. (1%)	0.10†	2.01†	5.59†	5.42†	0.40†

*All the values are averages of 5 determinations except those of elongation ratios which are determined on 15 individual rice grains in each case. †Highly significant.

TABLE 3. EFFECT OF GAMMA RADIATION ON THE ORGANOLEPTIC ATTRIBUTES OF RICE.*

Radiation dose (krad)	Colour (0–10)		Flavour (0–10)		Texture (0–10)	
	Basmati-370	IR-8	Basmati-370	IR-8	Basmati-370	IR-8
0	7.4	6.8	7.2	5.4	7.0	5.0
10	7.8	6.6	7.0	5.6	7.2	5.0
20	7.4	6.8	6.8	5.6	6.8	5.0
50	7.4	6.8	6.8	5.8	6.8	4.9
100	6.2	4.4	5.0	3.8	5.4	2.4
250	4.0	3.0	2.4	2.4	2.4	1.8
500	2.6	1.6	1.4	0.8	2.2	0.8
1000	0.6	0.6	0.6	0.2	0.8	0.2
L.S.D. (1%)	1.60†	1.26†	1.39†	1.17†	1.22†	1.13†

*All the scores are average of 20 judgements. †Highly significant.

Basmati rice at 20 krad while Nadeem *et al.*[9] reported no change in the eating quality of the same variety of rice when irradiated up to 40 krad. Our results agree with those of Tape and Ferguson[10] who reported that irradiation up to 60 krad did not cause any defect in sensory acceptability of cooked Pakistani rice.

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References

1. P.B. Cornwell, Food Irrad. (Saclay), **6,** 2(1965).
2. A.S. Roseman, J.T. Hogan, R.B. Stone and J.C. Webb, Cereal Chem., **38,** 423 (1961).
3. J.T. Hogan and A.S. Roseman, Cereal Chem., **38,** 432 (1961).
4. A. Nishimura and K. Takoaka, Hakko Kogaku Zasshi, **38,** 615 (1960).
5. M.A. Hamid, M.T. Nadeem, W.A. Farooqi and A.S. Bhatti, International Rice Commission (IRC), Newsletter, **15,** 26 (1966).
6. S. Okakoua, M. Mukutani, M. Sugihara and I. Hashida, Radioisotopes (Tokyo), **14,** 97 (1965).
7. M.A. Hussain, H.N. De, S.U. Chowdhry and N. Nabi, PAEC–PCSIR joint project of rice irradiation. Taste panel report on organoleptic tests. AECK-Pak RB/1 (1966).
8. A. Matsuyama, *Recent Advances in Food Irradiation Research in Japan* (STI-Pub., 1967), pp. 767.
9. M.T. Nadeem, A. Sattar, M. Ali and A. Muhammed, Food Irrad. (Saclay), **10,** 13 (1969).
10. N.W. Tape and W.E. Ferguson, Food Irrad. (Saclay), **7,** 22 (1966).
11. F. Aziz and P.J. Dyne, *A Practical Course in Radiation Chemistry* (A.E.C. Lahore, 1963), pp. 40.
12. American Association of Cereal Chemists, *Cereal Laboratory Methods* (The Association: St. Faul, Minnesota, 1962). 7th edition.
13. J.V. Halick and K.K. Keneaster, Cereal Chem., **33,** 315 (1956).
14. J.V. Halick and V.J. Kelly, Cereal Chem., **36,** 91 (1959).
15. O.M. Batcher, K.F. Helmintoller and E.H. Dawson, Rice J., **59,** 4 (1956).
16. J.K. Krum, Food Eng., **27,** 74 (1955).
17. W.G. Cochran and G.M. Cox, *Experimental Designs* (J. Wiley, New York, 1965), 2nd edition, p 106.
18. S.P. Lai, K.F. Finney and M. Milner, Cereal Chem., **36,** 401 (1959).
19. B.S. Rao, A.R.V. Murthy and R.S. Subrahmanya, Proc. Indian Acad. Sci., **36B,** 70 (1952).
20. O.M. Batcher, P.A. Deary and E.H. Dawson, Cereal Chem., **34,** 277 (1957).
21. J.T. Hogan and R.W. Plank, Cereal Chem., **35,** 469 (1958).
22. V.R. Williams., W.T. Wu, H.Y. Tasi and H.G. Bates, J. Agri. Food Chem., **6,** 47 (1958).
23. V.L. Hall and J.R. Johnson, Cereal Chem., **43,** 297 (1966).
24. B.O. Juliano, A.V. Cartano and A.J. Vidal, Cereal Chem., **45,** 63 (1968).
25. M.A. Chaudhry and G. Glew, J. Food Technol. (U.K.), **7,** 163 (1972).
26. Ibid., J. Food Technol. (U.K.), **8,** 295 (1973).