Technology Section

Pakistan J. Sci. Ind. Res., Vol. 16, Nos. 3–4, June–August 1973

EFFECT OF GAMMA RADIATION AND STORAGE ON THE BIOCHEMICAL AND TECHNOLOGICAL PROPERTIES OF SOME PAKISTANI WHEAT VARIETIES

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(Received February 1, 1973)

Abstract. This investigation was carried out to study the effect of gamma radiation (10–1000 krad) and storage (one year) on C-591 and Mexi-Pak wheat varieties. Biochemical parameters investigated were moisture, ash, fat, sugars, protein, gluten (fresh and dry), amino acids, fat acidity and protein solubility. Bread making and 'roti making' properties of irradiated and unirradiated wheat were also studied. It is concluded from this investigation that gamma radiation doses up to 100 krad have no adverse effect on both varieties of wheat and the irradiated wheat remains wholesome from biochemical, technological and organoleptic points of view during storage period of one year.

Infestation of wheat and other cereals in storage by insects and other microorganisms results in a tremendous loss to human diet and has been of great concern to man throughout the ages. F.A.O. has estimated that one-fifth of world food crop planted by mankind is destroyed by insects, microorganisms and other pests.[1] These losses in specific areas may be higher (up to 50%) and are greatest in those underdeveloped parts of the world where the population is already undernourished.

The primary object of wheat irradiation is to control insect infestation and thus the pioneers in the field were mainly concerned with this basic aim.[2,3] Work carried out by these investigators has shown that a dose of 25 krad can eliminate the insect pests from wheat grains. However, it is also of utmost importance that radiation doses proposed for disinfestation must not produce undesirable changes in wheat. During the last 15 years extensive investigation has been carried out on the effect of irradiation on wheat in various countries including U.S.S.R.,[4,5] Canada,[6–8] U.S.A.[9–17] and European countries.[18–20] Investigation on the biochemical and technological properties of Pakistani irradiated wheat varieties have not been carried out before. Keeping in view the importance of radiation technology in disinfestation of wheat, investigations on this project were started to study radiation induced changes in macro and micro-nutrients bread making and roti making properties of C-591 and Mexi-Pak wheat varieties during storage period of one year.

Experimental

Two indigenous wheat varieties, i.e. C-591 and Mexi-Pak were procured from the local market and irradiation was carried out in a gamma cell 220, (Atomic Energy of Canada Limited) with a dose rate of 4 krad/min. Levels of radiation used were 0, 10, 20, 50, 100, 500 and 1000 krads. After irradiation, wheat of each treatment was stored separately in glass jars at room temperature. Lids of these glass jars were provided with two holes to facilitate aeration in order to avoid accumulation of CO_2.

Samples drawn immediately after radiation and 3-months thereafter were cleaned and milled on Buhler automatic experimental laboratory mill and 100% flour was used for biochemical analyses. After about 3 months storage the unirradiated wheat became infested with insects, therefore, unirradiated wheat of the same variety which was not infested was used for subsequent analytical work. Moisture, ash, protein, fat, sugars, fat acidity and gluten (fresh and dry) were determined according to Cereal Laboratory Methods.[21] Changes in protein solubility occurring due to treatments and storage were detected by measuring turbidity of 5% potassium sulphate extracts of ground wheat.[10] Results were expressed as per cent transmittance read at 550 nm. Tryptophan was determined by the method of Spies and Chamber.[22] Other amino acids were determined by ion exchange chromatography using E.E.L. model 193, high speed amino acid analyser.

Breads were prepared from irradiated and control wheat flours in the Cereal Section of the Punjab Agricultural Research Institute, Lyallpur, by straight-dough method as described in Cereal Laboratory Methods.[21] The formula of ingredients used for bread making is as under: maida (55% extraction), 100 g, yeast, 25 ml suspension (2 g); sugar +salt, 25 ml solution (1 g sugar+2 g salt); water, per cent water absorption of flour.

Per cent water absorption was calculated according to Cereal Laboratory Methods.[21] The volumes of the breads were determined by seed displacement method.[23] Breads were evaluated by the method of Blish[24] for external (crust colour and loaf type) and internal (crumb colour, grain and texture) characteristics; each characteristic was assigned a score between 0 and 10. Overall quality was determined by the following formula:

Quality score = 0.1 (loaf volume − 200) + grain + texture + crumb colour + loaf type + crust colour.

Freshly milled and sifted flour (atta) from irradiated and unirradiated wheat was used for 'roti' making. 'Roties' were prepared according to the standard method developed in the Cereal Section of the Punjab Agricultural Research Institute, Lyallpur.[25] Acceptability of 'roties' was determined organoleptically by a panel of 10 judges on a nine-point hedonic scale.[26] The results were statistically analysed by the analysis of variance technique.

Results and Discussion

Biochemical Properties

Moisture, Ash, Fat, Protein and Sugars. The effect of radiation doses and storage time on these macro-nutrients of wheat is presented in Tables 1 and 2. Irradiation, at any level used, virtually caused no change in moisture, ash, fat and protein contents of wheat. Similar effect of irradiation on these wheat constituents has been reported by other workers.[11–13,16,17] These biochemical constituents of wheat remained unchanged during storage of wheat except moisture which decreased in both the varieties.

Higher doses of irradiation caused an immediate increase in reducing, nonreducing and total sugars in both varieties. Sosedov *et al.*[4] reported that high radiation doses produced appreciable changes in the carbohydrate complex of wheat resulting in an increase in sugars and a decrease in starch contents. Similar effect of irradiation (up to 1 Mrep) on Conley wheat has been reported by Lai *et al.*[12] In our studies values for sugars remained unchanged throughout the storage period of one year.

Gluten. Gluten protein is very important constituent of wheat because its quantity and quality influences the baking properties. It is clear from Tables 1 and 2 that there was no effect of gamma irradiation at any dose level either on fresh or dry gluten contents in C-591 and Mexi-Pak wheat varieties. However, gluten contents decreased throughout the storage period. Lee[14] irradiated different wheat varieties at 700 krad and reported less recovery of crude gluten, but our results are in agreement with those of Sosedev *et al.*[4] and Doguchi[27] who did not find any adverse effect on the quantity of wheat gluten up to 1 and 3 mrad dose levels respectively.

Fat Acidity. Irradiation doses used in this experiment had no direct effect on the splitting of fat of these Pakistani wheat varieties (Tables 1 and 2). Fat acidity values of all the samples increased with storage time but there was comparatively more increase in unirradiated and low level irradiated wheat

TABLE 1. EFFECT OF GAMMA RADIATION AND STORAGE ON BIOCHEMICAL PROPERTIES OF C-591 WHEAT.

Wheat constituents (%)	Radiation dose (krad)							L.S.D. (5%)	Storage period (months)					L.S.D. (5%)
	0	10	20	50	100	500	1000		0	3	6	9	12	
Moisture	7·94	7·99	7·91	7·96	7·93	7·82	7·82	NS	8·95	8·02	7·90	7·73	6·95	0·161*
Ash	1·69	1·70	1·69	1·69	1·70	1·69	1·69	NS	1·70	1·69	1·70	1·70	1·69	NS
Fat	1·66	1·65	1·64	1·65	1·66	1·66	1·62	NS	1·66	1·65	1·63	1·64	1·66	NS
Reducing sugars	1·20	1·18	1·18	1·21	1·28	1·30	1·33	0·065*	1·23	1·23	1·24	1·23	1·26	NS
Nonreducing sugars	1·42	1·35	1·39	1·44	1·54	1·57	1·62	0·117*	1·51	1·52	1·48	1·45	1·43	NS
Total sugars	2·62	2·54	2·58	2·65	2·82	2·89	2·92	0·129*	2·74	2·76	2·72	2·68	2·69	NS
Protein	10·83	10·69	10·80	11·03	10·97	11·10	11·04	NS	10·87	11·03	11·05	10·82	10·85	NS
Fresh gluten	28·72	28·54	28·76	28·08	28·04	27·70	28·26	NS	29·17	29·09	28·07	27·97	27·20	0·723*
Dry gluten	7·36	7·60	7·36	7·14	7·32	7·02	7·52	NS	7·90	7·50	7·36	7·24	6·66	0·408*
Fat acidity (mg KOH/100 g)	23·88	23·32	22·20	21·92	20·46	19·76	19·20	2·740*	16·90	19·83	20·97	24·31	25·66	2·316*
Protein solubility (% transmittance)	27·40	27·50	26·90	27·30	27·00	27·25	27·20	N.S.	29·38	27·75	26·64	26·47	25·93	0·535*

NS, nonsignificant; *highly significant.

TABLE 2. EFFECT OF GAMMA RADIATION AND STORAGE ON BIOCHEMICAL PROPERTIES OF MEXI-PAK WHEAT.

Wheat constituents (%)	Radiation dose (krad)							L.S.D. (5%)	Storage period (months)					L.S.D. (5%)
	0	10	20	50	100	500	1000		0	3	6	9	12	
Moisture	7·94	7·91	8·13	7·92	8·00	7·82	8·00	NS	9·00	8·01	8·01	7·69	7·07	0·183*
Ash	1·44	1·43	1·44	1·43	1·42	1·43	1·42	NS	1·45	1·44	1·14	1·45	1·45	NS
Fat	1·57	1·58	1·59	1·57	1·58	1·59	1·55	NS	1·58	1·58	1·58	1·58	1·58	NS
Reducing sugars	1·10	1·14	1·14	1·07	1·11	1·20	1·23	0·071*	1·15	1·16	1·13	1·17	1·09	NS
Nonreducing sugars	1·33	1·35	1·23	1·35	1·45	1·53	1·63	0·038*	1·39	1·42	1·46	1·40	1·40	NS
Total sugars	2·42	2·49	2·38	2·42	2·57	2·73	2·86	0·0147*	2·54	2·58	2·59	2·57	2·49	NS
Protein	10·96	10·94	11·00	10·82	10·71	10·98	11·09	NS	11·08	11·19	10·92	10·89	10·57	NS
Fresh gluten	18·74	18·98	18·76	18·82	18·52	18·74	18·46	NS	20·41	20·00	18·60	17·39	17·19	0·891*
Dry gluten	6·34	6·46	6·52	6·44	6·20	6·36	6·16	NS	6·90	6·33	6·27	6·14	6·13	0·288*
Fat acidity (mg KOH/100 g)	25·76	25·20	23·94	23·04	22·68	21·50	20·88	2·450*	19·60	21·37	22·86	26·00	26·60	2·071*
Protein solubility (% transmittance)	26·20	26·60	26·70	26·55	26·30	26·65	26·25	NS	28·50	27·32	26·29	25·86	24·36	0·432*

NS, nonsignificant; *highly significant.

samples (up to 100 krad). Chung *et al.*[16] reported that lipids in cereals were degraded only at very high dose levels. Tipples and Norris[6] found that gamma radiation levels of 10^7 rads decreased the levels of unsaturated fatty acids. Our results are in agreement with those of Fifield *et al.*[17] Lai *et al.*[12] and Yen *et al.*[10] who found that irradiation doses of 175 krad, 1 and 3.75 Mrep respectively caused no change in fat composition of different wheat varieties.

Protein Solubility. The solubility of protein of unirradiated wheat did not differ from that of irradiated wheat samples during one year storage (Tables 1 and 2). However, protein solubility significantly increased (decrease in transmittance) during subsequent storage period. Yen *et al.*[10] showed decrease in protein solubility due to irradiation of damp wheat (20% moisture). This conflicts with the results reported by Gilles *et al.*[28] and Lee[14] where solubility increased due to irradiation. Sosedov *et al.*[4] also found slight increase in the protein solubility of dry wheat due to irradiation but when fresh grain were irradiated, the change in the wheat proteins was in the opposite direction. Our results agree with those of Calloway and Thomas[13] and Fifield *et al.*[17] who did not find any effect of irradiation on protein solubility of different wheat varieties.

Amino Acids. In the present investigation tryptophan was not affected at lower doses of radiation and it started decreasing at 500 krad and above in both the wheat varieties (Table 3). The tryptophan contents of very high dose-treated wheat samples were also lower after a storage period of one year. Other workers have also shown that the tryptophan contents of corn, wheat flour and rice were not affected by low doses of radiation.[13,19,30] Effect of irradiation (1 mrad) on other amino acids of both the wheat varieties is given in Table 4. Amino acids very slightly affected at this radiation dose include aspartic acid, threonine, serine, glutamic acid, leucine, isoleucine, tyrosine, phenylalanine, lysine and arginine, while proline, glycine, alanine and valine remained unchanged. Kennedy[31] found that methionine was the principal amino acid affected in wheat gluten when irradiation doses up to 5 mrad were employed. Our results also agree with those of Doguchi[27] who showed no significant change in the amino acids of wheat gluten irradiated at 10 mrad.

TABLE 3. EFFECT OF GAMMA RADIATION AND STORAGE ON THE TRYPTOPHAN CONTENTS (%) OF C-591 AND MEXI-PAK WHEAT VARIETIES.

Radiation dose (krad)	C-591		Mexi-Pak	
	Immediately after irradiation	After one year storage	Immediately after irradiation	After one year storage
0	0·167	0·168	0·160	0·158
10	0·174	0·173	0·157	0·152
20	0·169	0·165	0·172	0·170
50	0·172	0·164	0·161	0·161
100	0·160	0·151	0·157	0·149
500	0·163	0·152	0·152	0·143
1000	0·154	0·138	0·147	0·134

TABLE 4. EFFECT OF GAMMA RADIATION ON THE AMINO ACID CONTENTS (%) OF C-591 AND MEXI-PAK WHEAT VARIETIES.

Amino acids (%)	C-591		Mexi-Pak	
	Control	Irradiated (1 mrad)	Control	Irradiated (1 mrad)
Aspatric acid	0·616	0·491	0·552	0·390
Threonine	0·309	0·245	0·286	0·246
Serine	0·505	0·347	0·393	0·336
Glutamic acid	4·968	3·168	6·260	5·002
Proline	1·246	1·248	1·236	1·207
Glycine	0·478	0·555	0·508	0·507
Alanine	0·226	0·385	0·421	0·420
Valine	0·402	0·419	0·352	0·348
Isoleucine	0·363	0·135	0·343	0·252
Leucine	0·817	0·463	0·725	0·630
Tyrosine	0·299	0·165	0·297	0·226
Phenylalanine	0·439	0·389	0·453	0·406
Lysine	0·366	0·282	0·441	0·319
Arginine	0·412	0·337	0·554	0·358

Technological Characteristics

Bread Making Properties. Bread making properties of C-591 and Mexi-Pak wheat varieties as influenced by irradiation and storage time are given in Tables 5 and 6. Baking absorption increased slightly with an increase in radiation dose and this change was accentuated with the storage period. Radiation doses above 100 krad resulted in lower loaf volume and poor crumb grain. Breads prepared from wheat irradiated above 100 krad and stored for one year had unsatisfactory crumb grain with open, heavy and underdeveloped cell structure, while the loaf volume of these breads remained unchanged. Breads made from unirradiated and low dose (up to 100 krad) treated wheat were comparatively soft and the texture scores decreased slightly in breads made from stored wheat. Crumb colour of the loaves deteriorated appreciably after wheat was stored for one year but different radiation doses had no such effect. As regards loaf type, breads made from wheat irradiated above 100 krad had less break and there was a tendency towards a shell or flat top. Breads made from untreated and low dose treated wheat had appreciable break with tendency towards bold, smooth and rounded development. Storing of wheat for one year did not change this characteristic of bread. Crust colour was neither affected by radiation, nor storage period. Overall quality score of breads made from high radiation dose treated wheat was lower and it also decreased somewhat in breads made from stored wheat.

There is a considerable difference of opinion in literature on the effect of radiation on the baking qualities of wheat. Some workers considered that medium levels of radiation (up to 100 krad) improved the wheat or flour and produced bread of better volume and quality.[11,18,20,32] Others did not find any adverse or favourable change in baking quality when medium doses were applied.[7–9,17,19] This is also true in the present investigation as we did not find any appreciable change in the baking quality of Pakistani wheat varieties irradiated up to 100 krad. Lai *et al.*[12] did not obtain any indication that irradiation (up to 1 mrad) at any level improved the bread

TABLE 5. EFFECT OF GAMMA RADIATION AND STORAGE ON THE BREAD MAKING PROPERTIES OF C-591 WHEAT.

Radiation dose (krad)	Absorption (%)	Loaf type (0–10)	Crust colour (0–10)	Texture (0–10)	Grain (0–10)	Crumb colour (0–10)	Volume (ml)	Quality score
Immediately after irradiation								
0	73·0	*F(10)	Dark brown(10)	Soft resilient(10)	5·83	Creamy white (10)	600	85·83
10	72·5	,,	Brown	,,	6·66	,,	595	84·16
20	72·5	,,	,,	,,	5·83	,,	600	83·83
50	73·0	,,	,,	,,	5·83	,,	590	82·83
100	73·5	F-J (7·5)	,,	,,	5·83	,,	580	84·33
500	74·5	,,	Dark brown	Soft (7·5)	4·18	,,	515	72·68
1000	75·0	†J(7)	,,	,,	4·18	,,	500	68·68
After 1 year storage								
0	75·0	F	Dark brown	Soft	4·18	Yellowish white (5)	600	76·68
20	75·0	,,	Brown	,,	5·00	White (7·5)	600	78·00
50	75·0	F-J	Dark brown	,,	5·00	Yellowish white	595	74·50
100	76·0	F	Brown	,,	3·33	White	580	74·33
500	77·5	F-J	Dark brown	Fairly soft (5)	2·50	Yellowish white	525	62·50
1000	78·5	J	,,	,,	2·50	,,	505	60·00

*, Pronounced break and decided tendency towards bold, smooth rounded development; †, no appreciable break and an inclination towards shell or flat top.

TABLE 6. EFFECT OF GAMMA RADIATION AND STORAGE ON THE BREAD MAKING PROPERTIES OF MEXI-PAK WHEAT.

Radiation dose (krad)	Absorption (%)	Loaf type (0–10)	Crust colour (0–10)	Texture (0–10)	Grain (0–10)	Crumb colour (0–10)	Volume (ml)	Quality score
Immediately after irradiation								
0	71·0	*F(10)	Brown(8)	Soft resilient (10)	6·66	White (7·5)	580	80·16
10	72·0	,,	,,	Soft (7·5)	6·66	,,	585	80·66
20	71·0	F-J(7·5)	,,	Soft resilient	6·66	,,	580	80·16
50	70·0	F	Dark brown(10)	Soft	5·83	,,	575	78·33
100	72·5	F-J	Brown	Soft resilient	5·83	,,	550	74·33
500	74·0	† J(7)	Dark brown	Soft	5·00	,,	500	67·0
1000	75·5	,,	,,	,,	5·00	,,	490	64·0
After 1 year storage								
0	74·0	F	Dark brown	Soft	5·00	Yellowish white(5)	570	74·50
20	73·5	,,	,,	,,	5·00	,,	580	71·00
50	73·0	,,	Brown	,,	5·00	,,	575	73·00
100	74·0	,,	Dark brown	,,	3·33	,,	560	71·83
500	76·0	F-J	Brown	Fairly soft (5)	2·50	,,	525	60·50
1000	77·5	J	,,	,,	2·50	,,	500	57·50

*F, Pronounced break and decided tendency towards bold, smooth rounded development; †, no appreciable break and an inclination towards shell or flat top.

properties when an optimum baking formula was used. The apparent improvement only occurred in loaf volume when sup-optimum levels of sugar, malt or bromate were used. Lee,[15] Miller *et al.*[33] and Chung *et al.*[16] also reported gradual decrease in baking quality with high radiation doses. Our results obtained at higher radiation doses are in line with the findings of above workers, but disagree with those of Sosedov *et al.*[4] and Metlitskiy[5] who did not observe any deterioration in baking quality of normal wheat up to 1 mrad dose levels.

Roti Making Properties. Results of organoleptic evaluation of 'roties' (unleavened bread eaten in Indo-Pak subcontinent) prepared from irradiated and unirradiated wheat during storage are given in Table 7. It can be seen from this table that different radiation doses had no significant effect on 'roti' accept-

TABLE 7. EFFECT OF GAMMA RADIATION AND STORAGE ON THE ROTI MAKING PROPERTIES OF C-591 AND MEXI-PAK WHEAT VARIETIES.

Radiation dose (krad)	C-591		Mexi-Pak	
	Immediately after irradiation	After one year storage	Immediately after irradiation	After one year storage
0	7·4	6·7	7·1	6·8
10	7·2	6·8	7·0	6·4
20	7·2	6·6	7·1	6·6
50	7·4	6·8	7·2	6·6
100	7·5	6·8	6·7	6·6
500	7·1	6·5	6·7	6·5
1000	7·2	6·5	6·8	6·6

Mean score values (of 10 judges) for all the parameters are nonsignificant.

ability determined by hedonic scale rating. However, judges gave comparatively less scores to 'roties' prepared from wheat stored for one year. No defect of any type was reported by any judge regarding the acceptability of this product. While working on radiation preservation of 'chapaties' (other local name for 'roti'), Savagoan *et al.*[34] reported that 'chapaties' irradiated up to 1 mrad were highly acceptable organoleptically for at least two months.

Literature on effect of irradiation of wheat on consumer's acceptability of 'roti' is very scarce but some information on bread is available. Fifield *et al.*[17] reported burned odour in hot breads made from irradiated wheat. After breads cooled to room temperature, no significant difference in odour or flavour was detectable. Our results on 'roti' agree with those of Brownell *et al.*[9] and Milner and Yen[11] who found that irradiation produced no off-odour or flavour in bread, but disagree with those of Miller *et al.*[35] and Lai *et al.*[12] who reported detectable and objectionable flavour and odour development in breads made from irradiated wheat.

Acknowledgement. The authors are grateful to Messers Muhammad Sharif and Manzoor Ahmad, Cereal Section, Punjab Agricultural Research Institute, Lyallpur, for the help in study on the technological properties of wheat. Thanks are due to Mr. Farooq Maqsood for statistical analyses of experimental data. Critical review of the paper by Dr. Amin M. Hussain and Mr. W.A. Farooqi, Food Preservation Division, Nuclear Institute for Agriculture and Biology, Lyallpur, is also acknowledged.

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