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Nutritional changes in maize (*Zea mays*) during storage at three temperatures

Zia-Ur- Rehman*, Farzana Habib, S.I. Zafar

PCSIR Labortaries Complex, Biotechnology and Food Research Centre, Ferozpur Road, Lahore 54600, Pakistan

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Abstract

Nutritional changes in maize grains stored at 10, 25 and 45 °C for 6 months were studied. Significant decrease in pH and increase in titratable acidity was observed during storage of maize grains at 25 and 45 °C. Moisture contents of maize grains decreased by 25% at 25 °C and 38% at 45 °C after six months of storage. Total soluble sugars increased by 10.7% at 10 °C and 17.3% at 25 °C, whereas a 39.5% decrease was observed after 6 months storage at 45 °C. Total available lysine and thiamine contents in maize grains decreased by 13 and 9.26% at 25 °C, 16 and 20.4% at 45 °C, respectively, after 6 months of storage. Protein digestibility decreased by 5.19 and 9.0% at 25 and 45 °C, respectively, whereas decrease in starch digestibility was 9.86% at 25 °C and 15.1% at 45 °C on storage of maize grains for 6 months. However, no significant nutritional changes occurred during storage of maize grains at 10 °C.

Keywords: Maize grains; Nutritional changes; Storage

1. Introduction

Maize is used as one of the major sources of protein and energy in the preparation of different types of human foods in many parts of the world. Generally, in Pakistan, maize grains are stored in jute bags and earthen pots under adverse conditions of temperature and moisture. It has been reported that cereal and legume grains undergo pronounced biochemical and nutritional changes during storage. (Kumar & Singh, 1984; Onignide, & Akinyele, 1988; Rehman, Yasin, Shah, & Ehtheshamuddin, 1995; South, Morrison, & Nelson, 1991). The moisture contents in the grains or humidity and the storage temperature have been shown to cause dramatic changes in the acidity, pH, free amino nitrogen, protein and starch quality (Huyghebaet & Schoner, 1999; Pajic, Babic, & Rodosvljevic, 1992; Savich & Joldaspaeva, 1993; Zeleny & Coleman 1938; Zhang, Zhang, Wang, Zhou, & Zhang, 1997). Many workers have found that Maillard cross-linkages were formed in food stored under adverse conditions of temperature and moisture, with consequent reduction in protein digestibility (Marshall & Chrastil, 1992). The association between the physical changes and the changes in the chemical composition of food has made the biochemical and nutritional quality control of the stored products increasingly essential. The aim of this study was to evaluate the effect of storage temperature and time on the stability of maize grains with respect to some nutritional changes, including digestibility of protein and starch.

2. Materials and methods

Freshly harvested maize (*zea mays*) was obtained from Ayub Agriculture Research Institute, Faisalabad (Pakistan) and stored at 10, 25 and 45 °C for a period of 6 months. All maize samples were free from insect infestation and no chemicals were used for preservation. About 100 g of each sample with about 12% moisture were placed in screw cap plastic bottles of uniform size. Three bottles of each treatment were randomly selected at the end of each month, contents were pooled and thoroughly mixed.

The samples were analyzed for pH, titratable acidity, moisture, total available lysine, soluble sugars, thiamine

* Corresponding author.
E-mail address: ampl@nexlinx.net.pk (Z.-U. Rehman).

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and digestibility of protein and starch. The pH was determined on a filtrate of 2 g ground sample (80 mesh size) in 20 ml distilled water, using a glass electrode pH meter (PYE Unicam, England). The titratable acidity was expressed as sodium hydroxide required to neutralize the acids in 100 g sample, using phenolphthalein as an indicator (AOAC, 1990). Moisture was determined using the standard method of AOAC (1990). Total soluble sugars were estimated by the phenol- sulphuric acid method of Dubois, Giles, Hamillon, Rebers, and Smith (1956) using sucrose as standard, whereas thiamine contents in maize grain samples were determined by the thiochrome method, as described in AOAC (1990). The dye binding method was used for the estimation of total available lysine in maize samples after hydrolyzing with 6N HCl (Hurrell & Carpenter, 1979). Lysine concentration was determined by a difference method, in which measurements were made on a spectrophotometer (Hitachi 220S) at 475 nm before and after blocking the lysine with propionic anhydride, using acid orange 12 as a dye. Protein digestibility was measured after digestion with pepsin—HCl solution at 37.5 °C for 24 h (Price, Butler, Rogler, & Featherson, 1979). Starch digestibility in vitro was determined after digestion with pancreatic α-amylase in 0.1 M phosphate buffer at 37 °C for 2 h (Costas, 1982). All determinations were carried out in triplicate and standard deviations (S.D.) were calculated according to the method of

Table 1
pH, titratable acidity and moisture contents of maize grains during storage at three temperatures[a]

Storage time (months)	Moisture %			pH			Acidity mg NaOH/100g		
	10 °C	25 °C	45 °C	10 °C	25 °C	45 °C	10 °C	25 °C	45 °C
	a			a			a		
0	12.38±0.3	–	–	6.64±0.1	–	–	3.32±0.2	–	–
	a	a	a	a	a	a	a	a	a
1	12.30±0.4	12.00±0.4	11.60±0.6	6.62±0.1	6.55±0.1	6.22±0.2	3.30±0.1	3.50±0.1	3.65±0.2
	a	a	b	a	a	b	a	a	a
2	12.27±0.2	12.00±0.5	10.05±0.5	6.58±0.2	6.50±0.1	6.00[a]±0.2	3.28±0.1	3.77±0.2	3.80±0.2
	a	a	b	a	a	b	a	b	b
3	12.25±0.2	11.85±0.3	9.66[a]±0.4	6.55±0.1	6.43±0.2	5.88±0.1	3.25±0.2	3.89±0.2	4.20[a]±0.3
	a	b	c	a	b	c	a	b	b
4	12.24±0.4	10.09[a]±0.2	8.25±0.4	6.54±0.3	6.11[a]±0.2	5.71±0.1	3.25±0.1	3.99[a]±0.2	4.30±0.3
	a	b	c	a	c	c	a	c	c
5	12.24±0.3	9.77±0.4	8.00±0.2	6.54±0.3	5.89±0.1	5.65±0.1	3.24±0.1	4.22±0.1	4.45±0.2
	a	c	c	a	c	c	a	c	c
6	12.00±0.4	9.32±0.4	7.70±0.2	6.55±0.1	5.87±0.1	5.43±0.2	3.24±0.1	4.24±0.1	4.60±0.3

[a] Mean values ± SD triplicate determinations. Mean values within a column with different superscripts are significantly different at $P<0.05$.

Table 2
Total soluble sugars, total available lysine and thiamine contents of maize grains during storage at three temperatures[a]

Storage time (months)	Total soluble sugars %			Total available lysine %			Thiamine (mg/100g)		
	10 °C	25 °C	45 °C	10 °C	25 °C	45 °C	10 °C	25 °C	45 °C
	a			a			a		
0	3.64±0.1	–	–	2.77±0.1	–	–	27.0±0.1	–	–
	a	a	a	a	a	a	a	a	a
1	3.65±0.2	3.70±0.2	3.55±0.2	2.74±0.2	2.74±0.2	2.60±0.2	27.0±0.2	27.0±0.1	26.0±0.1
	a	a	b	a	a	b	a	b	b
2	3.74±0.1	3.86±0.2	3.00±0.3	2.72±0.2	2.60±0.2	2.54±0.2	27.0±0.2	26.0±0.1	25.5[a]±0.1
	a	a	b	a	b	b	a	b	b
3	3.80±0.1	3.86±0.2	3.00±0.1	2.70±0.2	2.56±0.1	2.50[a]±0.1	27.0±0.2	26.0±0.2	24.0±0.2
	b	b	c	a	c	c	b	c	b
4	3.85±0.2	3.89±0.2	2.75[a]±0.1	2.64±0.1	2.50[a]±0.1	2.46±0.1	26.0±0.1	25.5[a]±0.2	23.6±0.2
	b	b	c	a	c	c	b	c	c
5	3.98±0.3	4.03±0.2	2.40±0.1	2.60±0.1	2.43±0.1	2.40±0.1	26.0±0.1	25.0±0.2	23.0±0.1
	b	c	c	a	c	c	b	c	c
6	4.03±0.3	4.27[a]±0.2	2.20±0.2	2.60±0.1	2.40±0.1	2.22±0.1	25.8±0.1	24.5±0.2	21.5±0.1

[a] Mean values ± SD triplicate determinations. Mean values within a column with different superscripts are significantly different at $P<0.05$.

Steel and Torrie (1980). Duncan's multiple range test was used to determined significant differences ($P < 0.05$).

3. Results and discussion

Biochemical changes in maize grains occurred to various extents, depending on the temperature and time period of storage. The range of storage temperature included in this study (i.e. 10–45 °C) covered the atmospheric temperatures that the maize grains would encounter in Pakistan.

There was no change at all in pH and titratable acidity of maize grains kept at 10 °C for 6 months (Table 1). However, significant ($P < 0.05$) changes in pH and titratable acidity occurred on storing maize grains at 25, & 45 °C for different time periods. A decrease in pH and an increase in titratable acidity started to appear just after 1 month of storage at 25 and 45 °C. The mean titratable acidity of the stored corn grains was 4.22 mg NaOH/100 g at 25 °C and 4.45 mg NaOH/100 g at 45 °C after 5 months, while it was 3.32 mg NaOH/100 g for freshly harvested maize grains. pH of the freshly harvested maize grains was 6.64, whereas pH values of the maize grains, at 25 and 45 °C were 5.89 and 5.65 respectively after 5 months of storage. No further changes in pH and acidity were observed at 25 °C after 5 months. On the other hand, pH and titratable acidity of the stored maize grains were further changed, to some extent, at 45 °C after 5 months. The increase in the acidity in stored grains could be attributed to the increasing concentration of the free fatty acids, phosphates and hydrogen ions, which resulted from increased grain deterioration (Morrison, 1963). The bonding of the amino group of the amino acids, short chain peptides and protein, leaving the carboxylic ends free, and the presence of acid by-products of advanced Mallard reactions are other possible causes of the increased acidity in the samples stored at elevated temperatures (Fargerson, 1969; Gardner, 1979).

A gradual decline in the level of moisture took place at 25 and 45 °C while there was no change in moisture contents during storage of maize grains at 10 °C for 6 months (Table 1). The decrease in moisture became significant at 25 °C after 3 months and 45 °C after 1 month of storage ($P < 0.05$). Moisture contents of maize grains decreased by 24.71% at 25 °C and 37.80% at 45 °C during 6 months storage. These results are consistent with the findings of Rehman et al. (1995) who had already found a significant reduction in moisture content during storage of rice at 45 °C.

Table 2 shows significant changes in total soluble sugars during six months storage of maize grains ($P < 0.05$). About 39.5% decrease at 45 °C and a 10.7–17.30% increase in total soluble sugars were observed at 10 and 25 °C during 6 months of storage. The increase in the soluble sugars could be the result of amylolytic activity of the endogenous amylases (Kramer, Guyer, & Ide, 1949) whereas decrease in soluble sugars at 45 °C might be due to their involvement in Maillard reactions.

Total available lysine in freshly-harvested maize grains was 2.77% which was decreased to various extents during storage (Table 2). About 6% decrease in total available lysine was observed at 25 °C, after 2 months and at 45 °C, after 1 month, of storage of maize grains. However, 13.4% and 19.9% decrease in total available lysine were also observed at 25 and 45 °C, respectively, after 6 months' storage. On the other hand, there was only a 6% decrease of total available lysine at 10 °C during 6 months' storage. Decrease in total

Table 3
Protein and starch digestibilities of maize grains during storage at three temperatures[a]

Storage time (months)	Protein digestibility %			Starch digestibility %		
	10 °C	25 °C	45 °C	10 °C	25 °C	45 °C
	a			a		
0	77.0±1.23	–	–	57.7±1.33	–	–
	a	a	a	a	a	a
1	77.9±1.44	76.8±1.72	76.5±2.13	57.6±1.30	56.5±1.25	56.0±1.47
	a	a	b	a	b	b
2	76.8±1.05	75.7±1.69	75.0±1.73	56.9±1.72	54.5±1.49	54.0±2.69
	a	b	b	a	b	c
3	76.8±1.11	74.8±2.22	73.8^{a}±2.09	56.8±1.77	53.0±2.26	52.0^{a}±1.22
	a	b	c	a	c	c
4	76.7±2.36	74.0±1.89	73.0±1.80	56.7±1.34	52.5^{a}±2.00	52.0±1.45
	a	c	c	a	c	c
5	76.5±2.00	73.5^{a}±1.29	71.0±2.72	56.4±1.60	52.0±1.44	51.0±2.73
	a	c	c	a	c	c
6	76.4±1.89	73.0±1.80	70.0±1.45	56.2±1.11	52.0±1.60	49.0±1.89

[a] Mean values ± SD triplicate determinations. Mean values within a column with different superscripts are significantly different at $P < 0.05$.

available lysine, at 25 and 45 °C, was significant ($P<0.05$) while it was found to be non-significant at 10 °C during 6 months storage. The decrease in total available lysine, during storage at different temperatures, could be the result of some structural changes which inhibited proteolysis and amino acid solubility (Martin-Cabrejas et al., 1995; Sowunmi, 1981).

Storage of maize grains at 25 and 45 °C resulted reduction in thiamine contents by 9.26 and 20.4%, respectively, after 6 months (Table 2). On the other hand, thiamine contents (27 mg/100 g) in the maize grains remained unchanged during storage at 10 °C. These results are consistent with the findings of other workers who found reduction in thiamine content by 32% on storage of cow peas for six months (Onayemi, Osibogun, & Obembe, 1986). Similar losses of thiamine were also observed by other workers during storage of chick peas, lima beans and other cereal grains at elevated temperatures (Burr, 1973; Sudesh & Kapoor, 1994).

Protein and starch digestibilities of maize grains were significantly affected at 45 °C ($P<0.05$), whereas they remained unchanged at 10 °C during storage (Table 3). Initially, protein and starch digestibilities of maize grains were 77.0 and 57.7%, respectively. However, at 25 °C, protein and starch digestibilities of maize grains decreased by 5.19 and 9.86%, and 9.0 and 15.1% at 45 °C, respectively. These results are consistent with the findings of other workers who reported a distinct decrease in protein digestibility of wheat, maize and cowpeas during storage (Burr, 1973; Onayemi, 1986). Decrease in protein and starch digestibilities could be the result of Maillard reactions, during which free amino groups of protein and carbonyl groups of reducing sugars form complex intermediate compounds by interacting with each other during storage of food materials. These complex compounds might have inhibited the activity of proteolytic and amylolytic enzymes, which ultimately caused distinct reductions in protein and starch digestibilities (Marshall & Chrastil, 1992).

4. Conclusion

Nutritional quality of corn grains was adversely affected as a result of storage at elevated temperature. Protein and starch digestibilities of maize grains decreased by 9.86 and 15%, respectively, on storage at 45 °C during 6 months. Decrease in total soluble sugars, total available lysine and thiamine contents were about 39.5, 19.9 and 20.4%, respectively, on storage at 45 °C for 6 months. Losses in these nutrients also occurred during storage of maize grains at 25 °C but to lesser extents. However, no significant changes in any of these nutrients were observed on storage of maize grains at 10 °C. Therefore, it is suggested that maize grains should not be stored above 25 °C in order to minimize nutrient losses during storage.

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