Qatar Univ. Sci. J. (1995), 15 (1): 147 - 156

CHANGES IN SOME CHEMICAL CONSTITUENTS OF STORED GRAIN AND ANIMAL FEED IN TWO PROVINCES IN SAUDI ARABIA

By

ZAKY M.F. ROSTOM* AND SALAH A. OSMAN**
* Department of Entomology, Faculty of Science, Ain Shams University, Abbassiah, Cairo.
**Department of Chemistry, College of Education, King Faisal University, Al-Ahsaa, Saudi Arabia

التغير في بعض المكونات الكيميائية بالحبوب وعلف الحيوان المخزونة في منطقتين بالمملكة العربية السعودية

زكي محمد فتحي رستم وصلاح أحمد عثمان

أثناء تخزين حبوب القمح والذرة ونخالة القمح تم تقدير التغير في بعض مكوناتها الكيميائية وهي الحموضة الكلية والكربوهيدرات الكلية والسكريات المختزلة والنشا والبروتين الكلي والمستخلص الإثيري والصوديوم والبوتاسيوم والمغنسيوم والفوسفور الكلي والرماد والجلوتين المبلل والجاف والألياف الخام والكثافة النوعية .

وقد تم تخزين المواد المستخدمة في البحث في صوامع أو في مخازن عامة في كل من منطقتي الرياض والدمام بالمملكة العربية السعودية ، وفي كل من موسمي التخزين ١٩٨٧ ، ١٩٨٨ أخذت منها عينات بصفة دورية خلال ٦ فترات تخزينية مختلفة ، ومن على ٢ - ٣ ارتفاعات مختلفة داخل الصوامع .

ولتقدير أثر العوامل المؤثرة أثناء التخزين (المنطقة ونوع المادة المخزونة والإرتفاع داخل الصومعة والموسم التخزيني والفترة التخزينية) استخدمت ٤ نماذج مقترحة في تحليل النتائج شملت كل منها الظروف المتشابهة في احدى أو كلا المنطقتين .

وأوضحت الدراسة أن التغير في المكونات الكيميائية للحبوب وعلف الحيوان المستخدمة قد تأثر بشكل متنوع بالعوامل التي تمت دراستها

Key Words: Stored grain, Saudi Arabia

ABSTRACT

Changes in total acidity, total carbohydrates, reducing sugars, starch, total protein, ether soluble fraction, sodium, potassium, calcium, magnesium, total phosphorus, ash, dry and wet gluten, crude fibres and specific gravity of wheat and maize grains, and of wheat bran, during storage, were carried out. Commodities used were stored in bins, or in general stores, in Riyadh and Dammam provinces, Saudi Arabia. In each of 2 storing seasons, 1987 and 1988, samples of commodities were taken periodically at 6 different periods of storage. Grains were taken from 2-3 heights inside bins. Four linear models were suggested, each included similar conditions in one or both provinces, to make the effects of 5 factors studies (province, type of commodity, height inside bin, season, and period of storage) estimable. Changes in the chemical constituents of grain and animal feed used were found to be affected differently by these factors.

INTRODUCTION

A project surveying pest infestation of stored grain and animal feed in Riyadh (RD) and Dammam (DM) provinces, Saudi Arabia, in 1987 and 1988, had been carried out. RD area is a central arid locality, while DM lies on the eastern humid coast of the Arabian peninsula. The present work, being a part of that project, dealt with the changes of some chemical constituents and physical characteristics of grain and animal feed during storage. It is attempted to study the effects of 5 selected factors (province, type of commodity, height inside bin, season and period of storage) on deterioration of the commodities used. Items estimated were: total acidity, total carbohydrates, reducing sugars, starch, total protein, ether soluble fraction, sodium, potassium, calcium, magnesium, total phosphorus, ash, wet and dry gluten, crude fibres and specific gravity.

MATERIALS AND METHODS

Factors investigated were

1. Province and season. The experiment was carried out in plants of the Grain, Soils and Flour Mills Organization (G.S.F.M.O), Saudi Arabia, in RD and DM provinces, and repeated in 2 seasons, 1987 and 1988 (S1 and S2).

2. Type of commodity. Wheat variety Yocora Saudi 2 was stored in RD plant in 10 concrete star bins, each 29.3 m high and contained about 350 tonnes of grain. Five bins of wheat were exposed to routine treatment of fumigation and / or recycling (wheat in control bins, CW). The remaining five bins were not exposed to any treatment during the entire period of storage (wheat in experimental bins, EW).

A limited amount of maize grain (260 tonnes) was stored in a similar star bin, and treated as control commodity (CM), due to its high susceptibility to infestation and heating. At each sampling period, wheat was obtained from one experiment and one control bins, which bins were not used again, while maize samples were obtained from the same bin. Wheat bran (WB), which represented animal feed, was kept in a general store of final products in RD plant, packed in 50 Kg. bags and treated as control commodity.

In DM plant, due to the limited space available, only 2 concrete star bins were used. Each bin was 28 m high and filled with 255 tonnes of wheat. Wheat in one bin was treated as control and in the other as experimental grain. Maize grain and wheat bran were kept in a general store of final products in DM plant, packed and treated as bran in RD plant.

3. Height inside bin. In RD plant, at each period of storage, five samples of wheat. about 1 kg each, were obtained from 3 different heights, an uppermost (U), a lowermost (L) and at about midway of the bin (M). Periodic samples of maize were taken from U and L heights only to avoid unnecessary disturbance of grain. In case of bran, 5 samples, each 1 kg, were taken from a different bag at each sampling date. In DM plant, periodic samples of wheat were obtained from U and L heights of both EW and CW.

4. Period of storage. Storage extended for $11^1/_2$ months each season, during which period 6 samples were taken from each plant (T1 to T6). Sample T1 was obtained from each commodity at the beginning of either season, representing base line data, at 19-24 days period of storage. Sample T2-T6 were taken in February, April, June, September and November, at periods of storage of 60-70, 119-133, 189-209, 272-293 and 335-342 days, respectively. Each sample consisted of 5 replicates, 1 kg each.

Chemical analysis: Grain samples, used without further cleaning, were thoroughly mixed, air dried and finely ground in a dust-proof mill. Analysis, unless otherwise specified, was conducted according to the AOAC methods [1] as follows: total acidity: AOAC, 11.037; total carbohydrates (CHO): extraction of ground samples was made according to the method of Smith & Stallman [2] and Jacobs [3]; the acid soluble CHO were determined as glucose units using the anthrone-thiourea method as modified by Roa [4] and Zill [5]; reducing sugars: determined by the Somogi microcopper method, using air dried samples, according to whistler *et al* [6]; starch: Allen *et al.* [7]; total protein: AOAC, 2.061; ether soluble fraction: AOAC, 7.056; sodium and potassium: determined in the ash of samples using flame photometry; calcium and magnesium: determined in the ash of samples using EDTA as a complexing agent [8-10]; total phosphorus : AOAC 7.118 and 1.032; ash : combustion was made at 625°C at least 3 hrs; wet and dry gluten: by Jacab method [3], and drying was made at 105°C; crude fibers: According to Allen *et al.* [7]; specific gravity: calculated from the weight of 1000 cm^3 of grain, measured in a dry 1 L cylinder.

Statistical analysis: As far as the storing conditions in both of RD and DM plants were not always identical, similar conditions were grouped in each of the 4 suggested models, M1-M4, to make the effects of factors studied estimable. These models obviated the effects of the following factors; province (M1 and M4), height inside bin (M1-M3), type of commodity, season and period of storage (M1-M4; Table 1). Statistical analysis was carried out by the GLM test, using SAS program. Results were expressed as least square means of factors (LSMeans).

RESULTS

The LS means of the items analyzed, grouped in M1-M4, are given in Tables 2-5. Factors studied had significant main effects on changing these items as follows:

A. Province: In M1, which compared between RD and DM provinces in both seasons, significant differences between both areas were shown as follows: total carbohydrates, ether soluble fraction, crude fiber (RD > DM), total acidity, starch, total protein, Na, Mg, P and ash (DM > RD).

B. Type of commodity: M1 and M2, which compared between EW and CW in both seasons, revealed that differences between commodities stored in bins in RD and DM plants were mostly non significant, except for the following items: in M1: total carbohydrates, Ca (EW > CW), total protein and P (CW > EW); in M2: total acidity, Na (EW > CW) and P (CW > EW).

On the other hand, differences between commodities used in M3 and M4 were, in most cases, significant. In M3, which compared between CM and CW stored in bins in RD plant in both seasons, showed that values of CW > CM in case of total protein, Na, K, Ca, Mg, P, ash, crude fiber and specific gravity, and the reverse was true (CM > CW) for total acidity, total carbohydrates, reducing sugars, starch and ether soluble fraction. In M4, which compared between WB and CM stored in a general store in DM plant, in both seasons, values of WB > CM for total acidity, total protein, Na, K, Ca, Mg, P, ash, and crude fiber, while those of CM > WB for total carbohydrates, starch, and ether soluble fraction.

C. Height inside bin: M1 and M3, compared between 2-3 heights inside bin, and revealed that height had limited significant effects on items analyzed as follows in M1: total acidity, total protein, Mg, ash, dry and wet gluten (U > L), and total carbohydrates (L > U); in M2: reducing sugars, total protein, Ca, Mg, ash, dry and wet gluten (U > M, L, or U > M); total carbohydrates (M, L > U), and in M3: Ca, Mg, ash (U > L), and total carbohydrates (L > U).

D. Season: In M1-M4, which compared between 2 storing seasons 1987 and 1988, significant results were: follows: in M1: reducing sugars, starch, Ca and crude fiber (S1 > S2), total acidity, total carbohydrates, total protein, ether soluble fraction, K, ash, dry and wet gluten and specific gravity (S2 > S1); in M2: reducing sugars, starch, Na, Ca, P, crude fiber (S1 > S2), total acidity, total carbohydrates, ether soluble fraction, K, Mg, ash, dry and wet gluten and specific gravity (S2 > S1); in M3: starch, ether soluble fraction, Na, Ca, specific gravity (S1 > S2), total acidity, total carbohydrates, K and ash (S2 > S1) and in M4: total protein, Mg (S1 > S2), total carbohydrates, reducing sugars and P (S2 > S1).

E. Period of storage: In M1-M4, which compared between different periods of storage, most items analyzed were affected, and variable significant peaks were evident in one or more periods of storage in each item.

Conclusion: Under conditions of the present investigation, the chemical constituents of commodities stored in RD and DM plants, were affected differently by one or more of the 5 factors investigated: province, type of commodity, height inside bin, season and period of storage.

DISCUSSION

Total acidity

Deterioration of grains in storage is accompanied by an increase in acidity. Hydrogen ion concentration tends to increase with age, but because of the buffer action of the proteins and some other grain constituents, marked changes in the hydrogen ion concentration ordinarily do not occur until deterioration is fairly well advanced. Titratable acidity, on the other hand, is likely to increase significantly even in the very early stages of deterioration [11]. High fat acidity of grain during storage affects breadmaking processes, *viz.* harms milling properties and causes poor baking quality of flour [12] increases ash content and produces poor color [13] and [14]. Hutchins on [15], however, rejected these ideas and concluded that fat acidity did not provide valid information for evaluation of the baking quality of stored wheat or flour; wheat flour may maintain its baking quality for many years despite a progressive increase in fat acidity.

Zeleny and Coleman [16] indicated that acids in grain consists mainly of : a) FFA produced by the action of lipase's on fats, b) acid phosphates produced by the action of proteolytic enzymes on protein. Acidity values and other indexes of deterioration were determined periodically in stored wheat. Fat acidity, phosphate acidity and titratable total acidity increased as wheat deteriorated in storage. The amino acid acidity showed no increase. The rate of increase of fat acidity was greater than that of phosphate total acidity, particularly during early stages of deterioration.

In the present investigation, total acidity was variably affected by the 5 factors in the 4 models used. Results of other authors varied greatly. An increase in acidity in stored wheat was recorded [17-24]. Large fluctuations of acidity in corn during storage were recorded [25,26], and in wheat [23]. On the other hand, significant reduction in acidity of stored wheat was recorded [27,28].

Although fat acidity may be taken in consideration as an index of changes occurring during grain storage, yet a meaningful limit for fat acidity could not be specified [29] without considering the previous history of grain. There is no proof that an increase in fat acidity is identical with damage to grain. Rate of increase of fat acidity is generally an index of the changes in grains. On the other hand, it is believed that a decrease in polar wheat flour lipids is a better index of damage during storage than increase in FFA [29].

Carbohydrates, Starch and Reducing Sugars

Data of other authors showed capricious results of starch and different CHO contents of grains during storage, eg. an increase/decrease in the total sugar content [30], starch hydrolysis [31-33], starch hydrolysis accompanied by consumption of resulting sugars in respiration, a reduction/disappearance/increase of non-reducing sugars [18,30,33,35], increase/inappreciable changes/various fluctuations in reducing sugars [33,35,36], inappreciable changes/reduction in mono and di-saccharides.

Nitrogenous compounds

A drop in protein content was recorded by some authors on wheat during storage's [30,33,37,38]. On the other hand, protein content rose during storage of wheat, which was interpreted by respiratory losses of CHO [39,40].

Ether Foluble Fraction

Deteriortive changes in grain fats and oils may be either:

a) oxidative, resulting in a typical rancid flavors and odors, or b) hydrolytic, resulting in the production of free fatty acids (FFA). Grains contain active antioxidants and fats in unbroken kernels of grain are protected against effects of oxygen in air. Accordingly, development of oxidative rancidity is rarely a problem in grain storage, although it is often a serious problem in milled products. Whole wheat flour can be kept only for a relatively short time because it rancids readily regardless of its moisture content [32].

Fats in grains are readily broken down by lipases into FFA and glycerol during storage, particularly when temperature and moisture contents are high favoring general deterioration. This type of change is greatly accelerated by mold growth due to high lipolytic activity of the mold. Fat hydrolysis takes place much more rapidly than that of protein or CHO in stored grain. For this reasons FFA content of grain is a considered by some authors as sensitive index of grain deterioration. Data of ether extractable material recorded by other authors [41-43] pointed mainly to a reduction in lipids during deterioration in storage.

Minerals

Sparse data of other authors [44,45] showed an increase in P content during storage.

Ash

A significant drop in ash content of wheat during storage was detected [33].

Wet and Dry Gluten

A drop in wet and dry gluten in stored wheat was recorded [33]. The quality of gluten in wheat was found to deteriorate during storage [39].

Table 1

Factors included in 4 models suggested for comparison in 2 storing seasons, 1987 and 1988 at 6 different periods of storage, T1 - T6, in each season.

Model \ Factor	Province	Height	Commodity
1	RD, AM	U, L	EW , CW
2	RD	U,M,L	EW, CW
3	RD	U,L	CW, CM
4	DM	-	CM, WB

RD & DM = Riyadh and Dammam plants, respectively;
U,M & L = upper, middle and lower heights inside bin, respectively;
CM = maize in control bin; CW = wheat in control bin; EW = wheat in experimental bin; WB = wheat bran stored in a general store in Riyadh and Damman plants.

Table 2

Model 1 : Changes in the chemical constituents of grain and animal feed during 6 periods of storage in each of seasons 1987 and 1988; the model included wheat grain stored in experimental and control bins in RD and DM provinces, at an upper and lower heights inside bins

ITEMS Factors	Acidity	Carbohydrates	Reducing sugars	Starch	Protein	Ether soluble fraction	Sodium	Potassium	Caicium	Manesium	Phosphorus	Ash	Dry giuten	Wet gluten	Crude fibre	Speciffic gravity
I.Main effects																
PV:																
RD	0.35±0,0056	71.6±0.15a	1.08±0.02	55±0.44b	14.5±0.07b	1.78±0.01a	18.1±0.61b	408±2.8	63.6±1.02	137±1.4b	297±3.2b	1.76±0.01b	11.4±0.15	31.5±0.29	2.24±0.02a	784±2.3
DM	0.38±0.006a	71±0.15b	1.07±0.02	56.4±0.44a	14.9±0.07a	1.74±0.01b	25.8±0.61a	410±2.8	627±1.02	148±1.4a	355±3.2a	1.87±0.01a	11.8±0.15	31.9±0.29	2.16±0.02b	781±2.3
PR>F	0.0002	0.02	0.61	0.027	0.0002	0.014	0.0001	0.69	0.595	0.0001	0.0001	0.0001	0.08	0.45	0.004	0.36
GN:																
EW	0.37±0.005	71.8±0.15a	1.09±0.02	55.7±0.44	14.6±0.07b	1.75±0.01	22.3±0.61	406±2.8	64.9±1.02a	142±1.4	321±3.2b	1.81±0.01	11.7±0.15	31.4±0.29	2.21±0.02	784±2.3
CW	0.36±0.005	70.8±0.15b	1.06±0.02	55.8±0.44	14.8±0.07a	1.77±0.01	21.5±61	411±2.8	61.3±1.02b	143±1.4	331±3.2a	1.83±0.01	11.6±0.15	32±0.29	2.19±0.02	781±2.3
PR>F	0.069	0.0001	0.293	0.95	0.03	0.497	0.362	0.18	0.013	0.55	0.025	0.388	0.64	0.13	0.392	0.36
HT:																
U	0.37±0.005a	70.9±0.15b	1.09±0.02	55.8±0.44	14.8±0.07a	1.76±0.01	22.6±0.61	408±2.8	63.8±1.02	145±1.4a	327±3.3	1.85±0.01a	12.1±0.14a	32.9±0.29a	2.2±0.02	784±2.3
L	0.36±0.005b	71.7±0.15a	1.06±0.02	55.7±0.44	14.6±0.07b	1.76±0.01	21.3±0.61	4.9±2.8	62.6±1.02	139±1.4b	325±3.2	1.78±0.01b	11.2±0.15b	30.6±0.29b	2.2±0.02	780±2.3
PR>F	0.016	0.0002	0.399	0.84	0.024	0.67	0.148	0.74	0.363	0.003	0.58	0.0003	0.0001	0.0001	0.0936	0.264
SS:																
1987	0.34±0.005b	71.1±0.15b	1.11±0.02a	58.2±0.44a	14.6±0.07	1.67±0.01b	22.4±0.61	382±2.8b	68.9±1.01a	142±1.4	322±3.3	1.73±0.01b	11.2±0.14b	29.6±0.29b	2.26±0.02a	772±2.3b
1988	0.38±0.005a	71.6±0.15a	1.04±0.02b	58.2±0.44b	14.8±0.07	1.85±0.01a	21.5±0.61	436±2.8a	57.3±1.01b	142±1.4	330±3.3	1.91±0.01a	12.1±0.14a	33.8±0.29a	2.15±0.02b	293±2.3a
PR>F	0.0001	0.031	0.01	0.0001	-.051	0.0001	0.307	0.0001	0.0001	0.99	0.11	0.0001	0.0001	0.0001	0.0001	0.0001
T:																
T1	0.3±0.009	71±0.26	1.07±0.04	55.8±0.77	15.1±0.13	1.71±0.02	22.1±1.1	419±4.9	52.5±1.77	144±2.4	347±5.6	1.81±0.02	12.2±0.25	33.6±0.5	2.29±0.03	789±3.9
	c	b	ac	bc	a	b	ace	a	d	ab	ac	ab	ace	aceg	a	a
T2	0.34±0.009	70.9±0.26	1.01±0.03	54.3±0.77	15±0.13	1.69±0.02	29.3±1.1	416±4.9	57.1±1.77	135±2.4	348±5.8	1.84±0.02	10.9±0.25	29±0.5	2.15±0.03	783±4.1
	c	bc	ae	c	a	b	b	a	cd	b	a	ab	bgh	b	b	ab
T3	0.33±0.009	69.6±0.26	0.97±0.03	57.8±0.77	14.9±0.13	1.7±0.02	22.8±1.1	413±4.9	61.3±1.77	141±2.4	354±5.7	1.87±0.02	11.9±0.25	32.1±0.5	2.25±0.03	792±3.9
	c	c	be	ab	a	b	a	a	c	ab	a	a	a	di	ab	a
T4	0.42±0.009	72.9±0.26	1.08±0.03	51.1±0.77	14.9±.0.13	1.83±0.02	22.6±1.1	387±4.9	63.3±1.77	143±2.4	350±5.6	1.8±0.02	12.5±0.25	33.6±0.5	2.12±0.03	784±3.9
	a	a	a	d	a	a	a	b	bc	ab	a	ab	a	a	b	ab
T5	0.41±0.009	71.9±0.26	1.21±0.03	56.1±0.77	13.9±0.13	1.82±0.02	16.5±1.1	413±4.9	74.2±1.77	147±2.4	283±5.6	1.84±0.02	11.1±0.25	30.5±0.5	2.18±0.03	777±3.9
	ab	b	d	abc	b	a	d	a	a	a	bd	ab	dgi	fi	ab	ab
T6	0.38±0.009	71.3±0.26	1.1±0.03	59.2±0.77	a4.2±0.13	1.81±0.02	18.3±1.1	4.5±4.9	70.3±1.77	142±2.4	276±5.6	1.76±0.02	11±0.25	31.5±0.5	2.22±0.03	769±3.9
	b	b	a	a	b	a	f	ab	ab	ab	d	b	fhi	hij	ab	b
PR>F	0.0001	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.023	0.0001	0.025	0.0001	0.0001	0.002	0.002
II. INTERACTIONS															0	
PV'GN	0.857	0.204	0.385	0.222	0.056	0.687	0.884	0.252	0.0001	0.465	0.005	0.009	0.094	0.426	0.21	0.209
PV'HT	0.765	0.037	0.005	0.633	0.096	0.481	0.815	0.16	0.02	0.908	0.117	0.535	0.635	0.128	0.698	0.164
PV'SS	0.0001	0.092	0.042	0.0001	0.391	0.028	0.233	0.001	0.0001	0.066	0.0009	0.0001	0.112	0.417	0.063	0.0001
PV'T	0.512	0.0001	0.252	0.016	0.0001	0.18	0.0001	0.004	0.013	0.0001	0.004	0.0001	0.002	0.0001	0.0001	0.063
GN'HT	0.037	0.295	0.522	0.0001	0.109	0.077	0.341	0.273	0.024	0.782	0.164	0.472	0.011	0.016	0.063	0.741
GN'SS	0.107	0.264	0.328	0.752	0.0001	0.452	0.152	0.313	0.008	0.003	0.011	0.543	0.041	0.001	0.477	0.637
GN'T	0.081	0.0001	0.129	0.52	0.0001	0.407	0.012	0.082	0.03	0.016	0.087	0.466	0.083	0.074	0.244	0.503
HT'SS	0.952	0.001	0.004	0.692	0.91	0.843	0.06	0.385	0.098	0.082	0.235	0.0003	0.043	0.007	0.107	0.801
HT'T	0.321	0.05	0.467	0.996	0.923	0.865	0.199	0.995	0.538	0.002	0.011	0.144	0.0001	0.0001	0.462	0.64
SS'T	0.0001	0.0001	0.003	0.017	0.015	0.0001	0.0001	0.0001	0.002	0.0001	0.0001	0.0001	0.002	0.0001	0.0001	0.0002

Table 3

Model 2 : changes in the chemical constituents of grain and animal feed during 6 periods of storage in each of seasons 1987 and 1988; the model included wheat grain stored in experimental and control bins in RD province, at an upper , middle and lower heights inside bins.

Items Factors	Acidity	Carbohydrates	Reducing sugars	Starch	Protein	Ether soluble fraction	Sodium	Potassium	Calcium	Manesium	Phosphorus	Ash	Dry gluten	Wet gluten	Crude fibre	Speciffic gravity
I.Main effects																
GN:																
EW	0.355±0.01a	72.0±0.15	1.09 0.02	55.1±0.4	14.6±0.09	1.79±0.01	18.8±0.38a	407±2.8	61.4±0.89	133.6±1.5	290.1±2.7b	1.73±0.01	11.7±0.19	31.5±0.34	2.25±0.02	785±1.9
CW	0.338±0.01b	71.5±0.15	1.06±0.02	55.4±0.4	14.4±0.09	1.79±0.01	17.4±0.87b	407±2.8	63.1±0.89	136±1.5	303.7±2.8a	1.75±0.01	11.3±0.18	31.7±0.33	2.21±0.02	784±1.9
PR>F	0.047	0.059	0.226	0.61	0.289	0.752	0.009	0.96	0.184	0.266	0.0007	0.269	0.154	0.668	0.11	0.688
HT:																
U	0.36±0.01	70.9±0.196	1.14±0.02a	55.3±0.5	14.7±0.1a	1.77±0.02	18.6±0.46	404±3.4	65.9±1.1a	139.6±1.9a	292.5±3.4	1.79±0.02a	11.8±0.22a	32.4±0.4a	2.23±0.02	783±2.3
M	0.338±0.01	72.1±0.19a	1.06±0.03b	55.6±0.5	14.5±0.1ab	1.8±0.02	18.1±0.48	40.8±3.4	59.7±1.1b	131.5±1.9b	298.6±3.3	1.7±02b	11.7±0.22b	31.8±0.4b	2.22±0.02	787±2.3
L	0.341±0.01	72.2±0.19a	1.03±0.02b	54.8±0.5	14.3±0.1b	1.79±0.02	17.5±0.46	411±3.4	61.1±1.1b	133.4±1.9ab	299.6±3.3	1.74±0.02ab	11±0.22ab	30.6±0.42ab	2.24±0.02	784±2.3
PR>F	0.093	0.0001	0.002	0.594	0.021	0.43	0.221	0.321	0.0003	0.007	0.281	0.001	0.024	0.008	0.75	0.468
SS:																
1987	0.311±0.01B	71.4±0.15b	1.14±0.02a	59.2±0.4a	14.5±0.09	1.67±0.01b	19.3±0.38a	376±2.8b	71.5±0.89a	132.4±1.5b	302.2±2.8a	1.61±0.01b	11±0.18b	29.5±0.3b	2.26±0.02a	765±1.96
1988	0.381±0.01a	72.1±0.15a	1.01±0.02b	51.3±0.4b	14.5±0.09	1.9±0.01a	16.8±0.37b	439±2.8a	53±0.89b	137.3±1.5a	291.6±2.7b	1.88±0.01a	12±0.18a	33.7±0.3a	2.21±0.02b	804±1.9a
PR>F	0.0001	0.0006	0.0001	0.0001	0.93	0.0001	0.0001	0.0001	0.0001	0.026	0.007	0.0001	0.0003	0.0001	0.047	0.0001
T:																
T1	0.288±0.01	71.3±0.27	1.1±0.03	54.8±0.8	14.7±0.15	1.75±0.02	21.2±0.65	436±4.8	53.9±1.53	140.6±2.6	305.2±4.6	1.65±0.02	11.1±0.31	30.7±0.6	2.31±0.03	780±3.3
	o	ab	ab	bo	ab	bi	aceg	a	d	ab	ace	o	abcel	ace	ab	b
T2	0.324±0.01	71.9±0.27	1.05±0.03	56.7±0.8	14.4±0.15	1.72±0.02	17.7±0.65	408±4.8	56.7±1.53	107.2±2.6	317.2±5	1.78±0.02	10.5±0.31	28.6±0.6	2.37±0.03	784±3.5
	bo	a	bo	ab	b	o	bi	bc	d	c	ag	ab	ag	b	a	b
T3	0.331±0.01	70.8±0.27	0.94±0.03	58.6±0.8	14.6±0.15	1.71±0.02	15.3±0.65	409±4.8	59.5±1.53	133.3±2.6	318.4±4.7	1.83±0.02	11.8±0.31	31.7±0.6	2.18±0.03	798±3.3
	b	b	o	a	ab	o	d	b	cd	b	bg	a	bhi	ag	cd	a
T4	0.383±0.01	72.3±0.27	1.06±0.03	50±0.8	15.1±0.15	1.9±0.02	22.1±0.65	388±4.8	64.9±1.53	143.9±2.6	321.3±4.7	1.75±0.02	12.9±0.31	34.2±0.6	2.09±0.03	784±3.3
	a	a	bo	d	a	a	a	c	bc	ab	bg	ab	d	dh	d	b
T5	0.391±0.01	72.1±0.27	1.19±0.03	53.3±0.8	14.1±0.15	1.83±0.02	12.8±0.65	4.6±4.8	66.4±1.53	145.3±2.6	276.5±4.7	1.77±0.02	11.4±0.34	31.4±0.6	2.2±0.03	782±303
	a	a	a	o	b	ab	f	bc	ab	a	d	ab	ehj	al	bcd	b
T6	0.359±0.01	72.1±0.27	1.12±0.03	58.2±0.8	14.3±0.15	1.83±0.02	19.2±0.66	398±4.8	72±1.53	138.7±2.6	242.8±4.7	1.68±0.02	11.2±0.31	32.7±0.6	2.25±0.03	871±303
	ab	a	ab	a	b	ab	hi	bc	a	ab	f	bc	fgil	fghi	abc	b
PR>F	0.0001	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.003
II. INTERACTIONS																
GN'HT	0.078	0.111	0.305	0.003	0.108	0.288	0.029	0.935	0.082	0.899	0.018	0.002	0.178	0.427	0.251	0.402
GN'SS	0.239	0.89	0.551	0.003	0.043	0.281	0.008	0.102	0.318	0.007	0.0007	0.994	0.636	0.942	0.004	0.041
GN'T	0.0004	0.0009	0.876	0.007	0.001	0.189	0.0001	0.197	0.468	0.014	0.0001	0.039	0.016	0.003	0.129	0.077
HT'SS	0.596	0.0001	0.0008	0.366	0.345	0.889	0.054	0.288	0.234	0.122	0.204	0.198	0.407	0.578	0.306	0.688
HT'T	0.373	0.055	0.726	0.496	0.474	0.735	0.1	0.438	0.00009	0.105	0.108	0.0007	0.028	0.074	0.221	0.052
SS'T	0.0001	0.011	0.0001	0.0001	0.038	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.007	0.0001	0.0001	0.0001

Table 4

Model 3 : changes in the chemical constituents of grain and animal feed during 6 periods of storage in each of seasons 1987 and 1988; the model included wheat and maize grain stored in control bins in RD province, at an upper , middle and lower heights inside bins.

Items Factors	Acidity	Carbohydrates	Reducing sugars	Starch	Protein	Ether soluble fraction	Sodium	Potassium	Caicium	Manesium	Phosphorus	Ash	Crude fibre	Speciffic gravity
I.Main effects														
GN:														
CW	0.343±0.01b	71.2±0.14b	1.06±0.04b	55.4±0.39b	14.5±0.09a	1.79±0.02b	17.8±0.3a	408.3±3.6a	64±1..18a	137.8±1.9a	308.7±3.8a	1.8±0.02a	2.21±0.02a	785±2.4a
CM	0.516±0.01a	73.4±0.014a	1.71±0.04a	60.6±0.39a	8.45±0.09b	4.08±0.02a	10.4±0.3b	363.8±3.6b	13.1±1.18b	1.1±1.9b	283.1±3.8b	1.47±0.02b	1.84±0.02b	762±2.4b
PR>F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
HT:														
U	0.426±0.01	72.1±0.14b	1.42±0.04	57.7±0.39	11.5±0.09	2.91±0.02	14.1±0.3	389.2±3.6	40.4±1.18a	122.6±1.97a	297±3.8	1.67±0.02a	2.04±0.02	772±2.4
L	0.433±0.01	72.6±0.14a	1.34±0.04	58.4±0.39	11.5±0.09	2.96±0.02	14.1±0.3	382.9±3.6	36.8±1.18b	116.2±1.96	294.8±3.8	1.59±0.02b	2.02±0.02	775±2.4
PR>F	0.416	0.018	0.123	0.245	0.788	0.201	0.993	0.22	0.034	0.021	0.677	0.002	0.547	0.345
SS:														
1987	0.369±0.01b	72.1±0.14b	1.41±0.04	62.3±0.39a	11.5±0.09	2.98±0.02a	16.8±0.3a	374.4±3.6b	44.5±1.18a	118.8±1.97	298.4±3.8	1.56±0.02b	1.9±0.02	780±23a
1988	0.489±0.01a	72.6±0.14a	1.35±0.04	53.8±0.396	11.5±0.09	2.89±0.02b	11.4±0.3b	397±3.6a	32.6±1.18b	120±1.99	293.4±3.8	1.71±0.02a	2.06±0.02	768±2.3b
PR>F	0.0001	0.029	0.287	0.0001	0.547	0.022	0.0001	0.0001	0.0001	0.648	0.348	0.0001	0.053	0.002
T:														
T1	0.364±0.01	71.2±0.24	1.62±0.07	56±0.68	11.8±0.15	3.33±0.04	17.3±0.53	415±6.2	33.3±2	133.2±3.3	300.6±6.3	1.56±0.03	2.03±0.04	766±3.9
	c	c	a	bc	ab	a	aceg	a	b	ace	ace		b	bc
T2	0.337±0.01	72.1±0.24	1.29±0.07	60±0.68	11.4±0.15	3.11±0.04	16.5±0.53	400.4±6.2	95.7±2	98.9±3.3	317.2±7.1	1.63±0.03	2.31±0.04	787±4.5
	c	bc	bc	a	ab	b	a	ab	ab	b	agh		a	a
T3	0.333±0.01	71.8±0.24	1.11±0.07	58.9±0.68	11.4±0.15	2.81±0.04	11.8±0.53	363.3±6.2	39.3±2	114±3.3	310.9±6.3	1.67±0.03	2.01±0.04	793±3.9
	c	abc	c	a	ab	c	bi	c	ab	dg	agi		b	a
T4	0.484±0.01	72.7±0.24	1.48±0.07	54.4±0.68	11.9±0.15	2.74±0.04	14.6±0.53	364.6±6.2	38.7±2	121.8±3.3	322.8±6.3	1.65±0.03	1.83±0.04	781±3.9
	b	ab	ab	c	a	c	di	c	ab	fghi	bhi		c	ab
T5	0.521±0.01	73.1±0.24	1.42±0.07	58.2±0.68	11.2±0.15	2.81±0.04	11.1±0.53	381.4±6.2	43±2	124.5±3.3	279.7±6.3	1.66±0.03	2.05±0.04	765±3.9
	ab	a	ab	ab	b	c	fi	bc	a	ah	d		b	bc
T6	0.539±0.01	73.1±0.24	1.38±0.07	60.8±0.68	11.3±0.15	2.84±0.04	13.4±0.53	391.6±6.2	41.3±2	124.1±3.3	244.3±6.3	1.63±0.03	1.93±0.04	649±3.9
	a	a	abc	a	ab	c	hi	ab	ab	ai	f		bc	c
PR>F'	0.0001	0.0001	0.0001	0.0001	0.006	0.0001	0.0001	0.0001	0.014	0.0001	0.0001	0.164	0.0001	0.0001
II. INTERACTIONS														
GN'HT	0.828	0.016	0.938	0.011	0.077	0.121	0.567	0.013	0.01	0.744	0.123	0.388	0.655	0.075
GN'SS	0.0001	0.384	0.392	0.018	0.799	0.0001	0.0001	0.0001	0.0001	0.038	0.018	0.0002	0.02	0.0001
GN'T	0.0001	0.0001	0.009	0.014	0.091	0.0001	0.014	0.003	0.0009	0.0006	0.037	0.0001	0.0001	0.048
HT'SS	0.131	0.0001	0.501	0.475	0.243	0.99	0.623	0.128	0.358	0.711	0.634	0.585	0.953	0.169
HT'T	0.049	0.199	0.252	0.01	0.412	0.448	0.003	0.206	0.05	0.015	0.242	0.004	0.511	0.009
SS'T	0.0001	0.0001	0.0001	0.0001	0.172	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002

Table 5

Model 4 : changes in the chemical constituents of grain and animal feed during 6 periods of storage in each of seasons 1987 and 1988; the model included maize grain and wheat bran stored in a general store in DM province.

Items Factors	Acidity	Carbohydrates	Reducing sugars	Starch	Protein	Ether soluble fraction	Sodium	Potassium	Calcium	Manesium	Phosphorus	Ash	Crude fibre
I.Main effects													
GN:													
CW	0.495±0.02B	73.3±0.3a	1.78±0.04	62±1.7a	8.79±0.1b	4.21±.0.03a	16.7±1.4b	365±47b	16.4±2.6b	114.9±4.96	284.1±40.8b	1.45±0.06b	1.84±0.11b
CM	1.1±0.02A	53.9±0.3b	1.89±0.04	21.4±1.7b	17.6±0.1a	3.87±0.03b	76.1±1.4a	1176±47a	166.3±2.6a	452.5±4.9a	893.2±40.8a	5074±0.06a	8.83±0.11a
PR>F	0.0001	0.0001	0.054	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
SS:													
1987	0.79±0.02	62.9±0.3b	1.66±0.04b	42.6±1.7	13.5±0.1a	4.08±0.03	45.2±1.4	738±47	92.8±2.6	293.2±4.9a	529.6±40.8b	3.53±0.06	5.35±0.11
1988	0.81±0.02	64.3±0.3a	2±0.04a	40.8±1.7	12.9±0.1b	3.99±0.03	47.6±1.4	803±47	89.9±2.6	274.2±4.9b	647.8±40.8a	3.66±0.06	5.31±0.11
PR>F	0.486	0.001	0.0001	0.458	0.0001	0.058	0.245	0.33	0.43	0.01	0.049	0.136	0.81
T:													
T1	0.54±0.04	62.9±0.5	2.1±0.07	42.3±2.9	12.9±16	4.14±0.05	46.4±2.5	810±81	97.5±4.5	239.8±8.5	539±70.6	3.34±0.1	5.63±0.19
	aceg	b	a		b		b		ace	aceg		c	a
T2	0.68±0.04	63.3±0.3	1.41±0.07	42.2±2.9	12.7±0.16	3.00±0.05	67.3±2.5	673±81	73.7±4.5	288.2±8.2	559±70.6	3.33±0.1	5.29±0.19
	bi	ab	b		b		a		a	bij		c	a
T3	0.61±0.04	63.6±0.5	1.38±0.07	42.9±2.9	14.3±0.16	3.97±0.0.05	40.7±2.5	626±81	79.4±4.5	264.5±8.5	538±70.6	3.38±0.1	4.96±0.19
	ai	ab	b		a		b		al	al		bc	a
T4	1±0.04	65.2±0.5	2.37±0.07	39±2.9	12.5±0.16	3.99±0.05	40.3±2.5	799±81	97.3±4.5	291.1±8.5	657±70.6	3.79±0.1	4.98±0.19
	di	a	a		b		b		bg	did		ab	a
T5	1.1±0.04	62.9±0.5	2.35±0.07	38.4±2.9	13.9±0.1	4.09±0.05	44.9±2.5	849±81	128.8±4.5	327.6±8.5	669±70.6	3.96±0.1	5.75±0.19
	fi	b	a		a		b		d	f		a	a
T6	0.86±0.04	63.4±0.5	1.34±0.07	47.5±2.9	12.9±0.16	4.05±0.05	39±2.5	867±81	89.2±4.5e	291.1±8.5	515±70.6	3.78±0.1	5.39±0.19
	h	ab	b		b		b		efg	hi		ab	a
PR>F	0.0001	0.019	0.0001	0.172	0.0001	0.192	0.0001	0.229	0.0001	0.0001	0.555	0.0001	0.032
II. INTERACTIONS													
GN'SS	0.859	0.008	0.0001	0.103	0.0001	0.28	0.018	0.219	0.091	0.022	0.026	0.0007	0.083
GN'T	0.0001	0.0001	0.0001	0.58	0.0001	0.002	0.0004	0.153	0.0001	0.0001	0.179	0.0002	0.014
SS'T	0.0001	0.0001	0.0001	0.826	0.0001	0.0001	0.0001	0.414	0.011	0.0001	0.465	0.027	0.0003

ACKNOWLEDGMENTS

Thanks are due to KACST, Saudi Arabia, for funding this project [AT-7-164], to G.S.F.M.O., for providing facilities in Riyadh and Dammam plants, to Computer Centre, KFU and to Prof. Dr. Hussein Mansour, Faculty of Food and Agricultural Science, for their valuable help in statistical analysis.

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