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Physico-chemical properties of wheat (*Triticum aestivum*) under different storage receptacles

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ABSTRACT

Wheat is widely cultivated as a cash crop because it produces a good yield per unit area and grows well in a temperate climate even within a moderately short growing season. The demand of wheat remains high throughout the year because it is considered as staple food in many countries, which necessitates the proper storage and maintenance systems to obtain quality grains. Keeping this view point, the present study aimed to seek the physico-chemical properties of wheat variety- HD 2967, stored in different receptacles like silo, metal containers, plastic tank and in sacks. The physico-chemical characteristics like moisture, protein, ash, fat, carbohydrate, falling number, bulk density, angle of repose, angle of friction, hectolitre weight were recorded after every 45 days for a period of 180 days. The results revealed decrease in mean moisture (8.42 to 7.75%), protein content (13 to 11%), stirring number (1,821 to 1,021), 1,000 kernel seed weight (28.99 to 26.30 g), angle of repose (23.74° to 20.30˚), angle of friction (glass sheet- 29.16° to 14.03°, wooden sheet -22.73° to 16.69°, steel sheet -24.03° to 15.10° and on iron sheet- 30.87° to 21.80°) and colour value (L*,a*,b*,z*). An increase was observed in ash (1.78 to 2.02%) content and also in bulk density (748 to 828 kg/m^3). However, the physico-chemical properties of wheat grains remained within the reference range during the storage period and the results showed that no significant ($P<0.05$) difference was observed between the storage receptacles under the study period.

Key words: Containers , Physicochemical characteristics, Storage, Wheat

Wheat, an amble cereal grain, from the Levant region of the Near East but is now cultivated throughout the world. Wheat is the main constituent of vegetable protein for human food, as compared to other cereal grain such as maize (corn) or rice. Moreover, wheat is cultivated as a cash crop as it produces a good yield per unit area, grows well in a temperate climate with a moderately short growing season (FAO, 2015; USDA, 2016). The popularity of wheat food creates a huge demand in economy with significant food surpluses. In the Punjab region of India and Pakistan, as well as North China, irrigation has been a major contributor to increased grain output. Over the past four decades in developing countries, a massive use of fertilizer along with the increased availability of semi-dwarf varieties has greatly increased yields per hectares (Swaminathan, 2004). Previous researches have mentioned that owing to lack of storage structure, 10% of total wheat production is lost at farm level, another 10% is lost due to poor storage and road networks, and additional amounts lost at the retail level. The study conducted in ICAR-CIPHET, Ludhiana (India) on post-harvest losses of cereal grains showed that total loss of wheat in farm operations (during harvesting, collection, threshing, winnowing, drying, packaging and transport) was 4.07±0.29% and 0.86±0.13% during storage channel that includes from farm, godown, wholesale, retailers and processing. The overall total post harvest loss of wheat grains was 4.93±0.20% in 2005-07 (Jha et al., 2015). Another study claims that if these post-harvest losses of wheat grain could be eliminated with better infrastructure and retail network, in India

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alone enough food would be saved every year to feed 70 to 100 million people over a year (Basavaraja et al., 2000). The aim of the present research work is to investigate the physico-chemical properties of wheat under different storage receptacles so that post harvest losses can be minimised.

MATERIALS AND METHODS

Procurement of wheat grains

The freshly harvested grains of wheat variety- HD 2967, were procured and stored in different receptacles like silo, metal tank, plastic tank and in sacks for a period of six months. The atmospheric (temperature, °C and relative humidity, %) and physico-chemical parameters were monitored at an interval of 45 days for a period of six months.

Physico-chemical analysis

The moisture, ash, crude protein and crude fat were estimated using the standards methods (AOAC, 2000). Bulk density was calculated as weight of grains divided by volume occupied the grains and expressed as kg/m^3. 1,000 kernel weight was determined using Indosan (Ambala, India) seed counter. It is expressed as weight in grams of 1,000 seeds of grains. The falling number was estimated using Rapid Visco Analyser (RVA) by Tech Master, Newport Scientific (Australia) at a temp of 95°C with 160 rpm for 3 min for testing viscous properties (α- amalyse activity). The angle of repose can range from 0° to 90°. Angle of repose was calculated using different diameter of disc ranges such as 10, 15 and 20 cm.

$$Ø = \tan^{-1} \text{(Height of Cone/radius of disc)}$$

Angle of friction was determined on a fixed inclined plane made up of glass, iron, steel and wooden sheets with horizontal surface so that a body with second surfaces placed on it just starts sleeping. Angle of friction was calculated using the following formula:

Coefficient of friction = μ

Angle of friction = $Ø = \tan^{-1}\mu$

Coefficient of friction = Dead Weight/Sample weight

$Ø = \tan^{-1}$ (Dead Weight/Sample weight)

For analysing the colour value, wheat grains were processed to make it into fine flour and the colour of wheat flour was measured by using Minolta Spectrophotometer in the Hunter lab colour mode (Japan). The Hunter scale, 'L*' which, measures brightness band varies from 100 for perfect white to zero for black. The chromaticity dimensions (a* and b*) give understandable designations of colour i.e. the value 'a*' measures redness when positive, grey when zero and green when negative. The value 'b*' measures yellowness when positive, grey when zero and blueness when negative. In terms of these co-ordinates L*, a*, b*, z* these data's were converted to function of colour as total difference ΔE which was given on the display.

Statistical analysis

All the experiments were performed in triplicates and values are represented as Mean±SD. The difference between the means was further analyzed using Turkey's Post-Hoc Test at 0.05% level of significance on statistical package of social science (SPSS, 2007) version 16.

RESULTS AND DISCUSSION

Moisture

Change in moisture was observed after every 45 days for a period of six months among the different storage receptacles (Table 1). After six months of storage period, plastic container has reduced minimum moisture content as compared to rest of containers. However, that was statistically non-significant ($P>0.05$). The results are in line with the previous work that containers significantly affected the moisture content of grains of all varieties. One of the studies reported that grain moisture is an important attribute affecting the quality of flour. Increase in moisture content increases lipolytic and proteolytic activities resulting in production of more free fatty acids and loss of nutrients (lipid, protein) that contributes to inferior sensory qualities (Kent and Evers 1993; Hruskova and Machova 2002). However, another study reported that the moisture content increased under conditions of high humidity (Raza et al., 2010).

Bulk density

The effect of storage on test weight of wheat grains is given in Table 1. The bulk density of stored grains in sack decreased (748 to 734.41 kg/m^3) as compared to others containers i.e. metal (748-828.30 kg/m^3), plastic (748 to 792.71 kg/m^3) and sack (748 to 781.70 kg/m^3). One of the studies reported that wheat grains of higher test weight are usually considered to mill more readily and to yield finer flour, which can be related to greater ratio of endosperm to bran layer for kernel (Gaines et al., 1997). Similarly, the test weight of stored wheat grains affects the storage containers (Raza et al., 2010). Chaudhry et al. (1987) also observed that grains stored at 16% moisture content in cotton bags

Table 1 Effect of storage container on physical properties of stored grains

Parameter	0 days ^(30.5°C, 58 %RH)	45 days ^(27.45°C, 48.9%RH)	90 days ^(22.08°C, 50.70%RH)	135 days ^(28.30°C, 44.32%RH)	180 days ^(19.40°C, 55.76%RH)
Moisture, %					
Silo	8.42±0.16^{a}	7.67±0.16^{b}	8.96±0.38^{a}	7.77±0.12^{b}	7.48±0.71^{a}
Metal	8.42±0.16 ^{a}	7.65±0.02^{b}	9.15±0.52^{a}	8.04±0.29^{ab}	8.02±0.52^{a}
Plastic	8.42±0.16 ^{a}	8.38±0.13^{a}	8.96±0.31^{a}	9.37±1.14^{a}	8.34±0.59^{a}
Sack	8.42±0.16 ^{a}	7.16±0.28^{c}	7.30±0.37^{b}	8.25±0.25^{ab}	7.75±0.83^{a}
Bulk density, kg/m^{3}					
Silo	748.00±0.00	747.76±0.13	735.29±0.10	723.55±0.49	734.41±1.29
Metal	748.00±0.00	746.81±0.56	745.24±0.06	734.55±0.64	828.30±0.30
Plastic	748.00±0.00	720.98±0.04	714.58±0.01	709.33±0.45	792.71±0.50
Sack	748.00±0.00	747.80±0.10	746.69±0.01	744.55±0.69	781.70±0.13
1000 Kernel seed weight, g					
Silo	28.99±0.02	28.96±0.66	27.37±0.42	26.79±0.54	28.46±0.44
Metal	28.99±0.02	28.12 ±0.12	27.09±0.44	28.58±0.60	29.42±0.27
Plastic	28.99±0.02	28.27±0.41	27.33±0.34	28.84±0.52	26.30±0.57
Sack	28.99±0.02	27.49±0.76	28.53±1.12	28.66±0.49	26.43±0.56
Falling number					
Silo	1821.5±358.5	2086±2.82	1667.6±114.22	1428±16.97	1393±74.95
Metal	1821.5±358.5	1792±176.77	1649.33±70.61	1622.5±112.4	1552±19.79
Plastic	1821.5±358.5	2001±260.92	1390.66±115.33	1628±29.69	1618.5±4.94
Sack	1821.5±358.5	1979±23.03	1515.33±37.42	1414.5±20.50	1021.5±4.94

^implies storage temperature (°C) and relative humidity (% RH); *Tukey Post-Hoc test significance at 5% level; superscript with different alphabets implies significant difference at P<0.05

Table 2 Effect of storage container on chemical properties of stored grains

Parameter	0 days ^(30.5°C, 58 %RH)	45 days ^(27.45°C, 48.9%RH)	90 days ^(22.08°C, 50.70%RH)	135 days ^(28.30°C, 44.32%RH)	180 days ^(19.40°C, 55.76%RH)
Ash, %					
Silo	1.78±0.11^{a}	1.75±0.05^{a}	1.67±0.15^{b}	2.18±0.54^{a}	2.00±0.01^{a}
Metal	1.78±0.11^{a}	1.77±0.03^{a}	1.98±0.01^{a}	1.93±0.01^{a}	2.01±0.04^{a}
Plastic	1.78±0.11^{a}	1.79±0.07^{a}	1.84±0.02^{ab}	1.91±0.02^{a}	2.01±0.02^{a}
Sack	1.78±0.11^{a}	1.76±0.04^{a}	1.98±0.02^{a}	1.83±0.03^{a}	2.02±0.07^{a}
Protein, %					
Silo	13.06±0.10^{a}	13.69±0.28^{ab}	11.94±1.32^{a}	12.35±0.30^{a}	11.86±0.48^{a}
Metal	13.06±0.10^{a}	13.38±0.59^{ab}	12.07±0.97^{a}	11.35±1.14^{a}	10.98±0.45^{a}
Plastic	13.06±0.10^{a}	12.61±0.54^{b}	12.95±0.60^{a}	11.54±0.26^{a}	11.33±0.26^{a}
Sack	13.06±0.10^{a}	13.91±0.40^{a}	12.54±0.72^{a}	11.45±2.04^{a}	11.37±0.87^{a}
Fat, %					
Silo	1.54±0.06	2.29±1.01	1.03±0.31	0.85±0.53^{c}	2.22±0.35^{b}
Metal	1.54±0.06	4.14±1.24	4.79±2.50	2.67±1.22^{a}	3.42±1.12^{a}
Plastic	1.54±0.06	3.85±1.78	1.06±0.37	0.23±0.09^{d}	2.17±1.32^{b}
Sack	1.54±0.06	2.94±1.67	2.43±1.26	1.86±0.35^{b}	2.36±1.39^{b}

^implies storage temperature (°C) and relative humidity (% RH); *Tukey Post-Hoc test significance at 5% level; superscript with different alphabets implies significant difference at P<0.05

and tin container had lower test weight as compared to grains stored with 8 and 12% moisture level. These variations in test weight were related to change in moisture content of grains. The higher the moisture of grains the lower the test weight. Earlier researches reported that bulk density of wheat grain decreased from 695.750 to 646.451 kg/m^3 with the increase in moisture content (Bhaise et al., 2014).

1,000 kernel seed weight

The data on 1,000 kernel grain weight of wheat packed in different types of packing materials are presented in Table 1. The results indicated that the maximum 1000-grain weight decrease with progress of storage period from 28.99±0.02 to 28.46±0.44 g (silo), 27.46±0.27 g (metal), 26.30±0.57 g (plastic) and 26.43±0.56 g (sack). Chattahk et al. (2014) reported that with the progression of storage period, 1000 kernel seed weight decreased from 44.37 to 43.48 g after storage period of twelve months. In contrast, Hussain et al., (2015) reported that the thousand kernel weight increased from 38.597 g to 42.406 g with the increase in moisture content for grain.

Falling number

Falling number is directly related to α-amylase activity. It has considerable significance, since there is a direct relationship between enzyme activity and finished product. Pre-harvest sprouting or sprouting during storage, due to high temperature and humidity, increases the level of ά- amylase enzyme (Hussain et al., 2015; Bhise et al., 2014; Kruger et al., 1980). Stirring number decreased (Table 1) from 1821.5±358.5 to 1393±74.95 (silo), 1552±19.79 (metal), 1680.5±4.9 (plastic) and 1021±4.94 (sack) after six months storage period. Raza et al. (2010) also reported that falling number is affected by the atmosphere conditions. In contrast to present work, Gyori (1999) found no change in the falling number of wheat during storage for 10 months. Many other studies by various researchers also showed different results like, falling number of wheat stored in sacks did not change during the storage period of four months at a temperature of 10° to 13ºC (Zoltan and Zoltan, 2007). Hruskova et al. (2004**)** observed that the falling number increased over the storage period of 10 months in jute sacks at a temperature of 2° to 20ºC and with relative humidity of 51 to 72%. Similarly, Lukow et al., (1995) found that falling number values increased significantly in cotton bags for 15 months storage at ambient temperature (-4º to 25ºC) and relative humidity (28-73%). It is therefore not possible to reach at any conclusion regarding the suitability of storage containers based on falling number.

Ash

Results (Table 2) revealed ash content (%) increased in all the storage containers after six months i.e. 1.78±0.11% (initial) to 2.00±0.01% (silo), 2.01±0.04% (metal), 2.01±0.02% (plastic) and 2.02±0.07% (sack). However, containers and storage period does not affect the ash content significantly. Another study reported that the ash content was 1% in soft wheat (David et al., 2015).

Protein

Wheat is a good source of protein (12%) and the storage affects wheat protein content (FAO, 2002). The results revealed that during storage period, wheat protein content decreased from 13 to 11% in all the storage receptacles (Table 2).The maximum content of protein was in silo as compared to sack and plastic container. The results are in line with work reported by Pessu et al. (2005), that there was a significant decrease in protein content in different storage containers at the end of storage period. Another research finding reported that the protein content of wheat stored in earthen bin was 10.35% and in gunny bag 8.65% (Chukwu and Abdullahi, 2015).

Fat

Wheat as a staple diet for human beings contributes 20% of food calories of the world and contains 2% fat (David et al., 2015).The findings revealed that fat content increased in all the storage containers after a period of six months i.e. 1.54±0.06 (initial) to 2.22±0.35 (silo), 3.42±1.12 (metal), 2.17±1.32 (plastic) and 2.36±1.39 (sack) resulting in increased lipolytic activity (Table 2). However, metal container has the minmum loss of fat as compared to the rest of the containers. David et al. (2015) reported fat content as 1.33g/100g in soft wheat.

Angle of repose

Angle of repose decreased after a period of six months in all the storage containers. The angle of repose of wheat grains stored in different containers decreased (Table 3) from 23.74° to 22.95° (silo), 20.10° (metal), 22.29° (plastic) and 20.30° (sack). However, Bhise et al. (2014) reported that the angle of repose increased from 23.09° to 25.28° with the moisture range of 10 to 18% of cereal grains.

Angle of friction

Angle of friction on different materials such as glass, wood, steel and iron sheets decreased after a period of six months in all the storage containers (Table 3).

Colour value

The colour of stored wheat grain in different containers are measured in terms of L*, a*, b* and z*% value (Table 4). The L* and Z* values decreased in all the storage containers as compared

Table 3 Effect of storage on the angle of repose (°) and angle of friction (°) of stored wheat grains

Parameter	0 days ^(30.5°C, 58 %RH)	45 days ^(27.45°C, 48.9%RH)	90 days ^(22.08°C, 50.70%RH)	135 days ^(28.30°C, 44.32%RH)	180 days ^(19.40°C, 55.76%RH)
Angle of repose					
Silo					
20”	23.66	23.58	24.84	23.26	24.36
15”	23.74	23.65	23.26	23.74	22.95
10”	20.40	21.40	21.40	20.40	20.22
Metal					
20”	23.66	23.46	23.26	24.22	22.95
15”	23.74	23.25	22.29	20.80	20.10
10”	20.40	20.15	22.09	20.10	19.66
Plastic					
20”	23.66	23.44	23.74	24.03	20.30
15”	23.74	22.18	21.10	19.79	22.29
10”	20.40	20.80	21.10	21.40	24.70
Sack					
20”	23.66	22.98	22.78	23.55	21.98
15”	23.74	23.01	22.83	21.80	20.30
10”	20.40	21.22	22.09	21.80	18.77
Angle of friction					
Silo					
Glass sheet	29.16	23.66	17.95	20.90	14.03
Wood sheet	22.73	19.73	14.19	18.15	16.69
Steel sheet	24.03	21.55	14.19	20.00	18.77
Iron sheet	30.87	26.65	24.03	23.60	21.80
Metal					
Glass sheet	29.16	22.66	17.38	19.44	13.49
Wood sheet	22.73	18.55	15.85	16.96	20.80
Steel sheet	24.03	21.22	13.33	20.65	15.10
Iron sheet	30.87	23.56	23.31	22.14	24.22
Plastic					
Glass sheet	29.16	22.33	19.39	16.59	12.95
Wood sheet	22.73	19.56	15.37	18.10	19.79
Steel sheet	24.03	23.22	22.14	15.53	15.10
Iron sheet	30.87	25.55	23.74	18.10	22.78
Sack					
Glass sheet	29.16	27.55	24.89	16.69	14.03
Wood sheet	22.73	18.98	15.05	16.69	20.30
Steel sheet	24.03	21.68	16.22	19.49	15.64
Iron sheet	30.87	24.65	23.31	21.00	26.10

^implies storage temperature (°C) and relative humidity (% RH)

to a* and b* values, which increased slightly during the storage period. The findings are in line with the work reported by Bhise et al. (2014) that the Lightness (L*) of grain decreased from 58.42 to 56.40, a* value (red-green axis) decreased from 8.12 to 6.94, b* value (yellow-blue axis) decreased from 23.93 to 22.51 with increase in moisture content from 10 to 18 % of cereal grains. Hue angle (z*%) decreased from 14.44 to 13.59. A linear decrease in L*, a*, b* and hue angle with the increase in moisture content of wheat grain was observed during the study period.

Table 4 Effect of storage on the colour value of wheat stored in different containers

Parameter	0 days ^(30.5°C, 58 %RH)	45 days ^(27.45°C, 48.9%RH)	90 days ^(22.08°C, 50.70%RH)	135 days ^(28.30°C, 44.32%RH)	180 days ^(19.40°C, 55.76%RH)
L value*					
Silo	82.51±1.18	82.21±2.51	81.72±0.26	81.24±0.81	80.25±0.38
Metal	82.51±1.18	83.00±0.26	82.56±0.11	81.59±0.33	81.11±0.27
Plastic	82.51±1.18	84.32±1.43	82.72±0.32	82.89±0.43	81.55±0.24
Sack	82.51±1.18	83.19±0.97	80.65±0.13	81.07±1.09	81.57±0.29
a value*					
Silo	2.74±0.05	3.04±0.23	2.71±0.04	1.55±0.11	2.71±0.35
Metal	2.74±0.05	2.90±0.04	2.39±0.10	2.86±0.12	3.25±0.27
Plastic	2.74±0.05	2.72±0.04	2.47±0.11	2.38±0.08	2.59±0.23
Sack	2.74±0.05	2.87±0.10	2.91±0.06	2.95±0.12	2.47±0.11
b value*					
Silo	14.24±0.13	22.40±15.49	15.08±0.18	15.38±0.33	14.63±0.08
Metal	14.24±0.13	14.63±0.21	14.61±0.09	16.00±0.20	14.96±0.34
Plastic	14.24±0.13	14.13±0.21	14.70±0.17	14.74±0.19	14.73±0.11
Sack	14.24±0.13	14.78±0.47	15.53±0.11	15.33±0.29	14.11±0.28
z value*					
Silo	47.49±1.79	46.50±4.02	45.50±0.54	44.52±0.19	46.68±0.56
Metal	47.49±1.79	48.03±2.13	47.23±0.25	44.51±0.66	44.72±0.22
Plastic	47.49±1.79	50.50±2.30	47.42±0.62	47.61±0.71	45.56±0.48
Sack	47.49±1.79	48.07±1.14	43.52±0.25	44.31±1.85	46.10±0.68

^implies storage temperature (°C) and relative humidity (% RH)

CONCLUSION

The present study was aimed at examining the physico-chemical properties of wheat variety- HD 2967, stored in different receptacles like silo bag, metal containers, plastic tank and jute bags. The results revealed decrease in moisture, protein content and stirring numbers, angle of repose, angle of friction and colour value (L*,a*,b*,z*) in all the storage receptacles. However, the physico-chemical properties of wheat grains remained within the reference range during storage period and no significant differences were observed among storage receptacles under the study period.

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REFERENCES

AOAC (2000) Official Method of Analysis. By AOAC International.

Basavaraja H, Mahajanashetti SB, Naveen CU (2007) Economic analysis of post-harvest losses in food grains in India: A case study of Karnataka (PDF). Agricultural Economics Research Review **20**: 117–126.

Bhise SR, Kaur A, Manikantan MR (2014) Moisture dependent physical properties of wheat grain (PBW 621). International Journal of Engineering Practical Research **3**(2): 40–45.

Chattahk SH, Ibupotom HA, Laghari IA, Jamaliand AK, Baraich A (2014) Effect of different packing materials and storage conditions on the quality of wheat grain. Pakistan Journal of Agricultural Engineering and Veterinay Science **30**(2): 195–204.

Chaudhry NM, Ullah M, Anjum FM (1987) Effect of storage conditions on grain quality characteristic of wheat. Pakistan Journal of Agricultural Research **8**(1): 17–23.

Chukwu O, Abdullahi H (2015) Effects of moisture content and storage period on proximate composition, microbial counts and total carotenoids of cassava flour. International Journal of Innovative Science and Engineering Technology **2**(11): 753–763.

David O, Arthur E, Kwadwo SO, Badu E, Sakyi P (2015) Proximate composition and some functional properties of soft wheat flour. International Journal of Innovative Science and Engineering Technology **4**(2): 753-758.

FAO (2015) FAO Stat. Retrieved 27 January 2015. Mutation breeding - Expand Your Mind -Revolvybroom02.revolvy.

com/main/index.php?sMutation%20 breeding.

FAO (2002) FAO outlook. Food and Agricultural Organization of United Nations, Rome **2**: 36.

Gaines CS, Finney PL, Andrews C (1997) Influence of kernel size and shriveling on soft wheat milling and baking quality. Cereal Chemistry **76**: 700–704.

Gyori Z, Mezogazdasagi Termekek Tarolasaes Feldolgozasa. Egyetemi Jegzet (1999) DATE Debrecen. Agric Univ. Quality Series 1–89.

Hruskova M, Machova D (2002) Changes of wheat flour properties during short term storage. (Czek) Journal of Food Science **20**: 125–130.

Hruskova M, Skodova V, Blazek J (2004) Wheat sedimentation values and falling numbers. (Czek) Journal of Food Science **22**: 251–257.

Hussain S, Chattha HS, Hasfalina CM, Muhammad RM, Benish NM, Teang SL (2015) A comparative study of the quality of wheat grain stored in straw-clay, concrete block and ferrocement bins. Journal of Biodiversity and Environmental Science **6**(3): 73–83.

Jha N, Vishwakarma RK, Ahmad T, Dixit AK (2015) Assessment of quantitative harvest and post-harvest losses of major crops and commodities in India, Ministry of Food Processing Industries (Govt. of India), ICAR-Central Institute of Post-Harvest Engineering and Technology (ICAR-CIPHET), PO: PAU, Ludhiana-141004, Punjab (India), pp 64–67.

Kent NL, Evers AD (1993) Technology of Cereals. 4th ed., Elsevier Sci Ltd, U.K. 104 p.

Kruger JE, Tipples KH (1980) Relationship between falling number, amylograph viscosity and alpha amylase activity in Canadian wheats. Canadian Journal of Plant Science **61**: 817–828.

Lukow OM, White NDG, Sinha RN (1995) Influence of ambient storage conditions on the bread making quality of two hard red spring wheat. Journal of Stored Products Research **31**: 279–289.

Pessu PO, Adindu MN, Umeozor OC (2005) Effects of long-term storage on the quality of soybean, Glycine max (L.) Merrill, in different containers in Southern Nigeria. Global Journal of Pure and Applied Science **11**(2): 165–68.

Raza S, Khalil S, Naseem K, Gilani MA, Amjad M, Masud T, Naqvi SMS (2010) Effect of house hold storage receptacles on physico-chemical characteristics of wheat Sarhad. Journal of Agriculture **26**(2): 275–287.

SPSS (2007) Statistical Package of Social Science. SPSS Version 16.0 Command Syntax Reference.

Swaminathan MS (2004) Stocktake on cropping and crop science for a diverse planet. www.cropscience.org.au/icsc2004/plenary/0/2159_swaminathan.htm.

USDA (2016) USDA Branded Food Products Database Nutrient data laboratory. United States Department of Agriculture. (“Proof of Concept”) Release, May 2016. https://ndb.nal.usda.gov.

Zolton MP, Zolton G (2007) Variations in quality parameter of forage and medium quality winter wheat varieties in storage. Agricultural Con Science **72**: 221–225.