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Improvement in end-use quality of spring wheat varieties grown in different eras

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Abstract

Evaluation of wheat cultivars from different eras allows scientists to determine changes in agronomic and end-use quality characteristics associated with grain yield and end-use quality improvement over time. Forty-four spring wheat cultivars introduced or released since 1933 were evaluated for quality improvement using canonical variant analysis. It was observed that there was a considerable improvement in protein content from 1933 to 1964 whereas the genetic potential for straight grade flour protein from 11.34% in 1933–1964 to 12.13% in 1991–1996. Crude protein increased by 6.95% from 1933 to 1996. Ash content and flour yield declined by 9.55% and 5.51%, respectively. Total chapati scores of modern cultivars were 8.97% higher than those of cultivars grown earlier. The average spread ratio and overall cookie scores increased almost 5.53% and 4.44%, respectively from 1933 to 1996. It was also observed that overall cookie scores were highest during the period 1981–1990. The average dry gluten and total chapati scores of varieties grown since 1991 were approximately 10.20% and 74.72% respectively, which were 4.72% and 8.97% higher than those of cultivars grown since 1933. Average spread ratio and overall cookie scores increased almost 5.53% and 4.44% from 1933 to 1996, respectively. The era (1991–1996) containing the modern varieties showed a substantial improvement in lysine content than the era containing the oldest wheat varieties. Similarly amino acid score was also found to be 4.26% higher than the varieties released during the period 1933–1964.

Keywords: Improvement; End-use quality; Spring wheat varieties; Canonical variant analysis

1. Introduction

Common wheat (*Triticum aestivum* L.) belonging to the family *Gramineae* and the genus *Triticum* contributes 72% of the total protein and calories in the daily diet of people of Pakistan. The introduction of improved wheat varieties and agricultural practices formed a base towards launching the green revolution in Pakistan in 1966. In spite of significant achievements in wheat production, the challenge for Pakistan to feed its growing population remains the single most important issue. However, Pakistan achieved the level of self-sufficiency in wheat production during 1999–2000 and also exported some surplus to other countries (Ahmad, 2000).

The average life of a wheat variety ranges from 4 to 6 years in Pakistan. The wheat breeders developed new wheat varieties possessing an improved yield potential and disease resistance. However, general concerns have risen that new wheat varieties are inferior in quality characteristics (i.e. chapatti baking) as compared to the old tall varieties. The two main factors governing wheat quality are variety and growth environment (Quail, 1996). Within the limits of environment, quality is influenced by characteristics that can be altered by breeding, and is further modified during harvesting, farm drying, transportation and storage (Kent & Evers, 1994).

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The periodic evaluation for improvement of crop cultivars demonstrates the success of plant breeding plans and to identify the traits or target environments. The most direct of the several methods that have been used to estimate breeding progress is the evaluation of cultivars from different eras in a common environment (Cox, Shroyer, Ben-Hui, Sears, & Martin, 1988). This method has been used to estimate yield improvement in different crops, like oat by Lynch and Frey (1993), rice by Cuevas-Perez, Berrio, Gonzalez, Correa-victoria, and Tulande (1995) and wheat (*T. aestivum* L.) by Cox et al. (1988). In Pakistan such types of statistical tools to predict quality attributes in wheat have not been used. This work was undertaken to evaluate wheat varieties released in Pakistan with the objectives to find out quality improvement pattern during different eras. This information will form a basis to prepare breeding program for technological and nutritional quality improvement in developing new genotypes.

2. Materials and methods

2.1. Grain production

Field studies were conducted at the Wheat Research Institute, Faisalabad, Pakistan. The studies included samples of forty-four spring wheat varieties (*T. aestivum L*), obtained from the same institute. Wheat cultivars were selected on the basis of agricultural, genetical and environmental changes during different time periods in Pakistan. Wheat was seeded at 85–90 kg/ha in rows spaced 18 cm apart. Experimental areas received a broadcast application of ($N–P_2O_5–K_2O$) at the rate of 90–60–60 kg/ha, respectively, prior too planting. Soil test data indicated sufficiency of all other nutrients. Prior to initiation of differential irrigation treatments, the experimental area received uniform irrigation sufficient to maintain minimum available soil moisture content of 50% in the root zone. The grain samples, obtained by harvesting, were analyzed for kernel weight, which was expressed as grams per 1000 kernels.

2.2. Milling and baking analyses

2.2.1. Flour analyses

Grain samples from four replications of the experimental wheat varieties in each year were evaluated for milling and baking quality. Milling and baking evaluations were conducted at the Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan. The whole-wheat flour of each wheat variety was tested for total ash, crude protein, dry gluten and mixograph development time according to the methods described in AACC (2000). The tempered wheat grains were milled in a Quadrumate Senior Mill to obtain straight grade flour (break flour + reduction flour). *In vitro* protein digestibility of whole-wheat flour was measured by using the method described by Pederson and Eggum (1981). The amino acid profile was estimated in whole-wheat flour of each wheat variety by using high speed amino acid analyzer (L-8500 A, HITACHI, Tokyo, Japan) according to the method 07-01 (AACC, 2000) and following the instructions given in manufacturer manual. The amino acid score was determined by the following formula (FAO, 1985).

$$\text{Aminoacidscore} = \text{content of individual essential amino acid in food protein(mg/g of protein)} / \text{content of same amino acid in a reference pattern(mg/g of protein)}$$

2.2.2. Preparation and evaluation of chapattis and cookies

The chapattis were prepared from whole-wheat flour of each wheat variety according to the method developed by Haridas, Leelavathi, and Shurpalekar (1986). Flour (100 g, 14.0% moisture basis) and water as per treatment, determined from a 500 B.U. farinograph trace, were mixed for the optimum time indicated by the farinograph analysis. The dough was rested (optional) for 15 min before being cut into four equal sections. A section of the dough was then placed on a rolling board with a thickness guide of 1 mm. The dough was rolled in one direction, inverted, rotated at 90° and rerolled. A 15 cm diameter stainless steel cutting template was pressed onto the dough sheet to produce a uniform chapatti. The raw chapatti was placed on a preheated griddle at 225 °C. The chapatti was cooked for 40 s on side one, flipped and then cooked for 70 s on the second side. The cooked chapatti was quickly transferred (<10 s) to an adjacent oven maintained at 275 °C and allowed to puff for 20 s before removal and cooling at room temperature for 10 min. After cooling, the chapatti was placed in a resealable plastic bag and stored for 2 h prior to sensory evaluation.

Cookies were prepared according to the procedure described by McWatters, Ouedraogo, Resurrection, Hung, and Philips (2003) with slight modifications. The basic ingredients used were 380 g of flour blend, 100 g vegetable shortening, 225 g of granulated cane sugar, 21 g of beaten whole egg, 3.75 g of salt, and 1.8 g of baking powder. The dry ingredients were weighed and mixed thoroughly in a bowl by hand for 3–5 min. Shortening was added and rubbed-in until uniform. The egg was added and dough thoroughly kneaded in a mixer for 5 min. The dough was rolled thinly on a sheeting board to a uniform thickness (8.0 mm) and cut out using a round scorn cutter to a diameter of 35.0 mm. The cut out dough pieces were baked on greased pans at 160 °C for 15 min in a baking oven. The prepared cookies were cooled at room temperature (30 ± 2 °C) and packed in high density polyethylene bags.

2.3. Data analysis

Analysis of variance was carried out according to Steel, Torrie, and Dickey (1997). The canonical variate analysis was used to examine genetic directions in spring wheat breeding from 1933 to 1996 as perceived by five segments of the wheat industry according to GENSTAT 5 statistical analysis package (GENSTAT Committee, 1987).

3. Results and discussion

Various segments of wheat processing and data used for canonical variate analysis to study improvement in quality traits from 1933 to 1996 are shown in Table 1. Means of quality characteristics of spring wheat varieties for different eras are given in Table 2. Canonical variate analysis is presented in Table 3.

3.1. Scenario A: quality assessment before storage

The latent roots for both canonical variates (CV_1 and CV_2) have been found to be less than one reflecting that variation was more located within eras rather than among eras. CV_1 explained most of the variation (65.74%), whereas CV_2 explained 32.07% of the variation in kernel weight, crude protein and mixograph dough development time (MDT). The latent roots for CV_1 and CV_2 explained that grain protein accounted for most of the variation. It is interesting to note that average crude protein content increased from 12.27% in 1933 to 13.23% in 1996. The average MDT for the period 1933–1964 was 3.63% which was 19.33% less than the average mixing time for the period 1965–1996. This analysis indicated that quality assessor responsible for storage of the wheat would not necessarily detect the pattern in quality of wheats grown over years. It is possible, however, that production of cultivars such as Barani 83, Pavon and Punjab 96 with the production region would lead the processor to observe increase in protein and mixing requirement. The earlier studies (Van & Purchase, 1995) demonstrated that miller assessment of quality prior to binning did not detect a pattern in the quality of winter wheat varieties. This suggests that the predominant plantation of a wheat variety possessing better mixing requirement can lead the assessor to observe any increase in the mixing requirement of modern wheat varieties.

Table 1
Various segments of wheat processing and data used for canonical variate analysis to study improvement in quality traits from 1933 to 1996

Scenario	Segments of wheat processing industry	Data used for canonical variate analysis
A	Quality assessment before storage	Kernel weight Crude protein Mixograph development time (MDT)
B	Quality assessment in terms of flour produced	Ash content Dry gluten Straight grade flour yield (SGFY) Straight grade flour protein (SGFP)
C	Chapati quality	Crude protein Dry gluten Total chapati score
D	Cookie quality	Dry gluten Cookie spread ratio Overall cookie score Straight grade flour protein (SGFP)
E	Quality assessment in terms of nutrition	Crude protein Grain lysine Amino acid score Protein digestibility
F	Segments of wheat processing industry	Data used for canonical variate analysis

3.2. Scenario B: quality assessment in terms of flour produced

In this scenario, the latent root for the CV_1 was greater than one indicating that more variation existed between eras than within eras. CV_1 explained 80.61% of the variation in ash, dry gluten, straight grade flour yield (SGFY) and straight grade flour protein (SGFP). Further examination of the canonical coefficients with CV_1 showed SGFP a dominant contributor to variance within this response domain. It was also observed that there was a considerable improvement in protein from 1933 to 1964 whereas the genetic potential for SGFP from 11.34% in 1933–1964 to 12.13% in 1991–1996. This improvement of nearly 0.79% was probably the culmination of continuous selection for higher protein genotypes by breeders. The second canonical variate was less than one depicting no clear discrimination among eras. The CV_2 explained about 13.38% of the variation. The analysis indicated that ash and SGFY declined by 9.55% and 5.51%, respectively from 1933 to 1996. The decline in the SGFY is not appreciable by the millers. The findings of (Van & Purchase, 1995) are in contrary to these results as they observed an increase in SGFY from 1930 to 1983. The differences may be attributed to the differences in the type of cultivars tested as well as the environmental conditions persisted during growing conditions in both cases.

3.3. Scenario C: chapatti quality

With regard to chapatti quality characteristics 60.84% of the variance was explained by CV_1. Analysis of latent roots with CV_1 indicated that variation in dry gluten was the primary factor responsible for distinction among eras. The average dry gluten and total chapati scores of varieties grown since 1991 were approximately 10.20% and 74.72% which were 4.72% and 8.97% higher than that of cultivars grown since 1933. This indicated an improvement in chapatti quality.

3.4. Scenario D: cookie quality

The latent roots of both canonical variates were less than one, indicating that variation was more located within

Table 2
Means of quality characteristics of spring wheat varieties for different eras

Era	Varieties	KW	Ash	CP	DG	SGFY	SGFP	MDT	DIG	Lysine	AAS	TCS	CSR	OCS
1933–64	C 518	36.18	1.59	13.88	11.01	72.01	12.38	2.60	86.41	0.3755	49	61.88	5.86	26.64
	C 591	34.45	1.62	11.90	10.95	73.59	11.20	3.52	85.93	0.3325	51	74.21	5.97	27.25
	C 228	35.21	1.56	13.12	10.77	73.63	11.81	3.40	86.89	0.3490	48	69.46	5.76	26.02
	C 217	35.38	1.55	12.34	9.83	71.52	10.71	3.37	86.65	0.3333	49	72.65	5.56	25.42
	C 250	39.22	1.68	12.24	9.38	72.71	11.75	2.67	84.26	0.3032	46	65.72	6.51	29.95
	C 271	40.71	1.69	11.77	8.48	72.54	10.68	4.07	84.86	0.2796	43	62.38	6.81	31.20
	C 273	40.22	1.53	12.12	9.56	69.98	11.30	5.10	86.18	0.2973	45	73.48	7.77	32.82
	Dirk	45.20	1.34	11.56	7.92	74.40	10.91	4.27	86.41	0.3065	48	68.78	6.42	29.60
1965–80	Mexi pak	32.99	1.61	11.49	7.85	70.21	10.25	5.70	87.37	0.2889	46	65.57	6.69	30.25
	Barani 70	44.26	1.57	12.11	7.51	69.04	11.53	6.15	86.17	0.2601	39	66.83	6.25	29.17
	Chenab 70	42.39	1.43	10.90	9.03	72.93	10.41	5.92	86.65	0.2897	48	62.68	7.24	32.14
	SA 42	43.46	1.78	10.13	8.85	67.37	9.63	3.45	84.74	0.2972	53	65.16	7.02	30.37
	Blue silver	45.33	1.49	10.78	8.09	71.16	10.12	3.00	86.17	0.3054	51	67.14	7.69	32.79
	Pari 73	41.85	1.51	13.59	10.35	70.57	11.98	5.60	87.60	0.3063	41	72.50	6.64	28.64
	Lyallpur 73	40.81	1.53	13.14	9.59	69.67	11.87	6.15	87.84	0.2947	41	72.15	5.91	26.84
	Sandal 73	38.76	1.46	13.02	11.45	71.28	12.46	6.20	86.41	0.2558	36	65.82	6.80	31.18
	Pothohar	36.22	1.43	13.41	11.95	69.24	11.97	4.42	85.69	0.3041	41	68.04	5.98	27.72
	Yecora	39.60	1.54	13.16	13.52	70.99	12.01	6.95	86.41	0.3151	44	70.65	6.78	28.77
	SA 75	30.00	1.67	13.69	11.41	71.41	12.20	3.75	87.84	0.3249	43	69.32	5.97	27.48
	Arz	37.55	1.50	13.91	11.53	69.65	12.75	4.65	87.37	0.3307	43	72.15	6.80	31.28
	LU 26	49.01	1.51	12.93	10.30	73.49	11.64	6.37	88.56	0.3239	45	77.32	6.19	28.41
	Punjab 76	28.81	1.72	13.20	8.77	69.13	12.17	5.90	88.32	0.3356	46	65.64	6.47	30.21
	Pavon	31.43	1.63	14.20	12.85	70.39	12.70	5.20	85.69	0.3292	42	70.64	7.01	30.97
	WL 711	35.44	1.85	12.06	8.42	69.67	11.82	4.35	84.26	0.3051	46	62.28	6.78	31.13
	Chenab 79	36.52	1.36	13.10	9.07	68.18	11.60	7.10	88.32	0.3052	42	63.90	6.50	28.27
	Bahawalpur 79	40.24	1.60	13.88	11.44	73.73	12.65	2.65	87.84	0.3085	40	70.38	7.85	33.26
1981–90	Punjab 81	39.24	1.51	12.09	9.12	70.15	11.48	2.80	88.79	0.3131	47	65.72	6.48	30.59
	Pak 81	37.05	1.66	13.52	9.24	72.21	12.27	4.35	87.60	0.3460	47	68.49	7.25	30.27
	Barani 83	40.06	1.56	14.74	10.72	71.84	13.14	5.75	87.13	0.2965	36	67.54	6.76	28.73
	Kohinoor 83	32.37	1.57	13.90	11.27	67.16	12.52	3.55	87.60	0.3185	42	71.06	7.23	32.23
	Faisalabad 83	39.71	1.55	13.34	11.48	71.26	12.44	2.92	86.18	0.3292	45	65.06	7.93	34.06
	Faisalabad 85	40.78	1.63	13.91	11.28	70.82	12.70	2.90	85.21	0.3433	45	76.48	6.84	31.39
	Punjab 85	37.49	1.57	13.66	9.77	70.40	12.44	5.00	85.21	0.3270	44	64.58	6.50	30.64
	Satluj 86	37.72	1.60	12.81	9.83	67.73	12.05	5.50	85.21	0.3185	45	71.98	6.65	29.52
	Chakwal 86	38.67	1.63	13.74	11.68	70.57	12.68	4.40	85.69	0.3142	41	69.83	7.23	32.26
	Rawal 87	41.19	1.53	13.29	9.85	69.46	12.09	4.27	86.17	0.3250	44	69.02	6.42	30.30
	Punjnad 88	38.59	1.45	13.70	10.91	69.36	12.40	3.35	85.21	0.3416	45	59.51	7.21	32.21
	Shalimar 88	40.44	1.44	12.62	9.60	70.04	11.89	3.25	86.17	0.3189	46	65.45	7.32	32.34
1991–96	Rohtas 90	35.74	1.47	13.45	9.07	68.10	12.04	5.55	86.89	0.3434	46	78.97	5.99	27.21
	Pasban 90	32.78	1.32	13.18	9.99	65.78	12.16	5.90	86.65	0.3433	47	75.69	6.61	28.56
	Inqulab 91	40.89	1.47	13.02	10.87	72.31	12.18	3.75	85.93	0.3558	50	72.76	6.45	30.38
	Parwaz 94	40.77	1.43	13.18	10.52	68.12	12.05	3.72	85.93	0.3397	47	73.40	6.43	30.31
	Shahkar 95	38.62	1.32	12.39	9.51	66.51	11.6	3.47	85.72	0.3776	56	74.15	6.58	28.47
	Punjab 96	34.15	1.48	14.14	11.21	70.50	12.73	3.42	89.27	0.3923	50	73.36	8.04	34.33
LSD	(0.05)	0.56	0.13	0.29	1.02	2.31	0.49	1.34	1.65	0.04	6.95	1.01	0.23	0.71
1933–64	Average	38.32	1.57	12.37	9.74	72.55	11.34	3.63	85.95	0.3221	47	68.57	6.33	28.61
1965–80	Average	38.59	1.57	12.71	10.11	70.45	11.65	5.20	86.85	0.3045	44	68.23	6.70	29.94
1981–90	Average	38.61	1.56	13.44	10.40	70.08	12.34	4.00	86.35	0.3243	44	67.89	6.99	31.21
1991–96	Average	37.16	1.42	13.23	10.20	68.55	12.13	4.30	86.73	0.3587	49	74.72	6.68	29.88

KW = kernel weight, CP = crude protein, DG = dry gluten, SGFY = straight grade flour yield, SGFP = straight grade flour protein, MDT = mixograph development time, DIG = protein digestibility, AAS = amino acid score, TCS = total chapati score, CSR = cookie spread ratio, OCS = overall cookie score.

eras than among eras. CV_1 explained most of the variation (93.49%), whereas CV_2 explained only 5.68% of the variation. The latent roots for CV_1 and CV_2 indicated that SGFP accounted for most of the variation. It is interesting to note that average spread ratio and overall cookie scores increased almost 5.53% and 4.44%, respectively, from 1933 to 1996. It was also observed that the spread ratio and overall cookie scores were maximum during the period

Table 3
Canonical variate analysis of quality traits for 44 spring wheat varieties grown in Pakistan from 1933 to 1996

Scenario	Parameters	Canonical variate analysis factors	
		CVA_1	CVA_2
A	Latent roots		
	Variation explained (%)	65.74	32.07
	Kernel weight	0.05	0.09
	Crude protein	0.65	0.98
	Mixograph development time	−0.78	0.39
B	Latent roots	1.05	0.17
	Variation explained (%)	80.61	13.38
	Ash content	−4.18	−6.79
	Dry gluten	−0.19	0.21
	Straight grade flour yield	−0.44	−0.05
	Straight grade flour protein	1.13	−1.12
C	Latent roots	0.38	0.24
	Variation explained (%)	60.84	38.49
	Crude protein	−0.22	−1.36
	Dry gluten	0.32	0.34
	Total chapati score	−0.25	0.06
D	Latent roots	0.60	0.04
	Variation explained (%)	93.49	5.68
	Dry gluten	0.36	−0.56
	Cookie spread ratio	−0.16	0.41
	Overall cookie score	−0.26	−0.47
	Straight grade flour protein	−1.53	1.14
E	Latent roots	0.85	0.24
	Variation explained (%)	72.70	20.27
	Crude protein	2.57	−5.39
	Grain lysine	−140.54	−172.90
	Amino acid score	0.65	1.18
	Protein digestibility	0.33	−0.13

CVA_1 and CVA_2 = first and second canonical variates, respectively.

1981–1990. This revealed an indication of increment in the cookie quality scores.

3.5. Scenario E: quality assessment in terms of nutrition

For this scenario, CV_1 explained 72.70% of the variation. The latent roots of canonical variate indicated that variation was more located within eras than among eras. CV_2 explained only 20.27% of the variation. The latent roots for CV_1 indicated that grain lysine accounted for most of the variation with identical results in CV_2. The era containing the modern varieties (1991–1996) showed a substantial improvement in lysine content than the era containing the oldest wheat varieties. Similarly amino acid score was also found to be 4.26% higher than the varieties released during 1933–1964. A negative relationship between protein and yield is often observed in the improvement of wheat varieties (Deckard, Tsai, & Tucker, 1984). It is important that the potential to realize sufficient levels of lysine should be maintained even at higher grain yield levels.

4. Conclusions

It was demonstrated that substantial progress has been made in the breeding of spring wheat varieties from 1933 to 1996 with improvement in chapatti and cookie making quality as well as from nutritional point of view. Though the importance was of lesser magnitude but appears to be sufficient to the consumers. The results will provide better understanding and information to the plant breeders as well as nutritionists about the varieties of wheat produced in these particular eras as well as providing knowledge about the impact of environment and breeding techniques during these specified periods.

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