Pak. J. Agri. Sci., Vol. 43(3-4), 2006

NEAR INFRARED SPECTROSCOPIC TECHNIQUE TO PREDICT DIFFERENT WHEAT QUALITY CHARACTERISTICS

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Wheat quality is expressed by physico-chemical and rheological parameters that is influenced by wheat characteristics and milling process. Several methods based on different techniques are being used to determine these characteristics of wheat. Near Infra Red spectroscopic (NIR) method is preferably used when large number of samples in short time and immediate results of wheat flour quality is desired. In the present study, forty seven spring, two durum and one triticale wheat varieties were evaluated for different physical, chemical and rheological parameters through NIR technique. The NIR values for hardness, moisture, protein, water absorption and Zeleny value ranged from 63.83 to 71.33, 8.92 to 11.68, 10.49 to 14.03, 59.64 to 63.64 ml and 50.67 to 80.34 ml, respectively in different wheat varieties. NIR hardness positively correlated with moisture content, NIR protein and Zeleny value as determined by the technique. NIR moisture content was positively correlated with Zeleny value, NIR protein and water absorption capacity. NIR protein was positively correlated with Zeleny value while negatively correlated with crude protein as measured by Kjeldahl method. The findings of the present study indicated that NIR technique may effectively and efficiently be used in determining different physical, chemical and rheological parameters of wheats.
Key words: Wheat quality, physico-chemical and Rheological parameters, NIR technique

INTRODUCTION

The term wheat quality is a complex of many factors and cannot be expressed in terms of a single property but depends on several milling, chemical, baking and rheological dough properties. The term wheat quality reflects in terms of its suitability for a particular purpose or use for which it intends to be. The major factors influencing wheat quality are cultivar, climatic conditions, cropping year, process of harvest and storage conditions.
Numerous techniques and methods have been developed to quantify different wheat quality parameters. NIR spectroscopic technique is also used to predict wheat composition and functionality world wide especially for moisture and protein determination of both wheat and flour (William et al., 1986). Thus, the speed of wheat analysis is increased by the use of NIR technique as NIR method is capable of generating instantaneous results for many wheat and wheat flour quality parameters in addition to cost reduction. The parameters including moisture and protein (Williams and Thompson, 1978), ash and wet gluten content (Hruskova *et al.*, 2000), insect damage (Baker *et al.*, 1999), colour (Wang *et al.*, 1999), vitreousness (Dowel, 2000), wheat classes (Delwiche and Massie, 1996), aflatoxin and fuminsin (Dowel, 2000), Zeleny sedimentation value of wheat and flour (Hruskova and Famera, 2003), total sugar, crude fat (Suzuki *et al.*, 1986) and physiological dough properties (Delwiche *et al.*, 1998) are being used in recent years to evaluate quality of wheat by NIR technique.

Near-infrared reflectance spectroscopy (NIRS), (Manely *et al.*, 1996; Norris *et al.*, 1989) and near-infrared transmittance spectroscopy (Delwiche, 1996) may also be used for measurement of grain texture which is the most recently approved methods (Approved Method AACC, 2000, 39-70A). The technique is used for differentiation among strength of adhesion between starch and protein, which varies across hard and soft wheats. It is manifested with absorbance (log I/R) which is higher for hard wheat than in soft wheat (Elizabeth and Dowell, 2003). NIR has the potential to measure Zeleny sedimentation value of wheat and flour (Hruskova and Famera, 2003). The quality of wheat and flour is expressed by physical and chemical properties of dough but none of the individual test can represent the wheat quality completely (Pyler, 1988). The objective of the present study was to investigate the capability of NIR spectroscopy for measuring wheat quality characteristics subsequently to observe the correlation between different quality parameters.

MATERIALS AND METHODS

Fourty seven common wheat (*Triticum aestivum* L.) varieties, two durum wheat varieties and one triticale promising line released since 1933 to 2004-05 were studied in this project which were grown during two consecutive crop years i.e. 2003-04 and 2004-05. The wheat varieties were grown at Wheat Research Institute, Faisalabad under similar conditions by applying similar inputs in both the crop years, cultivated on 10-15th November in both crop years and fertilizer was applied as NPK at the rate of 100:75:50 kg/ha. The crop received four irrigations during the whole grown period. The plants were harvested during the last week of April each year. The equal grain samples of each wheat variety were collected in triplicate and stored at 25°C temperature. To protect the wheat from stored grain pests the tablets releasing phosphine gas were used.

Wheat Milling

The whole wheat flour was prepared by grinding wheat grains through UDY cyclone mill (Seedburo Equipment Co., IL) fitted with 0.5 mm sieve. The mill was carefully cleaned after each sample to avoid mixing of the other samples.

Grain Hardness by Near Infrared Reflectance (NIR)

Each wheat variety was tested for grain hardness by running through NIR Analyzer Inframatic 8620 (Perten Instruments, Inc., IL, USA) according to the procedure as described in AACC (2000) method No. 39-70 A.

Moisture Content

a. Oven Drying

The moisture content was determined by drying 3 g sample in an air forced draft oven at a temperature 105± 5 °C according to the procedure of AACC (2000) method No. 44-15 A.

b. NIR Technique

The moisture content of each wheat variety was analyzed through NIR technique by using Inframatic (IM) 9100 (Perten Instruments, Inc., IL) according to the procedure given in AACC (2000) method No. 44-16. The IM 9100 is widely used filter based NIR instrument for whole grain analysis with 12 specific wavelengths in the ranges 1,000-1,400 nm.

Protein Content

a. Kjeldhal's method

The nitrogen content in whole wheat flour samples was estimated according to Kjeldahl's method according to the procedure as described in AACC (2000) method No. 46-10. The protein percentage was calculated by multiplying nitrogen percent with a factor 5.7.

b. NIR technique

The protein content in each sample was determined by using NIR technique by running the flour samples through (Inframatic 9100, Perten Instruments, Inc. IL) according to the procedure described in AACC (2000) method No. 39-11.

Zeleny Value

The Zeleny sedimentation value of each wheat variety was estimated by running flour sample through NIR instrument, IM 9100 (Perten Instruments, Inc. IL).

Water Absorption Capacity

The water absorption capacity in each wheat flour sample was measured through Inframatic 8620 (Perten Instruments, Inc. IL).

STATISTICAL ANALYSIS

The data collected were analyzed according to standard statistical procedure (Steel *et al.*, 1996). The analysis of variance was carried out on the data for 50 cultivars repeated over two consecutive crop years with triplicate samples.

RESULTS AND DISSCUSION

NIR Hardness

The NIR hardness of different wheat varieties (Table 1) was highly significantly affected by the crop years and wheat cultivars whereas, interaction of crop year and varieties showed non-significant differences for NIR hardness value.

The NIR hardness (Table 2) ranged from 63.83 to 71.33. The highest hardness value for this parameter was recorded in wheat varieties C 271 followed by Pothohar, Chakwal 86, Wadanak-85, C 217, C 518, C 250 and C 273 while lowest hardness value were ranked in T 96725, Punjab 85, Faisalabad 85, Shakar 95, Bakhar 02, Rohtas 90 and WL 711. NIR hardness was positively and highly significantly correlated with water absorption ($r = 0.899$), moisture content ($r = 0.227$), moisture NIR ($r = 0.507$), Zeleny value ($r = 0.381$) and protein NIR ($r = 0.136$) but negatively correlated with crude protein ($r = -0.156$) (Table 3).

The present study revealed that 4 wheat varieties fell in the category of fairly soft (in the range 57-64) while all other 46 varieties fell in the category of soft (in the range 65-72) according to the NIR hardness scale given by Williams *et al.* (1986). The results of this study are in line with the previous studies which showed that most of the Pakistani spring wheats are medium hard and soft (Anjum and Walker, 1991; Ahmad, 2001; Mahmood, 2004) according to the hardness value measured by PSI and Pearling Value.

Moisture Content

The moisture content is extremely important in any measurement of wheat kernel texture.

It can be determined by oven method in whole wheat flour of different wheat varieties. Moisture content was significantly affected due to differences in the crop years and wheat varieties (Table 1). The interaction between crop years and wheat varieties was found to be non significantly different for moisture content. The NIR moisture in whole wheat flour of different wheat varieties was significantly affected due to the differences in crop years while wheat varieties and interaction between crop years and wheat varieties was found to be non significant for NIR moisture content. The moisture content ranged from 8.92 to 11.68 % (Table 2) which was found to be the lowest in C 591 and highest in Punjab 96, respectively. Moisture content showed positive correlation with NIR hardness (r = 0.226) but negative correlation with moisture NIR (r = -0.275). Moisture content NIR was positively correlated with Zeleny value (r = 0.337), protein NIR (r = 0.246), water absorption (r = 0.576) and NIR hardness (r = 0.507).

The findings of the present study are well supported by the findings of different researchers (Slaughter *et al.*, 1992; Butt, 1997; Mahmood, 2004). The NIR moisture content ranged from 9.10 to 10.53 % which was found to be highest in C 250 and the lowest in Punjab 81. The results of present study are in collaboration with the findings of other researchers (Hruskova and Famera, 2003; Miralbes, 2003). The difference between wheat varieties is due to genetic variability of different wheat varieties and difference between crop years is due to environmental changes during crop years.

Table 1. Mean squares for wheat quality parameters of different wheat varieties grown during two crop years

Source	d.f.	Hardness NIR	Moisture %	Moisture NIR	Crude protein	Protein NIR	Zeleny Value	Water Absorption
Crop Years	1	950.55**	38.81**	51.09**	10.33 NS	7.74**	929.06**	371.69**
Samples	4	7.34	1.35	0.65	2.64	0.27	6.05	1.23
Varieties	49	17.08*	2.22*	0.76*	3.35**	4.12**	314.87**	5.14 *
Crop Years X Varieties	49	3.50 NS	0.78 NS	0.39 NS	1.54 *	2.12**	21.44 NS	1.30 NS
Error	196	11.94	1.47	0.53	1.03	1.14	22.77	3.24

* = Significant (P<0.05); ** = Highly significant (P<0.01); NS = Non-significant (P>0.05)

Protein content

The protein content is an important criterion while considering quality of wheat. The crude protein content was significantly affected by wheat varieties and significant for interaction between crop years and wheat varieties while affect of crop years was not significant. The NIR protein content was significantly affected by crop years, wheat varieties and their interaction. The crude protein content (Table 2) ranged from 10.00 to 13.4 % and found to be highest in Chenab 70, Barani 83 and Punjab 76 while lowest in Sandal 73 and Pari 73 wheat varieties. The results are in line with the earlier findings of Anjum *et al.* (2005) and Ahmad (2001). The NIR protein content ranged from 10.49 to 14.03 % and found to be highest in Barani 83, Punjab 85, C 591 and Pavon while lowest was found in Wadanak 85, T 96725 and Durum 97 wheat varieties. Crude protein was negatively correlated with Zeleny value (r = -0.186). Protein NIR was positively correlated with water absorption (r = 0.198), moisture NIR (r = 0.246) and Zeleny value (r = 0.719) (Table 3).

The results are in collaboration with the findings of Ram and Singh (2004) and Giroux *et al.*, (2000) who also observed almost similar values. The differences observed between the crop years in the protein content may be attributable to the variation in environmental conditions prescribed during the different crop years. The protein content has been reported to be influenced by genetic as well as non genetic factors like soil, climatic conditions and use of fertilizer etc (Kent and Evers, 1994).

Zeleny sedimentation Value

The Zeleny sedimentation value actually gives the degree of sedimentation of flour suspended in a lactic acid solution during a standard time interval and this is taken as a measure of the baking quality. Swelling of the gluten fraction of flour in lactic acid solution affects the rate of sedimentation of a flour suspension.

The statistical results regarding Zeleny sedimentation value of different wheat varieties represented that the effect of crop years and wheat varieties was highly significant and interaction of wheat varieties and crop years was non significant.

The Zeleny sedimentation value (Table 2) ranged from 50.67 to 80.34 ml and found to be highest in GA 2002, C 518, Barani 83, C 273 and Pavon while lowest Zeleny sedimentation value was found in wheat varieties i.e. Bakhar 2002, Punjab 81, T 96725,

Table 2. Mean values for different wheat quality parameters with grown during two crop year

Sr. No.	Varieties	NIR Hardness		Moisture % (Air oven		Moisture contents by NIR		Protein (Kjeldahl's)		Protein NIR		Zeleny Value		Water Absorption	
1	C-518	69.33	±1.91	10.60	±0.25	10.00	±0.16	11.27	±0.36	13.44	±0.58	77.50	±1.95	62.65	±0.80
2	C-591	68.67	±1.07	8.92	±0.50	9.50	±0.30	12.29	±0.42	13.55	±0.53	74.17	±2.09	62.63	±0.31
3	C-228	69.17	±0.93	9.86	±0.48	9.55	±0.27	12.15	±0.75	13.20	±0.45	69.83	±2.50	62.75	±0.30
4	C-217	69.67	±1.60	9.60	±0.40	9.45	±0.25	10.56	±0.35	12.57	±0.33	66.50	±1.38	62.63	±0.88
5	C-250	69.33	±1.28	11.20	±0.51	10.53	±0.36	10.43	±0.28	11.82	±0.49	69.50	±2.16	62.27	±0.39
6	C-271	71.33	±1.34	10.63	±0.61	9.92	±0.33	11.41	±0.46	12.14	±0.36	67.50	±1.82	63.53	±0.74
7	C-273	69.33	±1.93	11.15	±0.59	10.42	±0.18	11.71	±0.40	13.11	±0.54	75.17	±2.75	63.20	±0.08
8	DIRK	66.33	±1.48	10.24	±0.51	10.39	±0.33	10.43	±0.30	13.41	±0.30	67.00	±2.03	62.38	±0.41
9	M.PAK-65	66.83	±1.29	10.20	±0.34	9.96	±0.30	11.95	±0.69	11.35	±0.47	53.00	±1.99	61.43	±0.66
10	BARANI-70	67.83	±1.62	9.99	±0.45	10.34	±0.53	12.56	±0.48	11.91	±0.32	60.67	±1.62	62.03	±0.54
11	CHENAB-70	68.83	±2.05	10.38	±0.53	10.52	±0.13	13.40	±0.45	12.09	±0.22	61.83	±2.10	62.17	±0.67
12	S A-42	68.00	±1.38	9.93	±0.53	10.15	±0.43	12.35	±0.55	13.30	±0.37	68.83	±2.43	63.64	±0.18
13	LYP-73	66.67	±1.53	11.03	±0.57	10.02	±0.39	12.11	±0.39	13.37	±0.43	65.67	±2.30	62.02	±0.82
14	PARI-73	66.00	±1.58	11.35	±0.54	9.70	±0.47	10.40	±0.41	11.90	±0.40	60.50	±1.76	61.03	±0.49
15	POTHWAR	70.00	±1.50	11.00	±0.54	10.18	±0.21	11.68	±0.35	12.93	±0.47	71.17	±2.05	63.08	±0.92
16	SANDAL-73	66.67	±1.40	10.74	±0.68	10.36	±0.35	10.00	±0.30	12.53	±0.38	65.67	±1.98	61.31	±0.60
17	YACORA-70	66.17	±1.75	10.92	±0.61	9.57	±0.41	12.51	±0.32	12.43	±0.65	64.33	±2.36	61.49	±0.84
18	ARZ	67.33	±1.52	9.48	±0.55	9.95	±0.27	11.27	±0.27	11.94	±0.37	60.33	±1.88	61.52	±0.06
19	SA-75	67.50	±1.50	11.25	±0.61	9.80	±0.47	11.09	±0.32	11.48	±0.42	62.00	±2.16	62.18	±0.99
20	LU-26S	66.33	±1.94	10.61	±0.56	9.95	±0.41	12.51	±0.29	12.18	±0.51	66.17	±2.12	61.43	±0.76
21	PUNJAB-76	67.83	±2.50	11.15	±0.32	9.81	±0.27	12.79	±0.42	12.11	±0.66	55.50	±2.55	62.02	±0.92
22	PAVON	67.83	±1.24	10.41	±0.44	9.61	±0.30	11.71	±0.34	13.62	±0.57	72.83	±2.59	61.92	±1.03
23	WL 711	65.83	±1.47	10.90	±0.60	9.91	±0.27	11.98	±0.38	12.28	±0.66	55.00	±2.39	61.95	±0.59
24	BARANI-83	69.17	±1.93	10.43	±0.50	10.16	±0.34	12.95	±0.31	14.03	±0.41	75.17	±2.06	62.76	±1.15
25	CHENAB-79	66.50	±1.59	11.22	±0.49	9.93	±0.44	12.55	±0.45	11.97	±0.31	59.00	±2.34	61.82	±1.29
26	PB-81	66.83	±1.71	11.49	±0.60	9.10	±0.38	12.14	±0.49	11.52	±0.34	51.17	±2.54	62.20	±0.79
27	FSD-83	67.83	±1.17	10.64	±0.43	9.91	±0.34	12.47	±0.52	12.65	±0.32	58.00	±1.64	62.42	±0.73
28	KOHINOOR-83	66.33	±1.54	11.52	±0.66	9.27	±0.39	11.04	±0.45	12.35	±0.47	63.67	±2.19	61.35	±0.60
29	PAK-81	68.17	±1.44	9.89	±0.49	10.03	±0.38	12.76	±0.50	12.36	±0.36	64.17	±1.80	61.74	±0.82
30	FSD-85	64.00	±0.94	11.50	±0.48	9.70	±0.43	11.71	±0.54	13.25	±0.62	71.33	±1.64	59.78	±0.57
31	PUNJAB-85	63.83	±1.38	10.35	±0.55	9.89	±0.36	11.31	±0.56	13.75	±0.45	66.83	±2.43	59.81	±0.73
32	CHAK-86	70.00	±1.64	10.42	±0.51	9.80	±0.21	11.91	±0.70	12.83	±0.42	70.50	±2.26	62.18	±1.08
33	SHALIMAR-88	67.50	±1.60	11.00	±0.46	9.81	±0.17	12.18	±0.38	11.57	±0.32	61.34	±1.76	62.05	±0.95
34	INQLAB-91	67.50	±0.68	10.11	±0.37	9.55	±0.48	10.65	±0.39	12.90	±0.59	67.33	±1.75	61.94	±0.79
35	PASBAN-90	67.33	±1.53	10.90	±0.43	9.98	±0.25	10.88	±0.41	11.18	±0.42	62.17	±2.17	61.47	±0.44
36	ROHTAS-90	65.50	±1.78	10.39	±0.46	9.72	±0.52	11.15	±0.51	13.26	±0.53	67.33	±1.92	61.33	±0.84
37	PERWAZ-94	66.00	±0.98	11.30	±0.40	9.67	±0.32	11.68	±0.44	12.27	±0.37	62.67	±1.93	61.70	±0.59
38	PUNJAB-96	66.50	±1.60	11.68	±0.45	9.50	±0.46	11.75	±0.66	11.51	±0.38	55.00	±2.05	61.37	±0.46
39	SHAKAR-95	64.67	±1.16	10.13	±0.38	9.53	±0.43	11.10	±0.31	12.14	±0.28	54.50	±1.99	60.05	±0.33
40	KOHISTAN-97	69.33	±2.06	10.53	±0.44	9.95	±0.15	11.60	±0.28	12.76	±0.58	64.50	±2.09	62.97	±0.67
41	MH-97	68.50	±1.17	10.66	±0.49	9.50	±0.34	12.36	±0.46	11.88	±0.42	60.50	±1.36	61.87	±0.68
42	CHENAB-2000	66.67	±1.26	10.45	±0.38	9.38	±0.27	12.11	±0.36	12.40	±0.41	64.83	±1.68	61.01	±0.62
43	UQAB-2000	67.33	±1.60	11.52	±0.63	10.23	±0.12	12.24	±0.60	11.77	±0.52	56.83	±2.15	62.53	±0.66
44	IQBAL-2000	67.50	±1.98	11.35	±0.49	9.60	±0.31	12.75	±0.37	11.26	±0.34	55.51	±1.41	62.78	±0.65
45	BAKHAR-02	65.00	±0.97	11.11	±0.51	9.55	±0.37	11.86	±0.44	11.36	±1.16	50.67	±2.20	60.78	±0.45
46	GA-02	68.00	±1.47	10.95	±0.37	9.80	±0.38	12.06	±0.45	12.83	±0.49	80.34	±2.73	62.85	±0.63
47	MANTHAR-03	68.00	±1.42	9.74	±0.47	9.15	±0.30	11.82	±0.39	11.32	±0.45	62.33	±1.50	60.63	±0.74
48	WADANAK-85	69.83	±1.53	11.34	±0.39	9.18	±0.42	11.27	±0.55	10.49	±0.40	52.67	±2.04	62.90	±0.80
49	DURUM-97	68.83	±1.33	11.02	±0.60	9.18	±0.25	12.48	±0.42	11.07	±0.47	55.00	±2.10	62.82	±0.95
50	T-96725	63.83	±1.17	10.86	±0.50	9.82	±0.32	12.44	±0.35	10.95	±0.30	52.00	±1.72	59.64	±0.78
	Mean	**67.47**		**10.68**		**9.81**		**11.79**		**12.33**		**63.52**		**61.92**	

Wadanak 85 and MexiPak 65. The Zeleny value was positively correlated with protein NIR (r = 0.719), moisture content NIR (r = 0.337), water absorption (r = 0.354) and NIR hardness (r = 0.381) but negatively correlated with crude protein (r = -0.186) (Table 3). The results of the present study are in line with the earlier findings of researchers; Pedersen *et al.* (2004), Curic (2001) and Konopka *et al.* (2004). Hard wheats absorb more water due to more starch damage as compared to soft wheat (Hoseney *et al.*, 1998). This statement was well supported in our study because some of the medium hard wheats like SA 42, MexiPak 65, Wadanak 85, Durum 97, GA 02 possessed higher water absorption capacity as compared to the soft wheat varieties.

Table 3. Correlation matrix of different wheat quality parameters of the 50 spring wheat varieties grown during two crop years

	$Hard_{NIR}$	MC	MC_{NIR}	CP	PC_{NIR}	ZV	WA
$Hard_{NIR}$	1.0000						
MC	0.2260*	1.0000					
MC_{NIR}	0.5062**	-0.2750**	1.0000				
CP	-0.1557 NS	-0.1441 NS	-0.0937 NS	1.000			
PC_{NIR}	0.1355 NS	-0.0842 NS	0.2458**	-0.0711 NS	1.0000		
ZV	0.3814**	-0.1061 NS	0.3366**	-0.1857*	0.7186**	1.0000	
WA	0.8997**	0.361**	0.5755**	-0.1061 NS	0.1976*	0.3549**	1.0000

* = Significant (P<0.05); ** = Highly significant (P<0.01); NS = Non-significant (P>0.05)
$Hard_{NIR}$: NIR Hardness; MC: Moisture content; MC_{NIR}: NIR Moisture content; CP: Crude Protein P_{NIR}: Protein NIR; ZV: Zeleney Value; WA: Water Absorption.

Both higher gluten content and a better gluten quality give rise to slower sedimentation and higher Zeleny test values (Shewry and Tatham, 2000). Hruskova and Famera (2003) evaluated 318 wheat samples for Zeleny sedimentation value through NIR technique and found the range from 17 to 66 ml. Zanetti *et al.* (2001) observed the Zeleny sedimentation value in the range of 25 to 67 ml in different wheat varieties. The investigations of present study for Zeleny sedimentation test are little higher than the previous reported values. This attribute could be due to genetic and environmental differences in different wheat varieties.

Water absorption capacity

The effect of crop years and wheat varieties was highly significant while the interaction of wheat varieties with crop years was non significant for water absorption value of whole wheat flour of different wheat varieties (Table 1).

The water absorption value (Table 2) ranged from 59.64 to 63.64 ml and found to be highest in wheat varieties SA 42 followed by C 271, C 273, Pothohar, Kohistan 97, Wadanak 85 and GA 02 whereas the lowest water absorption value was found in T 96725, Faisalabad 85, Punjab 85, Shakar 95, Manthar 03 and Bakhar 02 showing non significant difference. Water absorption was positively correlated with moisture content (r = 0.361), moisture NIR (r = 0.576), Zeleny value (r = 0.354), protein NIR (r = 0.198), NIR hardness (r = 0.90) and negatively correlated with crude protein (r = -0.106) (Table 3).

CONCLUSION

The NIR is very quick, reliable and cheaper analytical technique which can effectively be used for estimation of different wheat quality parameters. The values determined by this technique are very close to the values determined by the standard procedures except some values due to the reasons described against their respective parameters. The information is valuable for cereal scientists for their intended uses.

ACKNOWLEDGEMENT

The authors are very thankful to the Higher Education Commission of Pakistan for providing financial support to complete this research project.

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