Diversity of Starch Pasting Properties in Iranian Hexaploid Wheat Landraces

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ABSTRACT

Wheat landraces possess a wide diversity in starch physical properties that could be useful in breeding for improved quality of specific products, such as various types of Asian noodles. The pasting properties (using a Rapid Visco-Analyser [RVA]) and flour swelling volume (FSV, using silver nitrate to inactivate α-amylase activity) of wholemeal, were measured for 242 hexaploid accessions of Iranian landrace wheat. FSV values and the peak viscosities were positively correlated (*r* = 0.73***). FSV values in the landraces ranged from 8.3 to 15.9 mL/g and peak viscosities ranged from 139 to 305 RVA units (RVU). In comparison, FSV of cvs. Eradu and Klasic were 18.6 and 15.0 mL/g, and peak viscosities were 355 and 303 RVU, respectively. Of the landraces, Iranian Wheat Accession (IWA) 8602488 had the highest peak viscosity (305 RVU) and exceptionally high hot- and cool-paste viscosities. Two accessions, IWA 8602430 and 8600544, displayed pasting characteristics considered desirable for high-quality Japanese white-salted noodles. Four landraces were identified that had starch with unusually high resistance to shear-thinning. Texture profile analysis was done on the wholemeal gels formed in the RVA canister. The variation in parameters such as hardness, chewiness, and adhesiveness in the landraces greatly exceeded that in the cultivars. The hot-paste viscosity, breakdown, setback, and final viscosity values, but not the peak viscosity or FSV, were highly significantly correlated with the hardness, chewiness, and adhesiveness of the gel. The Iranian landraces appear to present useful genetic variation for developing wheats for special uses.

The Asian noodle industry has become an increasingly important and fast-growing target market for improved-quality wheat from the major wheat exporters: the United States, Canada, and Australia (Crosbie et al 1990). The quality factors of wheat that govern the eating quality of noodles are very different from those for leavened baked bread, where the protein content and quality are the most important. In contrast, the pasting properties of starch have been identified as a major quality attribute for certain types of noodles, particularly Japanese white-salted noodles (WSN) (Nagao et al 1977, Moss 1980, Oda et al 1980), although protein content does influence the chewiness (Oh et al 1983) and color (Miskelly 1984). There is also potential for development of wheat starches better suited for use in composite flour noodles (Collado and Corke 1996). Considerable research effort is now focused on producing wheat for various uses with desirable starch pasting properties, such as high swelling volume and swelling power (Crosbie 1991, McCormick et al 1991), high peak viscosity (Moss 1980, Lee et al 1987, Crosbie et al 1990), low gelatinization temperature (Oh et al 1985, Endo et al 1988) and high rate of breakdown during viscoamylography (Oda et al 1980, Konik et al 1992).

Future wheat improvement may depend increasingly on the utilization of the genetically diverse and rich gene pool of wild relatives or landraces (Nevo and Payne 1987). Such genetic resources have been successfully used by plant breeders to improve agronomic traits, particularly disease and pest resistance. Landraces of wheat have resulted from selection within field populations by traditional agriculturists. Because they are agronomically adapted to field conditions, landraces may be more easily utilized as sources of novel genes or gene combinations than wild relatives (Damania et al 1985). Tetraploid or hexaploid wheat landraces have been evaluated to a limited extent for their potential use in modern plant breeding (e.g., for stress tolerance [Ehdaie et al 1988]; drought tolerance [Blum et al 1987]; salinity tolerance [Jafari-Shabestari et al 1995]; disease resistance [Broers and De Haan 1994]; and protein quality [Ereifej and Shibli 1993, Turchetta et al 1995]). We are not aware of any reports on wheat landrace starch quality other than our methodological study on a subset of the material reported in this article (Bhattacharya and Corke 1996).

In this study, the variation in the pasting properties of starch was studied in a collection of hexaploid landraces of wheat originating from different provinces of Iran, with the aim of identifying genotypes with wide starch diversity for potential use in breeding. Due to the limited availability of samples, wholemeal was used throughout the study instead of purified starch. An earlier study done with a subset of this collection showed extremely high correlation between the properties of purified starch and the corresponding wholemeal, provided the wholemeal was treated with silver nitrate to inactivate the effect of α-amylase, which may occur at high levels in the landraces (Bhattacharya and Corke 1996). We also examined the geographical origin (province of collection) of the accessions to determine whether this could be used to identify sources of high frequencies of particular characteristics.

MATERIALS AND METHODS

Wheat Samples

We used 242 hexaploid wheat landraces originating from Iran and which form part of a large base collection of about 12,000 accessions held at the University of California, Davis. These landraces originated from 16 different provinces (plus a group of unknown provincial origin) of Iran and are referred to by their Iranian Wheat Accession (IWA) numbers as used at the University of California, Davis. The grain used in these experiments was produced in uniform field conditions in row plots at the Agronomy Farm, University of California, Davis, using normal agronomic practices and harvested in May, 1995. Seven released cultivars or advanced breeding lines of common (hexaploid) wheat were used for comparison. Five of these were of United States origin (Klasic, Yecora Rojo, UC 896, Express, and Anza) supplied by the University of California, Davis. Two were of Australian origin (Eradu, a standard noodle cultivar and Kulin), both provided by G.

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B. Crosbie, Western Australia Department of Agriculture. All the samples were ground to wholemeal in an Udy cyclone sample mill (Udy Corp., Ft Collins, CO) fitted with a 0.5-mm sieve.

Flour Swelling Volume (FSV)

Wholemeal samples (0.45 g, dwb) were mixed with 12.5 mL 0.5 m*M* $AgNO_3$ in 125 × 16 mm Pyrex culture tubes and heated at 92.5°C according to the method described by Crosbie et al (1992) and Crosbie and Lambe (1993). The tubes were then centrifuged at 1,000 × g for 15 min at 10°C. The swelling volume was calculated by converting the height of the resultant sedimented gels to a volume basis, and the results were reported as mL/g of dry wholemeal.

Pasting Profile Determination

The pasting behavior of the wholemeal samples was studied using a Rapid Visco-Analyser model 3D (RVA) (Newport Scientific, Narrabeen, Australia) with addition of $AgNO_3$ to eliminate α-amylase activity. Wholemeal (4 g, 14% moisture basis) was mixed with 25 g of accurately weighed 1 m*M* $AgNO_3$ in the aluminum RVA sample canister. A programmed heating and cooling cycle was used, where the samples were held at 50°C for 1 min, heated to 95°C in 7.5 min at the rate of 6°C/min, held at 95°C for 5 min before cooling to 50°C in 7.5 min and holding at 50°C for 1 min. The peak viscosity (PV), holding strength or hot paste viscosity (HPV), breakdown (PV – HPV), final or cool paste viscosity (CPV), and setback (CPV – HPV) were recorded. All measurements were replicated twice.

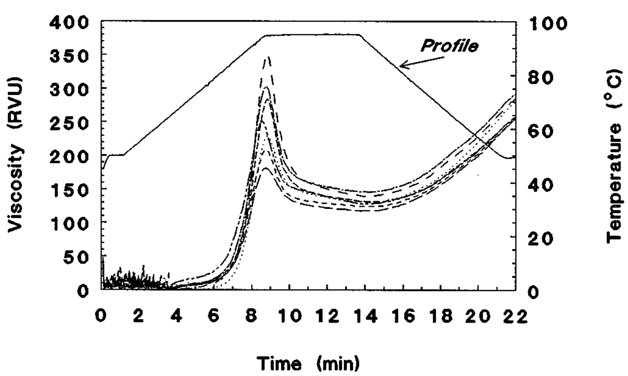

Fig. 1. Rapid Visco-Analyser pasting profiles of seven cultivars (in order of decreasing peak viscosity): Eradu, Klasic, UC896, Express, Kulin, Yecora Rojo and Anza. RVU = Rapid Visco-Analyser units.

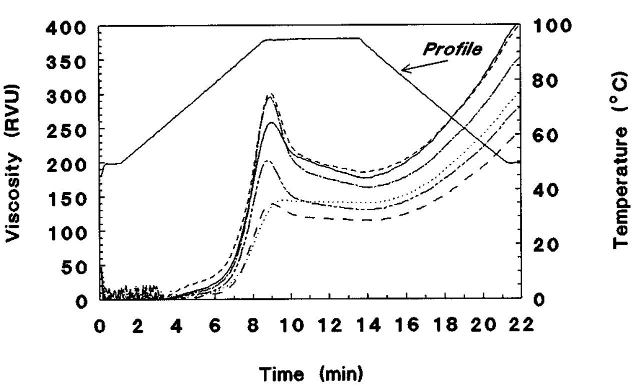

Fig. 2. Rapid Visco-Analyser pasting profiles of six Iranian landraces selected to illustrate diversity in peak and breakdown characteristics (in order of decreasing peak viscosity) IWA 8602488, 8600544, 8602453, 8602413, 8600234, and 8602596. RVU = Rapid Visco-Analyser units.

Texture Analysis

After the RVA cycle, the stirring paddle was removed and each sample was kept at 20°C for 24 hr in the aluminum canister for gelation to take place. The wholemeal gel formed was used for texture analysis using a QTS-25 texture analyzer (Stevens Advanced Weighing Systems, Leonard Farnell and Co. Ltd., England). A standard two-cycle program was used to compress the gels for a distance of 10 mm at a crosshead speed of 30 mm/min using a 7-mm cylindrical probe with a flat end. From the force-time curve obtained, textural parameters of hardness (maximum force on cycle 1) (g), gumminess (hardness × cohesiveness) (g), springiness (height recovered after the first compression) (mm), stickiness (i.e., adhesive force) (negative force between the first and the second peak) (g), adhesiveness (total negative area in cycle 1) (g/sec) and chewiness (gumminess × springiness) (g·mm) were automatically computed using the data processing software supplied with the instrument. Five to seven repeat measurements were taken of each of the two replicate gels per sample.

Statistical Analysis

The general linear model procedure of the Statistical Analysis System version 6.10 (SAS Institute, Cary, NC) was used for data analysis. Fisher's least significant difference (LSD) test was used to compare means at the 5% significance level. Pearson correlation coefficients were calculated using Statistica for Windows Release 4.5 (StatSoft, Inc., Tulsa, OK).

RESULTS AND DISCUSSION

Pasting Profiles

The RVA pasting profiles of the seven cultivated genotypes differed widely mainly in PV (Fig. 1). Their average PV was 260 RVU and ranged between 185 and 355 RVU (Table I). Cultivars Eradu and Klasic, which are commercially used for producing Japanese noodles of favorable quality, had the highest FSV, PV, HPV, and CPV values. UC 896 and Express had intermediate PV and CPV values, but Express had a higher FSV than expected from its PV. The varieties known to be unsuitable for making Japanese WSN (Kulin, Yecora Rojo, and Anza) had the lowest PV, CPV, and FSV.

The pasting characteristics of the landraces showed wide diversity in all parameters (Table I, Fig. 2). The upper range of FSV and PV in the landraces matched that of the cultivars, except for Eradu, which was much higher. The lower limit for FSV and PV and the upper limit for HPV, CPV, and setback exceeded those of the standard cultivars. The PV of the landraces ranged from 139 to 305 RVU with a mean of 209 RVU (Table I). Eight out of 242 accessions had PV values in the range of 281–305 RVU, 48 at 231–280 RVU, 138 at 181–230 RVU, and 48 from 139–180 RVU. IWA 8602488 had the highest PV (305 RVU) among all the landraces, comparable to Klasic (303 RVU). This genotype also displayed exceptionally high HPV, CPV and setback values (Table I and Fig. 2).

Two accessions, IWA 8602430 and 8600544, displayed PV similar to Klasic and fairly high rate of breakdown, making them potentially useful for improving WSN quality (Table I). The pasting profile of IWA 8602453 was characteristic of a high-amylose sample, fairly low PV followed by a substantial increase in its CPV, its setback being the highest among all samples (Fig. 2). Four other accessions (IWA 8600234, 8602176, 8600107, and 8600108) had RVA profiles like a lightly cross-linked modified starch, with low broad peaks in the range of 144 to 156 RVU, and negligible breakdown, which could be attributed to their somewhat higher amylose content. The mean amylose content of those four samples was 30% (range 26–33%), compared to a mean of 27% (range 21–33%) for a representative subset of the 242 landraces (M. Bhattacharya and H. Corke, *unpublished data*). Wheat starches used as stabilizers for oil emulsions in dressings have to be resistant to high-shear forces that occur in homogenization (J. J.

M. Swinkels, *unpublished data*). Genotypes possessing the trait of high resistance to shear thinning could be used to improve the starch quality of commercial varieties used in sauces and dressings.

Flour Swelling Volume

FSV values of the landraces ranged from 8.3 to 15.9 mL/g with a mean of 11.8 mL/g, while that of the cultivars ranged from 10.2 to 18.6 mL/g with a mean of 13.9 mL/g. IWA 8602430 and 8600544, which displayed high PV values, showed correspondingly high FSV values, while the four low-PV, low-breakdown accessions mentioned above gave low FSV values in the range of 9.8 to 11.3 mL/g (Table I). IWA 8602488, with high PV, did not show a correspondingly high FSV value. Overall, a strong positive correlation was found between the FSV values and the PV values (0.73, $P < 0.001$, $n = 242$) (Table II, Fig. 3a). This confirmed that where PV is considered appropriate as the main criterion for judging wheat quality, the FSV test could be used as a fairly reliable and rapid alternative. Crosbie (1991) reported that the FSV test may be used instead of PV for predicting Japanese WSN quality, as the test offers the advantage of short analysis time and small sample size. The FSV values also correlated significantly with the hot paste viscosity (0.42, $P < 0.001$), breakdown (0.73, $P < 0.001$), cold paste viscosity (0.42, $P < 0.001$) and setback (0.39, $P < 0.001$) ($n = 242$ in each case) (Table II).

TABLE I
Flour Swelling Volume (FSV) and Pasting Characteristics of Wholemeal from Iranian Landraces and Standard Cultivars

Genotype	Province of Origin	FSV (mL/g)	Pasting Characteristics (RVU)[a]				
			PV	HPV	Breakdown	CPV	Setback
Highest PV landraces[b]							
8602488	Yazd	13.4	305	188	118	405	218
8602430	Khorasan	14.7	304	168	136	352	184
8600544	Zanjan	15.9	297	166	132	351	186
8602105	Esfahan	12.8	289	176	113	381	205
8600495	Khorasan	11.9	283	180	103	384	204
8600482	Esfahan	12.8	282	186	96	383	197
8600506	Esfahan	12.0	282	173	109	373	200
8600942	Esfahan	12.8	281	179	102	381	202
8600949	Esfahan	12.9	280	168	113	356	188
8602453	Yazd	12.6	258	178	80	406	228
Lowest PV landraces[b]							
8600173	Esfahan	10.7	160	127	34	272	146
8600247	Esfahan	10.1	158	108	50	225	117
8602176	Khorasan	11.3	156	139	17	303	164
8600689	Khorasan	10.7	154	129	25	284	155
8600107	Hamedan	10.7	149	130	19	279	149
8600108	Hamedan	9.8	148	130	18	279	149
8600903	Khorasan	10.7	147	127	20	280	153
8600234	Yazd	9.8	144	140	4	300	160
8600501	Khorasan	9.3	143	119	24	260	141
8602596	Khorasan	9.5	139	115	24	242	127
Mean (n = 242)		11.8	209	147	63	314	167
Cultivars							
Eradu		18.6	355	144	211	286	142
Klasic		15.0	303	146	157	291	145
UC 896		13.1	285	133	152	257	124
Express		15.5	252	129	124	258	130
Kulin		13.2	232	134	98	281	148
Yecora Rojo		10.2	209	125	84	253	129
Anza		11.6	185	122	63	261	139
Mean (n = 7)		13.9	260	133	127	270	137
LSD[c]		1.6	5.5	5.1	3.8	5.5	4.3

[a] PV = peak viscosity, HPV = holding strength or hot paste viscosity, CPV = final or cool paste viscosity. Breakdown was calculated as PV – HPV and setback was calculated as CPV – HPV. RVU = Rapid Visco-Analyser units.
[b] Landraces ranked by decreasing PV; 10 highest and 10 lowest out of 242.
[c] Least significant difference ($P < 0.05$).

TABLE II
Correlation Coefficients (*r* values)[a] of the Textural and Pasting Parameters[b] of Iranian Landraces

	FSV	PV	HPV	Breakdown	CPV	Setback	Hardness	Gumminess	Chewiness	Stickiness	Adhesiveness
Peak viscosity	0.73***										
HPV	0.42***	0.72***									
Breakdown	0.73***	0.92***	0.39***								
CPV	0.42***	0.68***	0.97***	0.35***							
Setback	0.39***	0.62***	0.89***	0.31***	0.98***						
Hardness	–0.1	0.04	0.48***	–0.34***	0.52***	0.53***					
Gumminess	0.03	0.07	0.56***	–0.23**	0.58***	0.57***	0.96***				
Chewiness	0.04	0.05	0.54***	–0.25***	0.58***	0.58***	0.98***	0.95***			
Stickiness	–0.12	0.04	0.44***	–0.31***	0.47***	0.47***	0.87***	0.83***	0.83***		
Adhesiveness	–0.09	0.04	0.48***	–0.23**	0.49***	0.47***	0.83***	0.83***	0.81***	0.94***	
Springiness	0.05	0.01	0.37***	–0.23**	0.36***	0.34***	0.75***	0.68***	0.77***	0.73***	0.69***

[a] *** , **, * = $P < 0.001$, 0.01, and 0.05, respectively. $n = 242$.
[b] FSV = flour swelling volume, PV = peak viscosity, HPV = holding strength or hot paste viscosity, CPV = final or cool paste viscosity. Breakdown was calculated as PV – HPV and setback was calculated as CPV – HPV.

Textural Parameters of the Gels

Texture is the most important characteristic of Asian noodles, and starch properties play a major role in affecting texture (Nagao et al 1977, Toyokawa et al 1989). Various studies have reported that the RVA pasting parameters and the FSV values are significantly correlated with the textural properties of cooked Japanese noodles (Crosbie 1991, Crosbie et al 1992, Konik and Moss 1992, Panozzo and McCormick 1993, Konik et al 1994, Yun et al 1996). Since it was not possible to make noodles out of the landraces due to sample availability and time constraints, the gels formed in the canister after the wholemeal was cooked in the RVA were subjected to texture analysis. The landraces displayed a much wider range in all the textural parameters when compared to the cultivars. The hardness of the gels ranged from 13.3 to 22.3 g in the cultivars and between 14.5 and 47.0 g in the landraces, while chewiness ranged between 45 and 105 g·mm in the cultivars and between 59 and 264 g·mm in the landraces (Table III). Among the cultivars, UC 896 had the lowest values for all the textural parameters, and Anza the highest (except for springiness). It was remarkable that the range in most textural parameters for the seven cultivated lines corresponded closely to the range of the lowest 10 landraces ranked for hardness (Table III). The upper range in the landraces for these traits, generally about two-fold higher than the values observed for Anza, may be useful in developing wheat for some special products.

The correlation between the starch pasting characteristics and the textural parameters of the gels are shown in Table II and Fig. 3b. Surprisingly, in contrast to many of the results in the udon noodle literature (reviewed previously), the textural parameters did not show any significant relationship with either the PV or the FSV values. This could be partly due to the variation in the starch content of the diverse landrace material (Bhattacharya and Corke 1996), and also because the PV reflects starch swelling at high temperatures and need not have a direct relationship to texture of the cooled gel. However, the other RVA parameters like the HPV, CPV, breakdown, and setback correlated highly with the hardness, gumminess, stickiness, adhesiveness, and springiness of the gels. The RVA parameters were generally highly correlated among themselves, as were the textural parameters among themselves (Table II). Figs. 1 and 2 show that the cultivars and landraces differ in the relationship of PV to the other pasting parameters. Breakdown was significantly negatively correlated with the textural parameters. It is well established that wheat samples with high breakdown impart the low chewiness and firmness to the noodles that are desirable in Japanese WSN (Moss 1971, Oda et al 1980, Miskelly and Moss 1985, Konik et al 1994).

Based on these observations, it is suggested that the texture analysis of the gels formed in the RVA could be used as a further aid in predicting the eating quality of noodles in the early stages of wheat breeding when the sample size available is limited. When testing samples with wide starch diversity, as in the case of these landraces (or with wheat wild relatives), the joint use of the HPV, CPV, breakdown, and setback values along with the PV is recommended. The peak alone may not differentiate among useful types of variation in the starch pasting characteristics.

Relationship of Provincial Origin to Pasting Characteristics

The identification of extreme genotypes with desirable end-use traits that could be used in wheat quality improvement is the practical objective of landrace evaluation. We previously reported on the response of 229 hexaploid Iranian landraces to variation in soil salinity, finding several accessions from different provinces to

TABLE III
Textural Parameters of Wholemeal Gels from Iranian Landraces and Standard Cultivars

Genotype	Province of Origin	Hardness (g)	Gumminess (g)	Chewiness (g·mm)	Stickiness (g)	Adhesiveness (g/sec)	Springiness (mm)
Highest hardness landraces[a]							
8600311	Esfahan	47.0	28.9	260	13.5	182	9.0
8602453	Yazd	47.0	30.7	264	13.2	174	8.6
8602489	Yazd	46.8	27.6	260	14.0	181	9.5
8602571	Khorasan	43.8	26.4	240	14.0	181	9.1
8602597		43.3	25.3	241	11.5	160	9.6
8600908	Khorasan	42.8	25.1	233	15.0	189	9.3
8602102	Khorasan	42.7	24.9	230	16.3	206	9.4
8600234	Yazd	42.3	25.7	222	15.8	223	8.7
8600633	Khorasan	41.8	25.5	225	16.3	200	8.9
8602257	Khorasan	41.3	25.2	223	15.7	197	8.9
Lowest hardness landraces[a]							
8600115	Mazandaran	23.3	14.5	122	10.5	140	8.4
8600247	Esfahan	23.0	16.0	116	9.5	124	7.2
8602749		22.5	15.1	127	9.8	141	8.5
8602686	Fars	21.8	14.6	109	8.0	112	7.5
8600101	Kordestan	21.3	13.8	96	9.3	119	7.0
8602565		21.0	14.3	94	8.5	117	6.6
8602743		21.0	14.6	99	9.0	132	6.8
8600031	Bakhtaran	20.3	12.9	80	10.0	143	6.2
8602596	Khorasan	18.8	12.7	76	7.3	111	5.9
8602428	Khorasan	14.5	10.1	59	5.0	64	5.8
Mean (n = 242)		32.3	20.2	169	11.6	155	8.0
Cultivars							
Anza		22.3	13.8	105	9.3	117	7.7
Express		20.5	13.4	99	8.0	107	7.4
Kulin		19.5	12.8	100	7.0	100	7.8
Klasic		17.0	13.0	93	5.0	66	7.2
Eradu		16.5	12.9	76	5.0	79	6.0
Yecora Rojo		15.5	11.4	61	6.5	97	5.4
UC 896		13.3	10.4	45	3.8	63	4.4
Mean (n = 7)		17.8	12.5	83	6.4	90	6.5
LSD[b]		1.9	1.7	13	1.8	17	0.8

[a] Landraces ranked by decreasing hardness; 10 highest and 10 lowest out of 242.
[b] Least significant difference ($P < 0.05$).

be significantly more tolerant to high-salinity treatments (Jafari-Shabestari et al 1995). Certain provinces had higher frequencies of salinity-tolerant accessions when compared to others, suggesting that further evaluation of the collection for that trait should focus on accessions from those particular areas. The number of accessions from each province that ranked in the top 30 and the bottom 30 out of the 242 landraces in the present study are shown in Table IV. Zanjan province from the Northwest region of Iran had four and three of its five accessions in the top 30 for FSV and PV values, respectively (Table IV). This province also had four of its accessions ranking in the top 30 for high breakdown values.

Thus, the landraces of Zanjan province may be potentially important genetic resources for improving quality of Japanese noodle wheat. Few accessions from Yazd province, including IWA 8602488, displayed high resistance to breakdown, with four of its 12 accessions showing high PV, HPV, CPV, and setback values. Esfahan province in central Iran had 12 out of 47 accessions with high PV, while Khorasan province in the east of Iran had only five of its 89 accessions with high PV. Fars province had seven out of 14 accessions in the lowest 30 for FSV. It also had four in the lowest 30 for CPV and setback (Table IV) (compared to 0 in the highest 30). Half or more of the lowest 30 for PV, HPV, and setback came from Khorasan. Nevertheless, despite these trends, extreme variation in the starch pasting properties could be observed within a single province. IWA 8602430 from Khorasan province had a PV as high as that of Klasic, and IWA 8600501 and 8602596, also from Khorasan, had the lowest PV values in the whole collection (Table I).

The landraces were grouped by their province of origin and their corresponding mean FSV values, RVA pasting and textural parameters were calculated (Table V). Significant differences in means for pasting characteristics were found among provinces. Zanjan province ranked first in mean FSV and breakdown and second in PV. Markazi province ranked first in CPV and setback, second in FSV, and third in PV, HPV, and breakdown. Gilan province, with only one accession, gave the highest PV among the province means. The mean PV and HPV of Yazd and Esfahan provinces ranked fourth and fifth respectively. Hamedan and

TABLE IV
Number of Accessions (N) from Each Province of Origin and Number that Ranked in the Top 30 (High) and Lowest 30 (Low) Out of 242 in Starch Pasting Characteristics and Textural Properties[a]

		FSV		PV		HPV		Breakdown		CPV		Setback		Hardness		Chewiness	
Province	N	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Markazi	2	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0
Gilan	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Mazandaran	5	0	0	0	0	1	1	1	0	1	1	1	1	0	2	1	2
East Azarbayjan	9	0	2	0	2	1	1	0	2	1	1	1	1	1	1	1	1
West Azarbayjan	6	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Kordestan	6	3	0	1	0	0	1	1	0	0	2	0	2	0	2	0	2
Bakhtaran	3	1	0	0	0	0	1	0	0	0	1	0	1	0	1	0	1
Khoozestan	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fars	14	1	7	2	3	1	3	3	2	0	4	0	4	0	3	1	2
Esfahan	47	4	5	12	6	10	4	11	3	11	4	10	4	7	5	6	4
Kerman	7	0	1	0	0	1	0	0	0	1	0	2	0	0	0	0	0
Khorasan	89	9	10	5	15	8	15	6	17	9	11	9	11	16	8	15	10
Zanjan	5	4	0	3	0	1	1	4	0	1	1	0	1	0	3	1	2
Hamedan	6	0	2	0	2	1	2	0	2	0	2	1	0	0	0	0	1
Hormozgan	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yazd	12	3	1	4	0	4	0	1	1	4	0	4	0	3	0	3	0
Unknown	27	4	2	1	2	1	1	1	3	1	2	1	4	3	5	2	5

[a] FSV = flour swelling volume, PV = peak viscosity, HPV = holding strength or hot paste viscosity, CPV = final or cool paste viscosity. Breakdown was calculated as PV – HPV and setback was calculated as CPV – HPV.

TABLE V
Means for Starch Pasting Parameters[a] of Total Landraces (N) Based on Province of Origin

Province	N	FSV	PV	HPV	Breakdown	CPV	Setback	Hardness	Chewiness
Markazi	2	13.6	232	157	75	339	182	33	183
Gilan	1	12.8	269	159	110	333	174	29	158
Mazandaran	5	11.8	220	146	74	316	169	30	157
East Azarbayjan	9	11.6	200	146	55	310	164	33	175
West Azarbayjan	6	11.7	219	148	71	311	163	32	175
Kordestan	6	12.6	211	143	68	303	160	27	137
Bakhtaran	3	12.1	203	139	64	293	153	29	151
Khoozestan	2	11.9	200	140	60	297	157	31	175
Fars	14	10.9	202	137	65	293	156	31	168
Esfahan	47	11.8	225	154	71	326	173	32	177
Kerman	7	11.6	216	154	62	335	181	34	187
Khorasan	89	11.6	198	144	55	309	165	33	177
Zanjan	5	14.2	257	146	111	308	162	28	158
Hamedan	6	10.8	188	144	43	309	165	33	176
Hormozgan	1	11.0	196	159	37	337	178	38	209
Yazd	12	12.0	225	157	68	337	180	35	195
Unknown	27	12.0	206	145	61	312	167	31	171
Mean	242	11.8	209	147	63	314	167	32.1	175
LSD[b]		1.6	47.4	21.0	35.2	45.7	26.0	7.8	48.5

[a] FSV = flour swelling volume, PV = peak viscosity, HPV = holding strength or hot paste viscosity, CPV = final or cool paste viscosity. Breakdown was caluclated as PV – HPV and setback was caluclated as CPV – HPV.
[b] Least significant difference ($P < 0.05$).

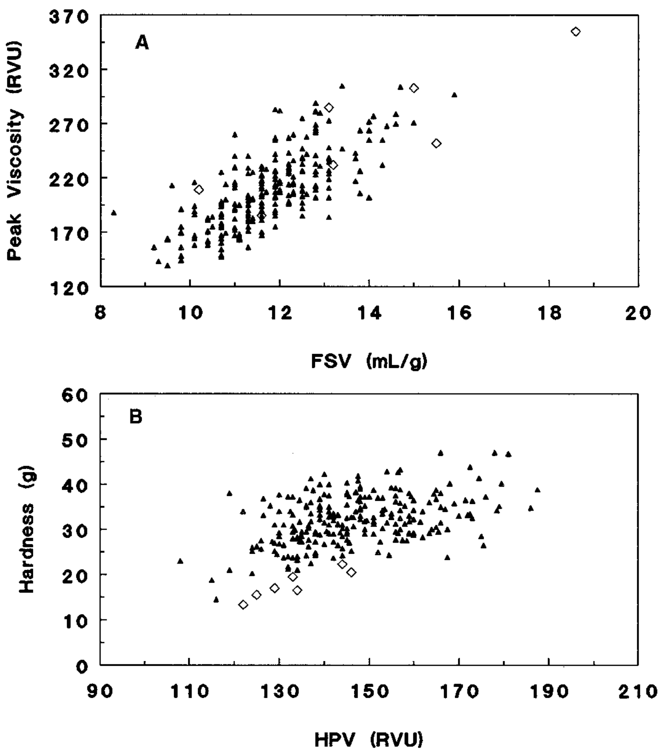

Fig. 3. Scatter diagrams of relationship between peak viscosity and flour swelling volume (FSV) (**A**) and between hardness and hot paste viscosity (HPV) (**B**) for 242 landraces (▲) and seven cultivars (◇). RVU = Rapid Visco-Analyser units.

Hormozgan province ranked the lowest in FSV, PV, and breakdown values, while Bakhtaran and Fars provinces ranked the lowest in CPV and setback values. Kordestan and Hormozgan provinces ranked the lowest and highest, respectively, for both gel hardness and chewiness.

CONCLUSIONS

The evaluation of only 242 landraces from a total collection of more than 12,000 accessions revealed a wide variation in starch pasting properties. Further investigations on the amylose and starch content are being conducted on selected genotypes to gain better insight on their pasting characteristics (M. Bhattacharya and H. Corke, *unpublished data*). Because of the wide diversity of wheat-flour-based products, especially in Asia, it is clear that different starch properties will be optimal for different products. The development of wide diversity of starch traits in wheat cultivars will enable flexibility in responding to new market demands.

Of the 242 Iranian hexaploid wheat landraces studied, two accessions had pasting characteristics similar to those of Klasic, a commercial variety used for making noodles, while four accessions displayed high resistance to shear thinning, possibly due to their high amylose content. The holding strength (HPV), cold paste viscosity, breakdown, and setback values obtained from the RVA are related to essential textural parameters of the starch gel and can be incorporated in predictive tests for noodle quality.

We feel that the wide use of FSV or RVA PV, with the exclusion of other pasting data, to screen for starch diversity should be reevaluated. FSV and PV seem to be appropriate and useful in the special case of Japanese WSN quality, but not for general studies of starch quality. PV is correlated to CPV, but CPV should, in many cases, be a more direct indicator of product texture. In our experiments, directly measured textural parameters were poorly correlated with PV but quite well correlated with other pasting parameters, such as HPV or CPV. FSV was uncorrelated to textural parameters and only moderately correlated to CPV. The near-exclusive use of single parameters such as FSV or PV also results in missing important variation in overall pasting profiles, such as extremely high or low breakdown (shear-thinning) which could be useful in specific situations. We speculate that much of the useful variation in wheat starch will be found within the normal range of PV but will represent variation in the other pasting parameters.

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