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Evaluation of Hard White Winter Wheat Breeder Lines for Alkaline Asian Noodles

OSU FOODTECHNOLOGY FACTS

Oklahoma Cooperative Extension Service • Division of Agricultural Sciences and Natural Resources

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Patricia Rayas-Duarte
FAPC Cereal Chemist

Cristina Fransisco
FAPC Research Assistant

Rationale/Background

About 40% of wheat products in Asian countries are consumed in the form of noodles (Crosby, 1991). As the largest wheat exporter country in the world, the United States needs to maintain its competitiveness in producing wheat of a quality desired by more sophisticated buyers. When Asian consumers choose wheat for noodle manufacturing, buying decisions are based on the final color and texture characteristics (Crosby, 1991).

The interest in hard white winter wheat (HWWW) has been generated by competition of Australian Standard White wheat from Western Australia, which has been tailored for white salted Asian noodles (Janto, 1998).

The interest in HWWW has grown in wheat-producing states in the U.S. and overseas markets. White Winter varieties may not only produce brighter and whiter flour than the red winter wheat varieties, but also lack the bitter aftertaste given by polyphenols present in the red wheat varieties.

The objective of this research was to compare the quality of Alkaline Asian noodles made from HWWW advanced breeder lines and commercial white varieties grown in different locations in Oklahoma.

Materials and Methods

Wheat Lines/Varieties -

Eight HWWW advanced breeder lines and two commercial varieties grown in three locations (Altus, Fort Cobb, and Sweetwater, OK) were donated by Dr. Brett Carver (OSU wheat breeder). Eltan (soft white winter) and Nu-West (hard white winter) varieties from Washington and Montana, respectively, were used for comparison. All samples were milled in a Quadromat Sr. mill (C.W. Brabender, Hackensack, NJ).

Protein Analysis

Flour protein content was measured using a near infrared (NIR) spectrometer (Perten Instruments, Reno, NV), and the percent protein was calculated on a 14% moisture basis.

The table below shows the counties to which the locations belong and their annual wheat production in the crop years 1998 and 1999.

		*Wheat Production** *(Bushels in Millions)*	
Location	***County***	***1998***	***1999***
Altus	Jackson	5.9	3.75
Fort Cobb	Caddo	7.4	6.6
Sweetwater	Roger Mills	2.0	1.8

* Source - Oklahoma Agricultural Statistics 1998-1999.

Noodle Preparation

Alkaline noodles were prepared from 200 g flour and 10 ml alkaline solution containing 0.45% Na_2CO_3, 0.45% K_2CO_3, and 2% NaCl. Water absorption levels were adjusted to obtain an optimum sandy dough. Noodles were processed in a laboratory-scale noodle machine (H.H. Kejentaraan, Malaysia), adjusting the reducing roll gap from 4.0 to 1.0 mm in seven steps. Pieces (6 x 6 cm) of the dough were saved for color evaluation. Brightness, redness, and yellowness were measured with a Minolta colorimeter (Minolta Ltd., Osaka, Japan) using a triple layer of the raw dough at 2 and 24 hours after preparation. The dough pieces were stored in plastic bags at room temperature (26°C).

Peak viscosity was measured in a flour-water slurry at a 3.5:25 ratio (w/w) using a Rapid Visco Analyzer (Newport Scientific, Sydney, Australia).

Objective textural properties were measured with a Texture Analyzer, TA-XT2i (Stable Micro Systems, England). The test consisted of two compressions using a 2.54 cm cylindrical probe descending to a preset distance in the noodle with a constant load increase over the time used. Five independent observations were made on five 2-cm-long cooked noodle strands placed side by side. Due to the limited amount

of wheat from the breeder program, all analyses were done in a single experimental unit with subsamplings.

Results

Protein Content

The flour protein content ranged from 8.3 to 13.0% (see Figure 1). Wheat lines and varieties grown in Altus showed a higher percentage of protein than those from Fort Cobb and Sweetwater. The percent protein of wheat line OK97G611 showed the largest variability, while OK98G504W was less variable between locations. Averaging the three locations, OK98G505W contained 10.5% protein, the highest protein among the breeder lines tested. Comparing the average protein of the commercial varieties, Betty had the highest — at 12.5% — and the most consistent protein content compared to Oro Blanco and wheat lines in all locations. Oro Blanco had similar average protein content compared to all the breeder wheat lines tested.

Gain Weight

Thirty-five grams of noodles were cooked in boiling water for 2 minutes, rinsed with tap water, drained by tapping 10 times, stored in water and immediately analyzed. Gain weight was calculated as a percentage using initial and final weights. A higher value of gain weight will produce higher yields and more profits for the processor. Breeder line OK98G502W gave the highest (116.4%) and least variable gain weight among the lines and varieties in all three locations (see Figure 2). At 94.1%, wheat line OK97G611 had the lowest gain weight among the lines and varieties in all the locations. Breeder lines OK98G506W and OK98G507W exhibited the greatest variation of gain weight between locations. The commercial varieties Betty and Oro Blanco showed high and less variable gain weight in all locations — 110.5% and 114.0%, respectively. On the average, Oro Blanco was similar to breeder line OK98G502W, which had 116.4% gain weight.

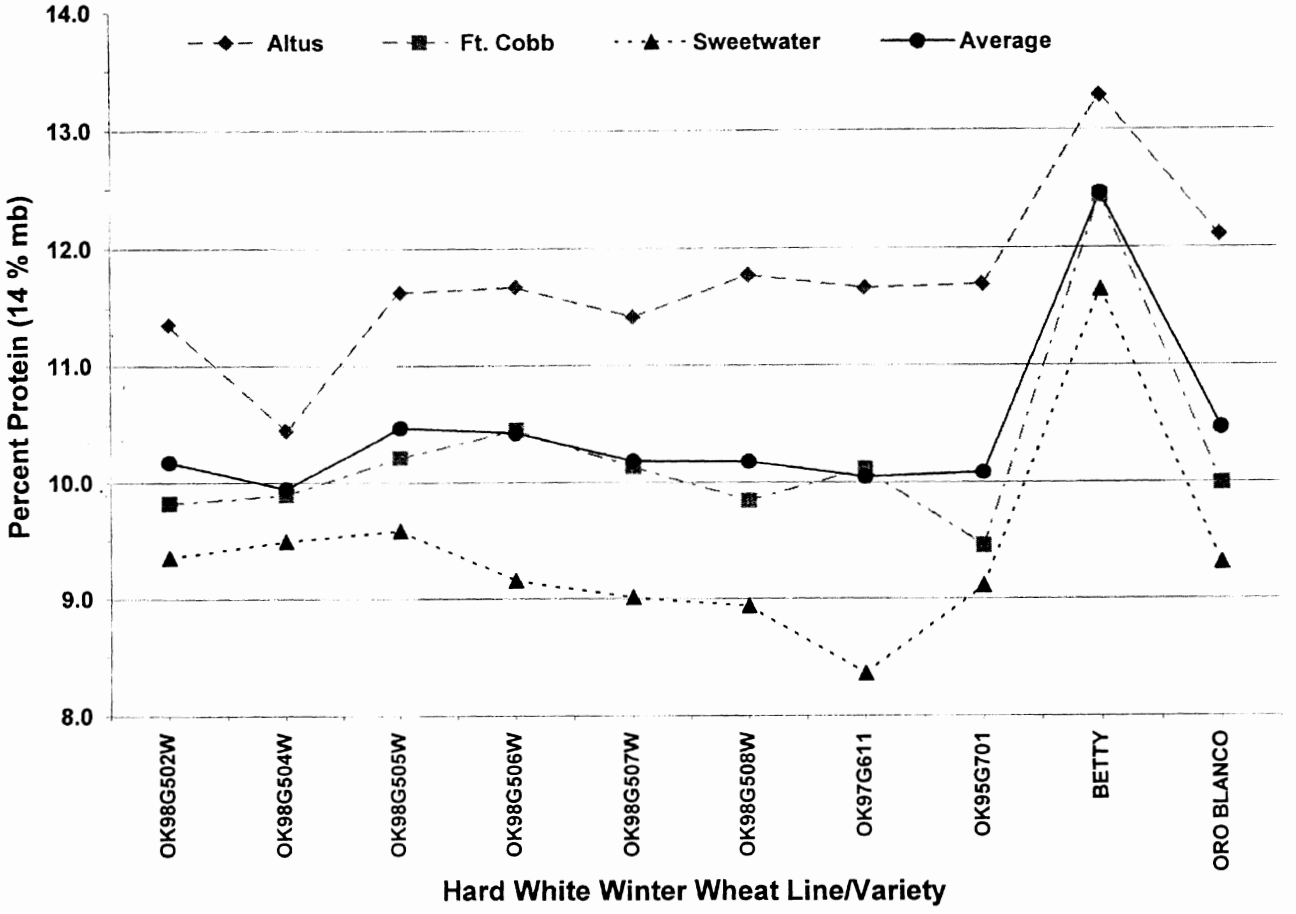

Figure 1. Percent protein (14% mb) of flour from hard white winter wheat breeder lines and commercial varieties grown in three Oklahoma locations (1998-1999 crop year). Standard deviation for Altus = ±0.7, Fort Cobb = ±0.8, Sweetwater = ±0.8, and average = ±0.7. Protein content (14%mb) for the comparison varieties Eltan and Nu-West were 7.3% and 10.9%, respectively.

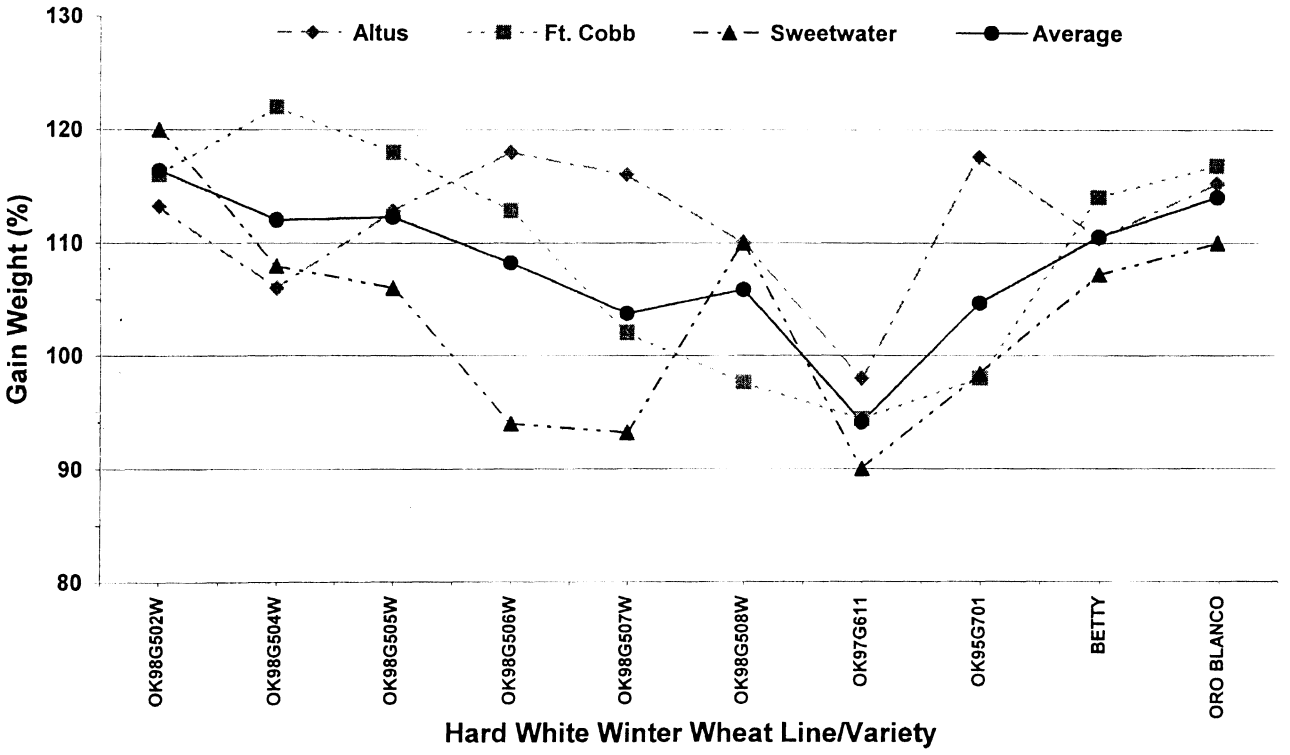

Figure 2. Gain in weight of Asian alkaline noodles made from hard white winter wheat breeder lines and commercial varieties grown in three Oklahoma locations (1998-1999 crop year). Standard deviation for Altus = ± 6.09, Fort Cobb = ± 10.07, Sweetwater = ± 9.44, and average = ± 6.44. Gained weight for the comparison varieties Eltan and Nu-West were 94.8% and 92.0%, respectively.

Color

Asian customers prefer bright and yellow alkaline noodles that retain a stable color up to 24 hours after preparation. Objective measurement of color is done by a colorimeter that gives values of brightness (L*), yellowness (b*), and redness (a*). Desirable values for L* are higher than 60, with a maximum value of 100 for bright noodles and 50 for a dull gray color. Values lower than 50 indicate overall darkness of the noodles. The a* and b* are the color coordinates: +a* and –a* are the red and green directions and +b* and –b* are the yellow and blue directions, respectively. The +a* and +b* values range from 10 to 60. Values less than 10 result in a gray and dull color. In alkaline Asian noodles, the basic pH enhances the xanthophylls, or yellow pigments, in the flour. Redness (+a*) values are an undesirable hue in alkaline noodles; the lower the value, the better, but values too low will produce a dull gray color.

Brightness (L)*

Table 1a shows the change in brightness of the alkaline Asian noodles from 2 to 24 hours. Delta-L* (ΔL*) is an estimate of the stability of the noodle brightness. Lower ΔL* values of noodles made from breeder line OK97G611 were observed (Table 1a) and ranked first among the lines and varieties in all locations. The average ΔL* value for this breeder line (2.7) was lower than the average ΔL* values of Betty (7.2) and Oro Blanco (5.1), which ranked 7th and 4th, respectively. Only breeder line OK97G611 gave a ΔL* value comparable to Eltan (3.0) and Nu-West (2.3), while the other samples gave higher ΔL* values, indicating a greater decrease in brightness.

*b**

The majority of the change in b* values in the samples tested were relatively small and negative (increase in blue), with an overall average Δb* of -3.0 (see Table 1b). In comparison to Eltan and Nu-West, the breeder and variety samples grown in Oklahoma indicate a marked deterioration from the original yellowness of the dough.

*a**

All the dough samples from Oklahoma-grown wheats showed small but negative Δa* values ranging from -0.1 to -0.7 (see Table 1c). These values are at the center of the color space, where gray color resides. Wheat lines OK98G504W and OK98G506W ranked first, while the commercial variety Betty ranked 9th, and Oro Blanco ranked 5th. The Δa* values from the breeder lines and varieties in this study demonstrated a shift to a grayish hue, which is undesirable in an alkaline noodle.

Table 1a. Color lightness values (L*)[1] at 2 and 24 hr of Asian alkaline noodles made from hard white winter wheat breeder lines and commercial varieties. 1998 -99 crop year.

Variety/Location	2 hr					24 hr					ΔL 2-24 hr[2]				
	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
OK98G502W	78.4	80.9	80.2	**79.8**	**(9)**	68.5	76.7	72.6	**72.6**	**(9)**	9.9	4.3	7.6	**7.2**	**(7)**
OK98G504W	77.4	80.5	84.7	**80.9**	**(5)**	70.7	69.3	79.6	**73.2**	**(7)**	6.6	11.2	5.1	**7.7**	**(10)**
OK98G505W	78.5	85.0	80.8	**81.4**	**(2)**	71.6	77.7	78.8	**76.1**	**(4)**	6.9	7.3	2.0	**5.4**	**(4)**
OK98G506W	79.8	84.9	84.2	**83.0**	**(1)**	73.2	77.0	79.0	**76.4**	**(3)**	6.6	7.9	5.2	**6.6**	**(5)**
OK98G507W	77.2	80.5	84.3	**80.7**	**(7)**	70.7	76.2	79.8	**75.6**	**(6)**	6.5	4.3	4.5	**5.1**	**(3)**
OK98G508W	79.0	80.2	82.8	**80.7**	**(7)**	69.9	74.9	74.7	**73.2**	**(7)**	9.1	5.3	8.1	**7.5**	**(9)**
OK97G611	78.2	81.3	83.0	**80.9**	**(5)**	75.1	78.0	81.4	**78.1**	**(1)**	3.1	3.3	1.7	**2.7**	**(1)**
OK95G701	82.6	78.5	82.9	**81.3**	**(3)**	74.9	75.3	80.4	**76.9**	**(2)**	7.7	3.2	2.6	**4.5**	**(2)**
Betty	67.3	80.8	79.7	**75.9**	**(10)**	58.1	72.7	75.3	**68.7**	**(10)**	9.3	8.1	4.4	**7.2**	**(7)**
Oro Blanco	82.8	79.3	81.4	**81.2**	**(4)**	75.5	74.8	77.8	**76.1**	**(4)**	7.3	4.5	3.6	**5.1**	**(3)**
Average	**78.1**	**81.2**	**82.4**	**82.4**		**70.8**	**75.3**	**77.9**	**77.9**		**7.3**	**5.9**	**4.5**	**4.5**	
SD[3]	4.3	2.1	1.8	1.8		5.1	2.6	2.8	2.8		1.9	2.6	2.2	2.2	
Eltan (WA)[4]	-	-	-	84.2		-	-	-	81.2		-	-	-	3.0	
Nu-West (MT)[4]	-	-	-	75.5		-	-	-	73.2		-	-	-	2.3	

Table 1b. Color (b*) values[1] at 2 and 24 hr of Asian alkaline noodles made from hard white winter wheat breeder lines and commercial varieties. 1998-99 crop year.

Variety/Location	2 hr					24 hr					Δb 2-24 hr[2]				
	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
Sweetwater	**Ave**	**Rank**													
OK98G502W	14.4	11.0	10.6	**12.0**	**(8)**	15.8	16.0	10.3	**14.0**	**(10)**	-1.4	-5.0	0.3	**-2.0**	**(6)**
OK98G504W	14.0	12.5	14.6	**13.7**	**(6)**	14.3	13.1	15.0	**14.2**	**(9)**	-0.3	-0.5	-0.4	**-0.4**	**(2)**
OK98G505W	17.4	13.4	10.7	**13.8**	**(4)**	16.7	13.7	15.5	**15.3**	**(7)**	0.6	-0.3	-4.8	**-1.5**	**(3)**
OK98G506W	21.3	13.6	14.0	**16.3**	**(1)**	20.4	14.3	14.8	**16.5**	**(4)**	0.9	-0.6	-0.7	**-0.2**	**(1)**
OK98G507W	15.1	12.3	14.4	**14.0**	**(3)**	15.3	19.1	14.6	**16.3**	**(5)**	-0.1	-6.7	-0.1	**-2.3**	**(7)**
OK98G508W	15.6	13.1	12.8	**13.8**	**(4)**	16.8	15.9	13.2	**15.3**	**(7)**	-1.2	-2.8	-0.4	**-1.5**	**(3)**
OK97G611	12.3	11.2	11.2	**11.5**	**(10)**	19.1	18.1	17.1	**18.1**	**(1)**	-6.8	-6.9	-5.9	**-6.6**	**(10)**
OK95G701	12.7	12.3	10.8	**11.9**	**(9)**	13.6	18.9	17.2	**16.6**	**(3)**	-0.9	-6.6	-6.5	**-4.6**	**(9)**
Betty	18.4	13.4	10.4	**14.1**	**(2)**	19.0	12.6	15.9	**15.8**	**(6)**	-0.6	0.8	-5.5	**-1.8**	**(5)**
Oro Blanco	12.7	12.9	12.0	**12.6**	**(7)**	12.9	19.2	18.0	**16.7**	**(2)**	-0.2	-6.2	-6.0	**-4.1**	**(8)**
Average	**15.4**	**12.6**	**12.2**	**12.2**		**16.4**	**16.1**	**15.2**	**15.2**		**-1.0**	**-3.5**	**-3.0**	**-3.0**	
SD[3]	2.9	0.9	1.7	1.7		2.5	2.6	2.2	2.2		2.2	3.1	2.9	2.9	
Eltan (WA)[4]	-	-	-	17.3		-	-	-	16.2		-	-	-	1.1	
Nu-West (MT)[4]	-	-	-	13.1		-	-	-	11.4		-	-	-	1.7	

Table 1c. Color (a*) values[1] at 2 and 24 hr of Asian noodles made from hard white winter wheat breeder lines and commercial varieties. 1998-99 crop year.

Variety/Location	2 hr					24 hr					Δa 2-24 hr[2]				
	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
OK98G502W	-0.99	-0.75	-0.72	**-0.82**	**(3)**	-0.84	0.18	-0.61	**-0.42**	**(3)**	-0.15	-0.93	-0.11	**-0.40**	**(5)**
OK98G504W	-0.69	-0.71	-0.79	**-0.73**	**(2)**	-0.42	-0.67	-0.82	**-0.64**	**(9)**	-0.28	-0.03	0.03	**-0.09**	**(1)**
OK98G505W	-1.24	-0.90	-0.67	**-0.93**	**(5)**	-1.14	-0.83	0.17	**-0.60**	**(7)**	-0.10	-0.07	-0.83	**-0.33**	**(3)**
OK98G506W	-1.75	-0.82	-0.85	**-1.14**	**(10)**	-1.48	-0.79	-0.91	**-1.06**	**(10)**	-0.27	-0.03	0.06	**-0.08**	**(1)**
OK98G507W	-0.88	-0.90	-0.84	**-0.87**	**(4)**	-0.73	-0.23	-0.85	**-0.60**	**(7)**	-0.16	-0.67	0.01	**-0.27**	**(3)**
OK98G508W	-0.91	-0.92	-0.98	**-0.94**	**(6)**	-0.77	0.23	-1.03	**-0.52**	**(4)**	-0.13	-1.15	0.05	**-0.41**	**(5)**
OK97G611	-1.02	-1.14	-0.95	**-1.04**	**(9)**	-0.29	-0.53	-0.23	**-0.35**	**(2)**	-0.73	-0.61	-0.72	**-0.69**	**(10)**
OK95G701	-0.98	-0.95	-0.94	**-0.95**	**(7)**	-1.02	-0.37	-0.39	**-0.59**	**(6)**	0.05	-0.58	-0.55	**-0.36**	**(5)**
Betty	1.80	-0.73	-0.86	**0.07**	**(1)**	2.59	-0.56	0.05	**0.69**	**(1)**	-0.80	-0.18	-0.91	**-0.63**	**(9)**
Oro Blanco	-0.96	-0.88	-1.03	**-0.96**	**(8)**	-0.96	-0.02	-0.63	**-0.54**	**(5)**	0.00	-0.86	-0.40	**-0.42**	**(5)**
Average	**-0.76**	**-0.87**	**-0.86**	**-0.86**		**-0.51**	**-0.36**	**-0.52**	**-0.52**		**-0.26**	**-0.51**	**-0.34**	**-0.34**	
SD[3]	0.94	0.13	0.11	0.11		1.14	0.39	0.41	0.41		0.29	0.41	0.39	0.39	
Eltan (WA)[4]	-	-	-	-1.98		-	-	-	-2.14		-	-	-	0.20	
Nu-West (MT)[4]	-	-	-	-1.02		-	-	-	-1.02		-	-	-	0.00	

[1]Lightness or brightness (L*), b* - high values desired, and a* - small values desired
[2]ΔL, Δa, Δb, - difference between 2 and 24 hr of raw noodles, small values desired
[3]SD - standard deviation
[4]Eltan and Nu-West - commercial varieties used for comparison

Notes:

Hatcher, DW; Kruger, JE; Anderson, MJ; 1999, Cereal Chem 76(4), 566-572.
Alkaline noodle should be bright (high L*) and display good yellow color (high b*).
Higher negative a* value means more green noodle.
Higher positive a* value means more red noodle.

Starch Peak Viscosity

Overall, the Sweetwater location showed the highest peak viscosity of flour, while Altus had the lowest (see Figure 3). High peak viscosities are associated with desirable texture characteristics in white noodles (Ross, 1997).

Texture

Objective evaluation of textural properties that is reproducible and not subject to regional taste and evaluator fatigue is valuable in breeding programs for screening purposes. There are a number of literature reports on textural properties of Asian noodles using sensory evaluation (the subjective method) with trained panelist from particular regions in Asia (Ross, 1997; Janto, 1998; and Yun, 1996). However, it is challenging to find native Asian evaluators from several regions willing to make a commitment of time for constant noodle evaluation sessions.

Hardness is a measure of the firmness of the noodles and probably the most important texture parameter. Hardness was measured as the maximum peak of the first compression. Smooth surface and higher elasticity (springy) properties are preferred in cooked Chinese wet alkaline noodles (Ross, 1997). In this study, the average score for hardness was 1551 ± 132 from all samples and locations as shown in Table 2a. The majority of the breeder lines and varieties were comparable to the firmness score of 1567 for Nu-West and higher than Eltan's 1147. The firmest noodles were obtained from breeder line OK98G508W, which had a score of 1791, and the softest were from line OK97G611, with a score of 1402. Nevertheless, the softest among the wheat lines and varieties scored higher than Eltan. However, Eltan showed the highest resilience value, meaning it produces a soft but resilient noodle structure (see Table 2c).

Springiness is a measure of the ability of the noodle to bounce back after pressure is applied. In the TPA analysis, springiness is calculated as the length along the X-axis of the two compression peaks, from the baseline to each peak. Springiness correlates with how rubbery noodles are perceived. Average springiness scores ranged from 0.95 to 1.04 ± 0.02 in all locations, as shown in Table 2a. The majority of the samples had springiness values similar to Nu-West, except for OK97G611 (0.97), OK95G701 (0.95), and Oro Blanco (0.95), which had similar values to the comparison variety Eltan (0.95).

Cohesiveness is measured by the ratio of the two compression areas. It is related to the extent to which noodle structure is disrupted during the two compressions by the testing probe. This measurement is associated with sensory evaluation of the noodle bite and springiness. The most cohesive noodles in the group were obtained from lines OK98G504W and OK98G506W (0.70), shown in Table 2b. These noodles have similar cohesiveness scores to Nu-West (0.71), but lower than Eltan (0.78). In contrast, the least cohesive noodle was made from OK97G611 (0.56). Overall, wheat lines and varieties tested had a cohesiveness score of 0.65, which is comparable to Nu-West's score of 0.71.

Gumminess is the energy required to disintegrate a semisolid food to a state ready for swallowing and is a combination of hardness and cohesiveness (Whistler, 1997). The overall gumminess score for all the samples in the three locations was 856 ± 126, which is within the range of Eltan and Nu-West; that is, 812 to 961. Wheat line OK98G504W demonstrated the highest score for gumminess (1050) among all the wheat lines and varieties Eltan and Nu-West (see Table 2b). In contrast, OK97G611 conferred the lowest score (620).

Chewiness is a combination of hardness, cohesiveness, and elasticity (6). Subjectively, chewiness is measured by "tooth packing," where the evaluator uses molar compression on the noodles and then assesses how much the noodle's structure springs back. In this study, the average score for chewiness of all the samples across the locations was 846 ± 136 (Table 2c). Wheat line OK98G504W gave the highest score for chewiness (1060), while OK97G611 had the lowest score (598). Three lines OK98G506W, OK98G507W, and OK98G508W had a chewiness score similar to the Nu-West variety (938).

Resilience is the ability of the noodles to regain their shape after being compressed. In theory, this measure is positively correlated with elasticity. The overall score for resilience was 0.35 ± 0.05 (Table 2c). This score is similar to Nu-West (0.35) but lower than Eltan (0.50). The most resilient noodle was obtained from OK98G506W (0.43) and the least resilient from OK95G701 (0.28).

Adhesiveness is a negative force after the first compression cycle and is a measure of how sticky, tacky, or gooey the noodles are (Whistler, 1997). All samples adhered to the probe with an overall score of -52.76 ± 14.57. This value is similar to Eltan (-50.0) but higher than Nu-West (-34.5). Wheat lines and varieties with higher adhesiveness than Eltan (-50.0) were OK98G504W (-73.0), OK98G505W (-60.4), OK98G506W (-67.1), OK98G504W (-66.5), and Oro Blanco (-58.2). Only wheat line OK98G507W (-29.1) had lower adhesiveness than Nu-West (-34.5), and was the top-ranking sample in this property.

Conclusion

The texture of alkaline noodles has been reported to be influenced by quality and content of protein and starch characteristics (Ross, 1997; and Miskelly, 1985). Functionality of the protein and starch control the quality of the end product. In white salted noodles, a negative correlation of high protein content with brightness of noodles has been reported (Miskelly, 1985). In this report, the variety Betty and location Altus that produced the highest protein content also produced the darkest noodle. Eltan exhibited a lower value for the textural properties of firmness and hardness, but it was the most resilient and cohesive sample.

Among the breeder lines, OK97G11 demonstrated a promising noodle color stability, having the brightest color after 24 hours. However, this line also showed the lowest rank in all textural properties except for adhesiveness and had the lowest gain weight. Compared to the commercial varieties Eltan and Nu-West, OK97G11 line is short in three out of seven textural properties (cohesiveness, gumminess, and chewiness). A promising breeder line in terms of texture characteristics is OK98G504W, which shows top values for hardness, springiness, cohesiveness, chewiness, gumminess, and resilience values. The textural property to highlight in this line is the trend high adhesiveness value. It also had the least stable color with the highest decrease in brightness (L*) after 24 hours.

Overall, the Sweetwater location showed a trend to higher L* values, producing brighter noodles. The weight gained by the noodles after cooking showed large variation with no distinguishable trend at any specific location.

Table 2a. Evaluation of hardness and springiness of Asian alkaline noodles made from hard white winter wheat breeder lines and commercial varieties. 1998-1999 crop year.

	Hardness, g					Springiness				
Variety/Location	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
OK98G502W	1750	1187	1526	1488	**(6)**	1.01	0.99	0.98	0.99	**(3)**
OK98G504W	1338	2123	1794	1752	**(2)**	0.98	1.07	0.96	1.00	**(2)**
OK98G505W	1599	1347	1619	1522	**(5)**	0.98	1.16	0.98	1.04	**(1)**
OK98G506W	2103	1278	1489	1623	**(3)**	0.99	1.00	0.97	0.98	**(5)**
OK98G507W	1880	1425	1358	1554	**(4)**	0.99	1.01	0.98	0.99	**(3)**
OK98G508W	1925	1539	1910	1791	**(1)**	1.01	0.97	0.96	0.98	**(5)**
OK97G611	1610	1337	1257	1402	**(10)**	0.96	0.97	0.97	0.97	**(8)**
OK95G701	1434	1517	1369	1440	**(9)**	0.94	0.96	0.95	0.95	**(10)**
Betty	1486	1575	1352	1471	**(7)**	0.97	0.98	0.98	0.98	**(5)**
Oro Blanco	1622	1547	1239	1470	**(8)**	0.98	0.96	0.95	0.96	**(9)**
Average	**1675**	**1488**	**1491**	**1551**		**0.98**	**1.01**	**0.97**	**0.99**	
SD[1]	239	258	225	132		0.02	0.06	0.01	0.02	
Eltan (WA)[2]	-	-	-	1147		-	-	-	0.95	
Nu-West (MT)[2]	-	-	-	1567		-	-	-	0.98	

Table 2b. Evaluation of cohesiveness and gumminess of Asian alkaline noodles made from hard white winter wheat breeder lines and commercial varieties. 1998-1999 crop year.

	Cohesiveness					Gumminess				
Variety/Location	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
OK98G502W	0.73	0.67	0.62	0.67	**(5)**	1095	672	729	832	**(7)**
OK98G504W	0.66	0.72	0.73	0.70	**(1)**	743	1305	1100	1050	**(1)**
OK98G505W	0.66	0.73	0.65	0.68	**(4)**	867	856	846	857	**(5)**
OK98G506W	0.72	0.74	0.65	0.70	**(1)**	1264	808	803	959	**(3)**
OK98G507W	0.77	0.65	0.65	0.69	**(3)**	1271	752	748	924	**(4)**
OK98G508W	0.71	0.68	0.54	0.64	**(7)**	1163	883	861	969	**(2)**
OK97G611	0.64	0.53	0.50	0.56	**(10)**	842	534	484	620	**(10)**
OK95G701	0.57	0.68	0.58	0.61	**(8)**	698	936	618	751	**(9)**
Betty	0.60	0.74	0.68	0.67	**(5)**	733	1021	768	840	**(6)**
Oro Blanco	0.55	0.74	0.51	0.60	**(9)**	759	1027	497	761	**(8)**
Average	**0.66**	**0.69**	**0.61**	**0.65**		**944**	**880**	**745**	**856**	
SD[1]	0.07	0.06	0.08	0.05		230	214	182	126	
Eltan (WA)[2]	-	-	-	0.79		-	-	-	812	
Nu-West (MT)[2]	-	-	-	0.71		-	-	-	961	

Table 2c. Evaluation of chewiness and resilience of Asian alkaline noodles made from hard white winter wheat breeder lines and commercial varieties. 1998-1999 crop year.

	Chewiness					Resilience				
Variety/Location	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
OK98G502W	1103	667	713	**828**	**(6)**	0.36	0.37	0.41	0.38	**(3)**
OK98G504W	728	1397	1053	**1060**	**(1)**	0.35	0.33	0.45	0.38	**(3)**
OK98G505W	846	989	825	**887**	**(5)**	0.42	0.40	0.39	0.40	**(2)**
OK98G506W	1247	806	780	**944**	**(3)**	0.47	0.44	0.38	0.43	**(1)**
OK98G507W	1262	758	732	**917**	**(4)**	0.39	0.37	0.34	0.37	**(5)**
OK98G508W	1180	855	830	**955**	**(2)**	0.35	0.37	0.26	0.32	**(7)**
OK97G611	806	519	470	**598**	**(10)**	0.36	0.30	0.25	0.31	**(8)**
OK95G701	656	904	590	**717**	**(9)**	0.26	0.31	0.27	0.28	**(10)**
Betty	712	996	754	**821**	**(7)**	0.29	0.35	0.37	0.34	**(6)**
Oro Blanco	743	987	472	**734**	**(8)**	0.27	0.37	0.25	0.30	**(9)**
Average	**928**	**888**	**722**	**846**		**0.35**	**0.36**	**0.34**	**0.35**	
SD[1]	241	236	176	136		0.07	0.04	0.07	0.05	
Eltan (WA)[2]	-	-	-	775		-	-	-	0.50	
Nu-West (MT)[2]	-	-	-	938		-	-	-	0.35	

	Adhesiveness, g				
Variety/Location	Altus	Ft. Cobb	Sweetwater	**Ave**	**Rank**
OK98G502W	-60.8	-27.1	-54.1	**-47.3**	**(4)**
OK98G504W	-41.2	-81.8	-95.9	**-72.9**	**(10)**
OK98G505W	-63.3	-64.8	-53.0	**-60.4**	**(7)**
OK98G506W	-75.0	-57.0	-69.2	**-67.1**	**(9)**
OK98G507W	-21.3	-30.8	-35.1	**-29.1**	**(1)**
OK98G508W	-69.2	-25.2	-105.1	**-66.5**	**(8)**
OK97G611	-44.4	-33.6	-29.8	**-35.9**	**(2)**
OK95G701	-63.7	-39.8	-43.1	**-48.9**	**(5)**
Betty	-41.3	-46.2	-36.0	**-41.2**	**(3)**
Oro Blanco	-88.2	-48.0	-38.4	**-58.2**	**(6)**
Average	**-56.9**	**-45.4**	**-56.0**	**-52.8**	
SD[1]	19.63	18.15	26.24	14.6	
Eltan (WA)[2]	-	-	-	-50.0	
Nu-West (MT)[2]	-	-	-	-34.5	

[1] SD = Standard deviation

[2] Eltan and Nu-West = commercial varieties used for comparison

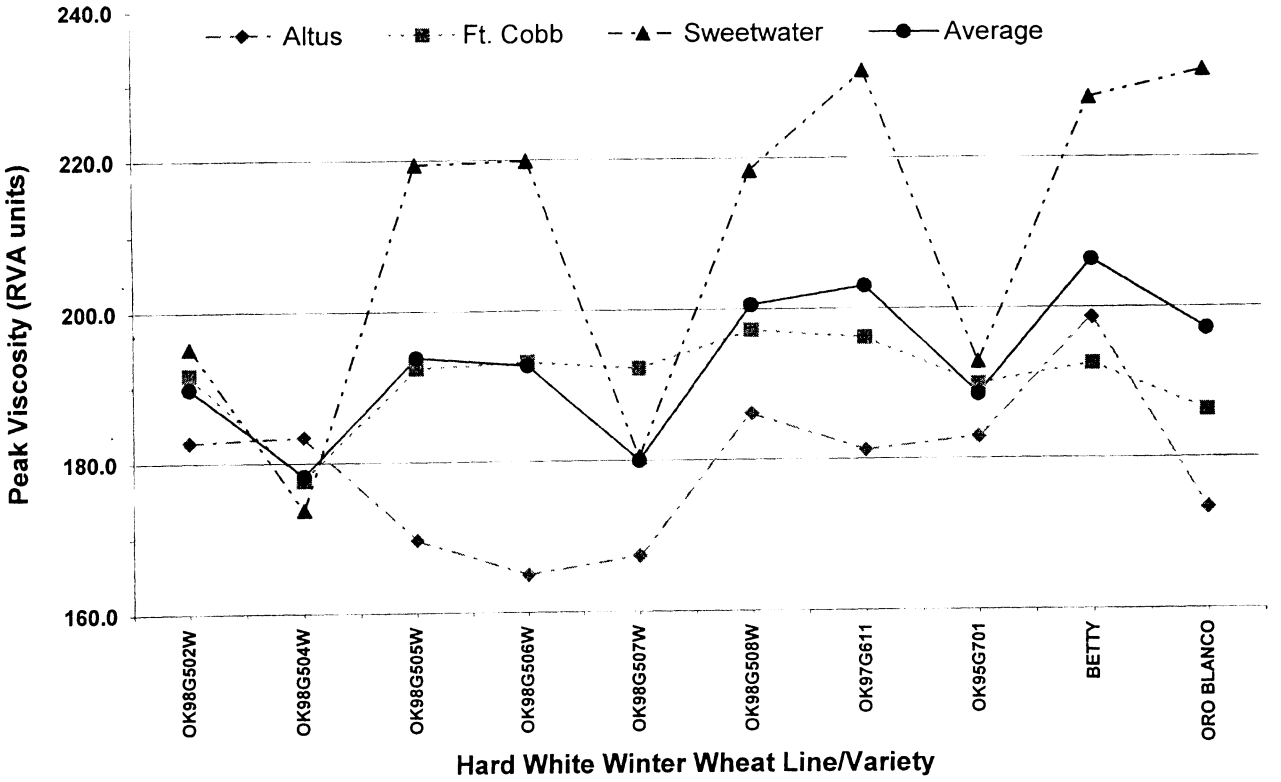

Figure 3. Peak viscosity of flour made from hard white winter wheat breeder lines and commercial varieties grown in three Oklahoma locations (1998-1999 crop year). Standard deviation for Altus = ±10.21, Fort Cobb = ±5.54, Sweetwater = ±21.65, and average = ±9.24. Peak viscosity for the comparison samples Betty and Oro Blanco were 206.4 and 197.1, respectively.

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