Discoloration of Dough for Oriental Noodles[1]

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ABSTRACT

Discoloration (as measured by CIE Lab L^* values) was highly correlated with protein and polyphenol oxidase (PPO). In a cultivar, the discoloration is more affected by protein than by PPO. Across cultivars that vary widely in protein, discoloration is affected more by cultivar-governed PPO than by protein. The protein content of a flour affects the water activity of a dough, which in turn influences the discoloration of noodle dough. Out of five compounds added to noodle doughs, only ascorbic acid at the 500 ppm level (alone or combined with storage under vacuum) effectively retarded discoloration. The effectiveness varied among three types of noodles (udon, Cantonese, and instant).

Color is an important quality criterion for oriental noodles. Moss (1971) distinguished three ways in which the quality of noodles may be affected by the quality of the wheat from which they are prepared. First, the whiteness or brightness of the dried noodle decreases with increasing protein level. Second, the color varies with textural changes during boiling. It is yet to be established conclusively whether color changes concurrently with changes in texture or whether color is correlated to intrinsic textural characteristics. It should be noted that changes in color as affected by texture, and measured by an instrumental method, may not be discerned by sensory evaluation. Third, the intensity of yellowness is developed in the alkaline medium of Kan-sui. Both the second and third factors are variety controlled.

The gray discoloration of noodles may be caused by the oxidation of tyrosine with consequent melanin formation (Fortmann and Joiner 1971, Moss 1971). The yellow color is attributed to flavones and may be governed, in part by the presence of germ particles in the flour (Moss 1971). Miskelly (1984) studied the influence of components contributing to the color and brightness of flour, flour paste, and Chinese and Japanese style noodles. Differences in brightness and yellowness were attributable to a multitude of factors including wheat cultivar, milling extraction rate, protein content, starch damage, and brown and yellow pigments. Most of the variation was attributed to genetic factors, but growth environment and milling procedures were also important.

According to Miskelly and Moss (1985), noodle brightness is related inversely to protein content and to flour-grade color. The authors drew attention to the dilemma facing manufacturers in producing Chinese noodles with optimum eating quality and color. As protein content increases, the eating quality becomes more attractive, yet the color becomes more objectionable. Kruger et al (1994) followed differences and changes in color and texture of Cantonese noodles from five flours of five Canadian wheat classes ranging in extraction from 30 to 75%. Generally, the lower the extraction the brighter the color and the lower the yellowness. The changes were largest during the first hour and to a large extent leveled off thereafter.

We have previously reported on the polyphenol oxidase (PPO) activities of wheats from various wheat classes and cultivars from both the United States and Australia, of wheat flours at various extraction rates, and of kernels separated by size from various varieties (Baik et al 1994a). PPO of wheats was affected by both cultivar and growing location. Wheat flour retained on average 3% PPO of the activity in wheat. PPO activities of the flours increased as the flour extraction rates increased (in agreement with Hatcher and Kruger 1993). Contrary to expectation, for a single variety, small kernels contained less PPO (on a weight basis and especially on a kernel basis) than did large kernels. Differences among kernels of various sizes for a single cultivar were smaller than differences in PPO among kernels of comparable sizes among various cultivars (Baik et al 1994a).

The objectives of this study were to follow the effects of various factors (wheat variety, protein content, and moisture content) on discoloration of doughs (stored under several conditions) for making udon, Cantonese, and instant noodles. Methods to retard discoloration were also investigated. The doughs were stored for up to 75 hr at room temperature (~23°C) as in household use and in a refrigerator (~4°C) as in a food store. It is recognized that, in practice, wheat from a single class (or even cultivar) is used to make a specific type of noodle. However, in light of the wide range in protein of wheats grown in the Pacific Northwest, it was deemed desirable to explore the effect of growing conditions, location, and protein content of wheats from several cultivars and classes on use for various noodle types.

MATERIALS AND METHODS

Materials

Three cultivars of soft white winter (SWW) wheat and three cultivars of club wheat were grown in four locations in the state of Washington in 1991-92 and were blended, each, by cultivar. Dual purpose cv. Wadual (SWW) was a composite of 10 isogenic lines grown in Royal Slope, WA, in 1990. A hard white spring (HWS) wheat line was grown in the state of Montana in 1991. Samples of the HWS cv. Klasic grown in two locations (Pullman, WA and Davenport, WA) in 1992 were obtained from wheat growers. In addition, samples of Klasic grown in seven locations in the state of Washington and of two new experimental HWS lines grown in four locations in the state of Washington in 1993 were obtained.

Whole wheat flours were prepared from those wheats in a Udy cyclone sample mill equipped with a screen with 0.5-mm round openings. Wheat samples were milled to about 60% flour extraction on a Bühler experimental mill. Two commercial wheat flours (Chinese noodle flour and Japanese noodle flour) were obtained from Nisshin Flour Milling Company, Tokyo, Japan, through the Washington Wheat Commission, Spokane, WA.

Analytical Methods

Moisture and ash were determined by AACC approved methods 44-15A and 08-1, respectively. Protein (N × 5.7) was determined by combustion with a nitrogen determinator (Leco Corporation, St. Joseph, MI). All determinations were made at least in duplicate and are reported on a dry weight basis.

Measurement of PPO Activity

Assays were performed by the oxygen consumption method of Marsh and Galliard (1986) with some modifications. Oxygen

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consumption was determined using a YSI model 18053 oxygen monitor (Yellow Spring Instrument Co., Yellow Spring, OH).

A sample (0.2 g of whole wheat flour or 2.0 g of flour, dwb) was weighed into the cell. Air-saturated 0.1*M* imidazole buffer (14 ml, pH 6.8) was added to the cell maintained at 35°C. After 5 min of stirring, 0.3*M* catechol (1 ml) was injected into the cell and the oxygen consumption was monitored for 5 min. All values were corrected for oxygen consumption by control samples without added substrate. In the study of Marsh and Galliard (1986), results were corrected for substrate autoxidation only for samples held at pH values >7. McCallum and Walker (1990) determined PPO activity as the difference between the basal rate of O_2 consumption and the initial rate following addition of the substrate. The latter was also the basis for the calculation of our results. Results are expressed as nmol of O_2 consumed per minute per gram. All PPO results are averages of at least triplicate assays and expressed as nmol of O_2 consumed per minute per gram, dwb.

Color Changes of Noodle Dough

Doughs for three types of noodles (udon, Cantonese, and instant) were prepared through mixing and sheeting according to the procedure described by Baik et al (1994b). In that publication, details of ingredient composition, dough mixing, and sheeting (initial sheeting, rest, and reduction) are given.

Cantonese noodle doughs with different water absorption levels (29–35%) were prepared from three wheat flours (SWW Daws and two HWS Klasic grown in 1993 in Reardon, WA and Lind, WA). Water activities of noodle doughs were measured immediately after dough mixing and after sheeting using a Decagon CX-1 psychrometer (Decagon Devices Inc., Pullman, WA). Freshly sheeted pieces of dough were kept in plastic bags and stored at 4°C or at 23°C for up to 75 hr. Color of noodle doughs was determined using a Minolta CM-2002 spectrophotometer (Minolta Camera Co., LTD, Chuo-Ku, Osaka, Japan) with an 11-mm measurement aperture. The CIE-Lab L^*, a^*, and b^* values denote lightness, redness-greenness, and yellowness-blueness, respectively.

Retarding Discoloration of Noodle Dough

Five reducing compounds (ascorbic acid, ascorbic acid 2-phosphate, 4-hexylresorcinol, sodium sulfite, and tocopherol) were incorporated into noodle doughs during mixing. Ascorbic acid, ascorbic acid 2-phosphate, and sodium sulfite were added as water solutions. Tocopherol and 4-hexylresorcinol were added to the dough in 95% ethanol solutions. PPO is particulate and not soluble and acts on soluble free phenolics (Moss 1971). Consequently, binding or absorbing the reducing compounds in an appropriate way may provide an effective treatment. The highest amount of each reducing compound permitted by the Food and Drug Administration to use in food systems was incorporated into noodle doughs. Udon and instant noodle doughs were prepared with the HWS Klasic (grown in Davenport, WA, in 1992) wheat flour sample.

Three levels (0, 500, and 1,000 ppm) of ascorbic acid were incorporated into the udon and instant noodle doughs made from the Montana HWS flour. Noodle doughs were stored in a refrigerator at 4°C in plastic bags, with and without applying vacuum, using a commercial food vacuum packer (Professional Marketing Group, Inc., Seattle, WA)

Statistical Analysis

Color measurements of noodle doughs are averages of three determinations. Data were statistically analyzed with the SAS computer packages (SAS 1986) for computing analysis of variance (ANOVA) in a completely randomized design, Fishers' least significant difference (LSD), and Pearson's correlation coefficients.

RESULTS AND DISCUSSION

Characteristics of Wheats and Flours

Protein contents and PPO activities of 10 wheats and 12 flours from 1990 to 1992 are reported in Table I. Ash contents among those flours varied little (0.39–0.46%). The HWS from Montana was higher in ash (0.55%) than the other flours. There were no significant differences in color of the 60% extraction flours as determined by the Minolta spectrophotometer.

Protein contents of the 10 wheats fell into two groups: from 11.1 to 12.6% in three samples of SWW and three samples of club wheats; and from 14.6 to 15.4% in Wadual, the sample of HWS (from Montana) and two samples of Klasic grown in Pullman, WA and Davenport, WA in 1992. Protein contents of flours were lower by ~1% than those of wheat samples. Generally, PPO activities were high in wheats high in protein. Higher PPO activities of wheats were observed in Wadual, the HWS, and two Klasics than were observed in two SWW (Daws and Stephens) and three club wheats. While the average flour PPO activity was only 3% of the wheat PPO activities, large variations in PPO activities among flour samples were observed. PPO activities of hard wheat flours (HWS from Montana and two Klasic grown in Pullman, WA and Devenport, WA in 1992) and Wadual were significantly higher (at the 5% level) than PPO activities of soft and club wheat flours, suggesting genetically governed variations. Japanese and Chinese noodle flours were both low in PPO activity

TABLE I
Characteristics of Wheats and Wheat Flours from 1990 to 1992

Samples	Wheat Ash (%)	Wheat Protein (%)	Wheat PPO[a] Activity (nmol O_2/min/g)	Flour Ash (%)	Flour Protein (%)	Flour PPO Activity (nmol O_2/min/g)
Soft white						
Nugaines	1.63	11.1	1,025	0.45	10.1	23
Daws	1.60	11.9	633	0.45	10.5	25
Stephens	1.62	12.6	418	0.44	10.6	20
Club						
Tres	1.60	12.5	444	0.46	10.5	18
Hyak	1.55	12.4	529	0.43	10.8	20
Rely	1.55	12.1	451	0.43	10.1	18
Wadual	1.63	15.4	1,038	0.43	13.5	29
Hard white spring (Montana)	1.77	14.8	1,293	0.55	13.7	29
Japanese noodle flour	...	...	...	0.44	10.3	21
Chinese noodle flour	...	...	...	0.44	13.1	18
Klasic (Pullman)[b]	1.38	14.9	1,437	0.41	13.9	31
Klasic (Davenport)[b]	1.52	14.6	1,071	0.39	13.7	30
Mean	1.585	13.23	833.9	0.443	11.73	23.5
LSD ($P = 0.05$)[c]	0.040	0.17	78.5	0.017	0.14	3.2

[a] Polyphenol oxidase.
[b] Two cv. Klasics grown in two locations in the state of Washington.
[c] Least significant difference. Differences between two means exceeding this value are significant.

even though their protein content was significantly different.

Protein content and PPO activities of the Klasic samples from seven locations and of the samples of two HWS lines, each, from four locations are summarized in Table II. Protein contents of wheats varied widely among growing locations both in the Klasics and the two HWS lines, ranging from 12.0 to 17.2% and from 12.3 to 16.8%, respectively.

PPO activities of the seven Klasic wheats grown in 1993 (Table II) ranged from 771 to 1,087 nmol of O_2/min/g (average 888) and were slightly lower than those of the two Klasic wheats grown in 1992 (Table I). Average PPO activities of wheats from the two HWS lines (ID00377S and K9205117) were 324 nmol of O_2/min/g lower than those of the seven Klasic wheats (Table II). There were no significant differences in PPO activities of wheats among growing locations in three groups of wheats (Klasics and two HWS lines). Flours from Klasic wheats from seven locations showed higher PPO activities than flours from the two HWS lines, each from four locations. Even though there were statistically significant differences in PPO activities in flours from growing locations, actual differences were small compared to those among the wheats because PPO activities of flour samples were only ~3% of those of wheats.

TABLE II
Protein Contents and Polyphenol Oxidase (PPO) Activities of Wheats (Grown in 1993) and Flours

	Wheat		Flour	
Samples	Protein (%)	PPO activity (nmol O_2/min/g)	Protein (%)	PPO activity (nmol O_2/min/g)
Klasic				
Pullman	14.7	884	14.2	24
Royal Slope	14.1	865	13.6	27
Reardon	12.0	908	11.4	26
Lind	17.2	800	15.9	19
Connell	16.9	771	16.7	21
Mayview	15.3	1,087	14.9	21
Fairfield	13.0	901	12.4	24
Mean	14.74	888.0	14.16	23.1
LSD ($P = 0.05$)[a]	0.32	141.3	0.16	4.6
HWS (ID00377S)				
Lind	16.2	640	15.6	5
Pullman	13.9	549	12.8	8
Connell	16.8	565	16.1	13
Royal Slope	12.3	555	11.4	11
Mean	14.80	577.3	13.98	9.5
LSD ($P = 0.05$)	0.15	44.9	0.16	4.0
HWS (K9205117)				
Lind	15.2	513	14.6	14
Pullman	12.7	516	11.7	18
Connell	15.6	568	14.8	14
Royal Slope	13.0	541	11.8	21
Mean	14.13	534.5	13.23	17.1
LSD ($P = 0.05$)	0.14	85.3	0.06	5.6

[a] Least significant difference. Differences between two means exceeding this value are significant.

Discoloration of Noodle Doughs

CIE Lab L^*, a^*, and b^* values and their decreases (ΔL^*, Δa^*, and Δb^*) during storage at 23°C for up to 75 hr in three types of noodle doughs (from 1990 to 1992 wheat flours) are reported in Tables III–V. L^* value, an index of lightness, was significantly lower in the high protein Wadual, the sample of HWS, and two Klasics than in the other flours in all three types of noodle doughs. The dough from the commercial Chinese noodle flour showed an intermediate L^* value. L^* value of the dough from the commer-

TABLE III
CIE Lab L^* Values of Noodle Doughs and Their Decreases After 75-hr Storage at 23°C

	Udon		Cantonese		Instant	
Samples	L^* at 75 hr	ΔL^*[a]	L^* at 75 hr	ΔL^*	L^* at 75 hr	ΔL^*
Soft white						
Nugaines	81.1	7.9	85.6	2.8	84.8	3.9
Daws	78.8	8.9	83.3	3.9	80.7	6.6
Stephens	78.3	9.7	84.0	3.9	82.1	5.6
Club						
Tres	78.3	9.4	84.8	3.5	83.9	4.0
Hyak	80.5	9.0	84.8	3.3	84.7	5.0
Rely	80.6	8.4	84.7	2.6	83.8	4.9
Wadual	68.4	17.6	73.1	9.5	68.7	15.0
Hard white spring	71.6	14.8	73.4	10.4	69.8	15.6
Japanese noodle flour	77.8	10.7	81.2	5.9	80.3	7.4
Chinese noodle flour	76.0	9.9	77.5	7.4	77.1	9.1
Klasic (Pullman)	70.5	13.7	73.4	8.7	65.0	18.3
Klasic (Davenport)	70.1	13.6	73.5	8.6	65.3	18.5
Mean	76.00	11.13	79.95	5.88	77.18	9.49
LSD ($P = 0.05$)[b]	1.19	1.41	0.76	0.76	0.90	1.16

[a] L^* value at 3-hr storage − L^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

TABLE IV
CIE Lab a^* Values of Noodle Doughs and Their Decreases After 75-hr Storage at 23°C

	Udon		Cantonese		Instant	
Samples	a^* at 75 hr	Δa^*[a]	a^* at 75 hr	Δa^*	a^* at 75 hr	Δa^*
Soft white						
Nugaines	4.4	−1.2	3.7	−1.0	3.4	−0.9
Daws	4.7	−1.4	4.3	−1.2	4.7	−1.9
Stephens	4.9	−1.4	4.1	−1.1	4.5	−1.5
Club						
Tres	4.9	−1.4	3.8	−1.0	4.3	−1.4
Hyak	4.4	−1.1	4.1	−1.0	3.7	−1.2
Rely	4.5	−1.3	3.7	−0.8	4.1	−1.6
Wadual	4.6	−0.8	5.3	−2.6	4.8	−2.5
HWS	5.0	−1.2	5.3	−2.5	5.3	−2.0
Japanese noodle flour	4.3	−1.3	4.2	−1.5	4.0	−1.5
Chinese noodle flour	4.7	−1.0	4.6	−1.3	4.9	−1.6
Klasic (Pullman)	5.2	−1.1	5.2	−1.9	5.7	−2.5
Klasic (Davenport)	5.0	−0.9	5.1	−2.0	5.4	−2.6
Mean	4.72	−1.17	4.46	−1.47	4.57	−1.76
LSD ($P = 0.05$)[b]	0.21	0.21	0.17	0.17	0.36	0.42

[a] a^* value at 3-hr storage − a^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

TABLE V
CIE Lab b^* Values of Noodle Doughs and Their Decreases After 75-hr Storage at 23°C

	Udon		Cantonese		Instant	
Samples	b^* at 75 hr	Δb^*[a]	b^* at 75 hr	Δb^*	b^* at 75 hr	Δb^*
Soft white						
Nugaines	23.6	−3.5	22.7	0.3	17.4	2.2
Daws	20.6	−2.1	24.6	−0.4	20.3	−1.0
Stephens	26.2	−3.5	25.0	−0.1	21.2	−1.4
Club						
Tres	21.0	−2.5	22.9	−1.6	19.2	−0.3
Hyak	19.4	−1.9	21.6	−0.2	15.6	0.9
Rely	21.0	−2.6	22.1	−0.5	17.5	0.4
Wadual	16.1	0.8	21.7	−2.4	17.3	−3.1
HWS	19.2	−0.8	23.0	−1.6	18.7	−1.4
Japenese noodle flour	21.5	−3.7	24.8	−1.9	20.4	−2.0
Chinese noodle flour	21.9	−2.0	26.2	−2.0	23.7	−3.4
Klasic (Pullman)	20.5	−1.5	23.3	−1.3	20.4	−1.9
Klasic (Davenport)	18.5	0.6	23.1	−2.0	20.0	−3.5
Mean	20.78	−1.89	23.42	−1.14	19.30	−0.98
LSD ($P = 0.05$)[b]	0.54	0.92	0.68	1.01	0.68	1.42

[a] b^* value at 3-hr storage − b^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

cial Japanese noodle flour was slightly lower than those from soft white and club wheat flours, but higher than that from the Chinese noodle flour. Overall, L^* values were highest in Cantonese noodle doughs and similar in instant and udon noodle doughs. Two of the Klasic flours showed much higher L^* values in udon doughs than in instant noodle doughs. ΔL^* during 75 hr storage was consistently higher in low L^* value doughs than in high L^* value doughs. Thus, Wadual, HWS, and the two Klasics (low in L^* values) showed significantly higher ΔL^* values in all three types of noodle doughs than the other flours. ΔL^* value was highest in udon, less in instant, and least in Cantonese noodle doughs. Doughs from the Japanese and the Chinese noodle flours showed slightly higher ΔL^* than soft and club wheat flours; still much lower than those of Wadual, the sample of HWS, and two Klasics. The color differences between Klasics and the other wheat flour noodle doughs were highly correlated with differences in starch (as measured by gelatinization, differential scanning calorimetry, or amylose-amylopectin parameters) or protein (as measured by dough mixing and breadmaking) (unpublished data).

CIE Lab a^* and Δa^* values showed either slight or insignificant differences among flours in three types of noodle doughs (Table IV). There were small differences in average a^* values among different types of noodle doughs. Still HWS and the two samples of Klasics had relatively higher a^* values than other flours in all three types of noodle doughs.

Although there were significant differences in b^* and Δb^* values among flours in three types of noodle doughs, no consistent trend was observed (Table V). Average b^* values of noodle doughs were highest in Cantonese and similar in udon and instant noodle doughs.

L^* and ΔL^*, a^* and Δa^*, and b^* and Δb^* values during 75-hr storage at 23°C in udon and Cantonese noodle doughs prepared from flours of seven Klasics and two HWS lines are summarized in Tables VI–VIII. L^* values of noodle doughs differed widely among the Klasic flours from 1993 from some of the seven locations, but their standard deviations (2.44 in udon and 2.91 in Cantonese noodle dough) were much smaller than those of the 12 samples from 1990 to 1992 (4.59 in udon and 5.32 in Cantonese noodle doughs). Similarly, small variations of L^* values and ΔL^* in noodle doughs were observed among the four locations in the two HWS lines. Overall, Cantonese noodle doughs showed higher L^* and lower ΔL^* values than udon noodle doughs.

TABLE VI
CIE Lab L^* Values of Noodle Doughs and Their Decreases After 75-hr Storage at 23°C

	Udon		Cantonese	
Samples	L^* at 75 hr	ΔL^*[a]	L^* at 75 hr	ΔL^*
Klasic				
Pullman	72.5	9.5	73.4	6.5
Royal Slope	72.5	10.4	75.2	6.9
Reardon	76.5	8.7	80.1	4.0
Lind	69.4	10.8	72.9	6.3
Connell	70.8	9.4	71.9	7.1
Mayview	72.0	10.6	73.6	7.5
Fairfield	75.2	10.2	77.5	5.8
Mean	72.70	9.94	74.94	6.30
LSD ($P = 0.05$)[b]	0.85	0.69	0.47	0.64
HWS (ID00377S)				
Lind	73.1	10.7	75.1	8.1
Pullman	75.3	11.0	78.8	7.2
Connell	72.2	10.0	73.6	8.5
Royal Slope	77.2	11.0	83.0	5.5
Mean	74.45	10.68	77.63	7.33
LSD ($P = 0.05$)	0.98	1.17	0.52	0.58
HWS (K9205117)				
Lind	73.5	9.8	74.1	8.8
Pullman	75.8	10.6	78.0	8.4
Connell	72.3	10.9	72.5	10.1
Royal Slope	72.5	14.8	78.6	8.6
Mean	73.53	11.53	75.80	8.98
LSD ($P = 0.05$)	0.62	0.72	0.47	0.54

[a] L^* at 3-hr storage − L^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

TABLE VII
CIE Lab a^* Values of Noodle Doughs and Their Decreases After 75-hr Storage at 23°C

	Udon		Cantonese	
Samples	a^* at 75 hr	Δa^*[a]	a^* at 75 hr	Δa^*
Klasic				
Pullman	4.8	−0.8	5.2	−1.9
Royal Slope	4.7	−0.9	4.9	−2.0
Reardon	4.7	−1.3	4.6	−1.7
Lind	4.6	−0.5	5.0	−1.6
Connell	4.6	−0.4	5.0	−1.6
Mayview	5.1	−1.0	5.2	−1.8
Fairfield	4.7	−1.2	4.8	−2.0
Mean	4.76	−0.88	4.96	−1.78
LSD ($P = 0.05$)[b]	0.11	0.18	0.15	0.20
HWS (ID00377S)				
Lind	5.1	−1.0	5.0	−1.3
Pullman	5.1	−1.4	4.5	−1.3
Connell	5.5	−1.0	5.2	−1.3
Royal Slope	5.0	−1.7	3.7	−1.2
Mean	5.18	−1.28	4.60	−1.27
LSD ($P = 0.05$)	0.20	0.28	0.14	0.17
HWS (K9205117)				
Lind	5.3	−1.2	5.5	−1.7
Pullman	4.8	−1.3	4.8	−1.9
Connell	5.3	−1.0	5.8	−1.9
Royal Slope	5.5	−2.1	5.1	−2.2
Mean	5.23	−1.38	5.30	−1.92
LSD ($P = 0.05$)	0.10	−0.14	0.12	0.18

[a] a^* at 3-hr storage − a^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

TABLE VIII
CIE Lab b^* Values of Noodle Doughs and Their Decreases After 75-hr Storage at 23°C

	Udon		Cantonese	
Samples	b^* at 75 hr	Δb^*[a]	b^* at 75 hr	Δb^*
Klasic				
Pullman	20.9	−1.0	24.6	−1.1
Royal Slope	18.1	−1.7	23.3	−4.0
Reardon	20.3	−3.6	23.7	−3.8
Lind	18.3	0.1	23.6	−1.8
Connell	19.3	0.4	24.4	−1.6
Mayview	20.7	−1.7	24.7	−2.7
Fairfield	20.3	−2.9	24.1	−3.8
Mean	19.70	−1.49	24.00	−2.69
LSD ($P = 0.05$)[b]	0.57	0.85	0.50	0.97
HWS (ID00377S)				
Lind	20.8	−1.1	26.9	−2.4
Pullman	23.2	−3.5	27.4	−3.0
Connell	22.3	−0.7	27.2	−1.8
Royal Slope	20.3	−3.9	23.5	−3.7
Mean	21.65	−2.30	26.25	−2.73
LSD ($P = 0.05$)	0.57	0.99	0.50	0.81
HWS (K9205117)				
Lind	19.7	−1.2	26.0	−3.2
Pullman	20.2	−2.4	25.8	−4.1
Connell	19.5	0.1	26.3	−3.1
Royal Slope	19.6	−4.4	24.6	−6.1
Mean	19.75	−1.98	25.68	−4.13
LSD ($P = 0.05$)	0.23	0.70	0.30	0.57

[a] b^* at 3-hr storage − b^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

Only small differences in a^* and Δa^* values of both udon and Cantonese noodle doughs were observed among flours from different locations (Table VII); a^* values varied more widely in Cantonese than in udon noodle doughs. Significant differences in b^* and Δb^* values were found among flours from seven Klasics and two HWS lines, but actual differences were relatively small (Table VIII); b^* values were much higher in Cantonese than in udon noodle doughs in seven Klasics and two HWS lines.

Effects of storage temperature on noodle dough discoloration are shown in Figure 1. L^* values of instant noodle doughs decreased much faster at 23°C than at 4°C, especially in Wadual and the sample of HWS. Similar results were observed in udon and Cantonese noodle doughs (not reported here). ΔL^* values during the first 15 hr showed larger differences among noodle doughs stored at 23°C than among those stored at 4°C. The results indicate that discoloration could be objectionable even within a short time after preparation (Kruger et al 1994). Consequently, developing means to retard discoloration is of major concern and importance.

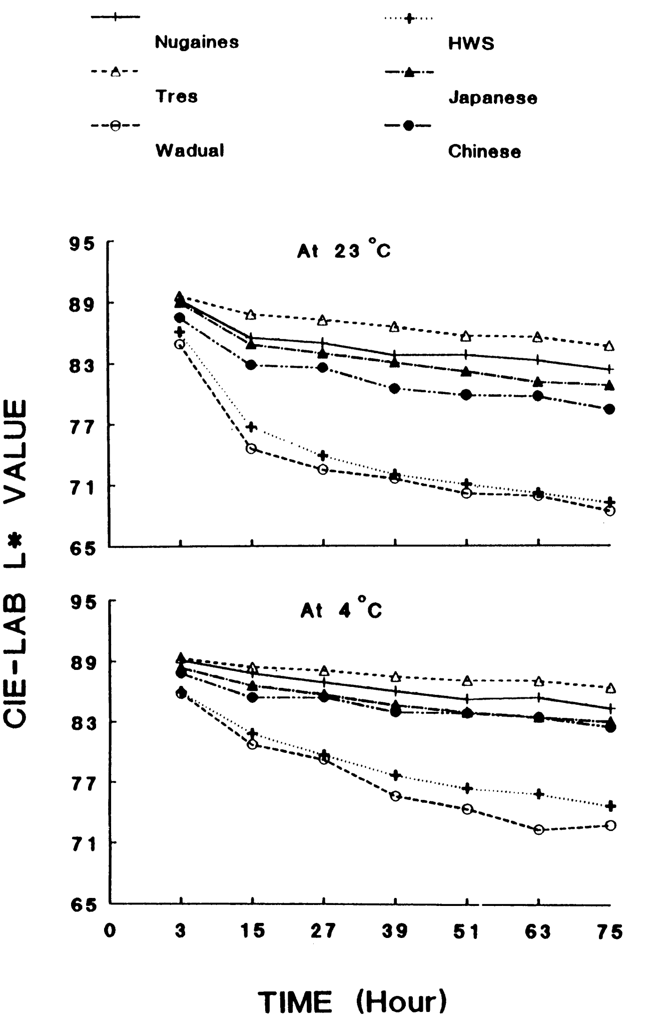

Fig. 1. CIE Lab L^* values in instant noodle doughs during storage at 23°C and at 4°C.

Linear Relationships among L* Values, PPO Activities and Protein Contents

Linear correlation coefficients between L^*, a^*, and b^* and ΔL^*, Δa^*, and Δb^* values of noodle doughs during 75-hr storage at 23°C, and PPO activities and protein contents of 1990 and 1992 wheats or flours are summarized in Tables IX–XI. There were highly significant correlations between PPO activities of both wheats and flours, and both the L^* values and the ΔL^* values of doughs in all three types of noodles (Table IX). The results are consistent with the hypothesis that PPO may be one of the main factors influencing discoloration of noodle doughs. L^* values of noodle doughs showed higher linear correlation coefficients with PPO activities of flours than with those of wheats probably due to a larger diversity of PPO-interacting components in wheat than in flour.

Linear correlation coefficients between L^* values of noodle doughs with protein (of wheat or flour) were higher than with PPO activity (Table IX). However, when PPO activities were determined in wheats that covered a wide range of protein content (Baik et al 1994a), it was observed that the varietal effect was much larger than the effect of protein content on PPO activities. Consequently, the varietal factor may be a very strong influence on both PPO activity and discoloration of oriental noodles, and protein content may govern, in part only, discoloration of noodle doughs.

While no significant correlations were observed between a^* and Δa^* values of udon noodle doughs and the PPO activities of wheats and flours, there were highly significant correlations between a^* and Δa^* values of Cantonese noodle doughs and the PPO activities of wheat and flours and between a^* and Δa^* values of instant noodle doughs and the PPO activities of flours (Table X). Protein content of wheats and flours were significantly correlated with both a^* and Δa^* values of three types of noodle doughs except for a^* values of udon noodle doughs.

PPO activities of flours showed a significant correlation only with Δb^* values of udon noodle doughs (Table XI). However, protein contents of wheats and flours were significantly correlated with Δb^* values of all three types of noodle doughs.

In the seven Klasics and eight samples of two HWS lines, each from four locations from 1993 (described in Table II), no significant correlations were observed between PPO activities and L^* values of noodle doughs *(data not reported here)*. However, the protein contents of wheat and flour, respectively, were highly correlated with L^* values of noodle doughs (−0.85*** and −0.82*** in udon noodle dough and −0.87*** and −0.89*** in Cantonese noodle dough). The results suggest that in a cultivar, protein content has a larger influence on discoloration of noodle doughs

TABLE IX
Correlation Coefficients Between Polyphenol Oxidase (PPO) Activities of Wheats and Their Flours, and CIE Lab L^* Values of Noodle Sheets[a]

	Udon		Cantonese		Instant	
	L^* at 75 hr	ΔL^{*b}	L^* at 75 hr	ΔL^*	L^* at 75 hr	ΔL^*
PPO activity						
Wheat ($N = 10$)	−0.74*	0.69**	−0.82**	0.81**	−0.82**	0.83**
Flour ($N = 12$)	−0.82**	0.78**	−0.83***	0.75**	−0.88***	0.88***
Protein content						
Wheat ($N = 10$)	−9.97***	0.97***	−0.94***	0.96***	−0.93***	0.93***
Flour ($N = 12$)	−0.93***	0.84***	−0.96***	0.94***	−0.94***	0.93***

[a] *, **, *** = Significant at least at the 5, 1, and 0.1% level, respectively.
[b] L^* at 3-hr storage − L^* at 75-hr storage.

TABLE X
Correlation Coefficients Between Polyphenol Oxidase (PPO) Activities of Wheats and Their Flours, and CIE Lab a^* Values of Noodle Sheets[a]

	Udon		Cantonese		Instant	
	a^* at 75 hr	Δa^*[b]	a^* at 75 hr	Δa^*	a^* at 75 hr	Δa^*
PPO activity						
Wheat ($N = 10$)	0.44	0.55	0.78**	−0.78**	0.60	−0.56
Flour ($N = 12$)	0.54	0.52	0.85***	−0.83***	0.69*	−0.80**
Protein content						
Wheat ($N = 10$)	0.58	0.66*	0.95***	−0.92***	0.82**	−0.88***
Flour ($N = 12$)	0.59*	0.72**	0.94***	−0.84***	0.84***	−0.79**

[a] *, **, *** = Significant at least at the 5, 1, and 0.1% level, respectively.
[b] a^* at 3-hr storage − a^* at 75-hr storage.

TABLE XI
Correlation Coefficients Between Polyphenol Oxidase (PPO) Activities of Wheats and Their Flours, and CIE Lab b^* Values of Noodle Sheets[a]

	Udon		Cantonese		Instant	
	b^* at 75 hr	Δb^*[b]	b^* at 75 hr	Δb^*	b^* at 75 hr	Δb^*
PPO activity						
Wheat ($N = 10$)	−0.40	0.54	−0.12	−0.45	0.11	−0.54
Flour ($N = 12$)	−0.54	0.72**	−0.25	−0.34	−0.05	−0.47
Protein content						
Wheat ($N = 10$)	−0.65*	0.84**	−0.17	−0.86**	0.18	−0.85**
Flour ($N = 12$)	−0.56	0.80**	−0.02	−0.67*	0.25	−0.75**

[a] *, ** = Significant at least at the 5 and 1% level, respectively.
[b] b^* at 3-hr storage − b^* at 75-hr storage.

TABLE XII
Water Activities (A_w) and CIE Lab L^* Values of Cantonese Noodle Doughs on Different Water Absorption Levels at 23°C

Samples and Percentage of Added Water	Protein (%)	A_w of Dough Freshly Mixed	A_w of Dough After Sheeting	L^* at 3 hr	L^* at 75 hr	ΔL^*[a]
Daws						
31%		0.969	0.964	90.3	87.1	3.1
33%	10.5	0.973	0.968	87.3	83.6	3.6
35%		0.977	0.969	86.1	80.7	5.3
LSD ($P = 0.05$)[b]		0.0049	0.0049	0.52	0.48	0.73
Klasic (Reardon)						
31%		0.972	0.965	87.9	82.9	5.0
33%	11.4	0.975	0.967	86.3	79.4	6.9
35%		0.980	0.967	84.8	77.1	7.7
LSD ($P = 0.05$)		0.0054	0.0065	0.57	0.54	0.55
Klasic (Lind)						
29%		0.968	0.963	84.2	75.6	8.6
31%	15.9	0.973	0.965	82.6	73.2	9.4
33%		0.982	0.968	81.8	72.7	9.1
LSD ($P = 0.05$)		0.0106	0.0037	0.26	0.58	0.76

[a] L^* value at 3-hr storage − L^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

than PPO activities. Failure to show correlations between PPO activity and L^* value of noodle dough might result from the insignificant or small differences in PPO activities among the flours from different locations or be related to the relatively low level of PPO activities of those samples.

Effect of Water Absorption on the Discoloration of Noodle Doughs

Table XII records the water activities of Cantonese noodle doughs with different water absorption levels immediately after mixing and after sheeting, and L^* and ΔL^* values during 75-hr storage at 23°C. As percentage of added water increased from 31 to 35% (or from 29 to 33% in Klasic from Lind, WA), water activities of noodle doughs increased (as expected) and L^* values of noodle doughs decreased. Significant differences of L^* values at 3-hr storage among doughs that varied in water absorption indicate that level of water absorption influences not only the discoloration, but also the measured color of noodle doughs. The color and discoloration determinations were made 3 hr after final sheeting as changes were rapid during the first 3 hr (Kruger et al 1994) and difficult to reproduce. Equilibration during the first 3 hr facilitated precise color measurements. Even at the same water absorption level, water activities of freshly mixed noodle doughs were different among flours, being higher in high protein flour (Klasics) than in the low protein flour (Daws). However, water activities of noodle doughs after sheeting were not significantly different among different flours. The results indicate that water absorption is not completed in the freshly mixed dough and may be affected during noodle dough mixing by factors other than protein content, such as flour particle size and damaged starch; as gluten is further developed during sheeting the free water is further absorbed.

TABLE XIII
CIE Lab L^* Values of Noodle Doughs Prepared with the Klasic Wheat (Grown in Davenport, WA in 1992) and Treated with Anti Browning Agents and Their Decreases After 75-hr Storage at 4°C

Treatments	Udon L^* at 75 hr	Udon ΔL^*[a]	Instant L^* at 75 hr	Instant ΔL^*
Control	76.6	6.5	73.1	10.1
Sodium sulfite (100 ppm)	76.6	5.4	70.8	11.5
4-Hexylresorcinol (50 ppm)	75.7	4.9	73.0	10.6
Tocopherol (1,000 ppm)	76.5	5.6	70.0	13.2
Ascorbic acid (1,500 ppm)	78.9	5.9	76.5	8.5
Ascorbic acid 2-phosphate (1,500 ppm)	79.1	4.8	77.5	8.7
LSD ($P = 0.05$)[b]	1.12	1.08	1.22	1.51

[a] L^* value at 3-hr storage − L^* at 75-hr storage.
[b] Least significant difference. Differences between two means exceeding this value are significant.

As flour protein content increased, L^* value of noodle dough decreased and ΔL^* value during storage increased. Therefore, it is assumed that the protein content of flour affects the water activity of noodle dough, which in turn influences the discoloration of noodle dough. A significant correlation ($r = 0.83$***, $n = 12$) between protein contents of flours and water activities of

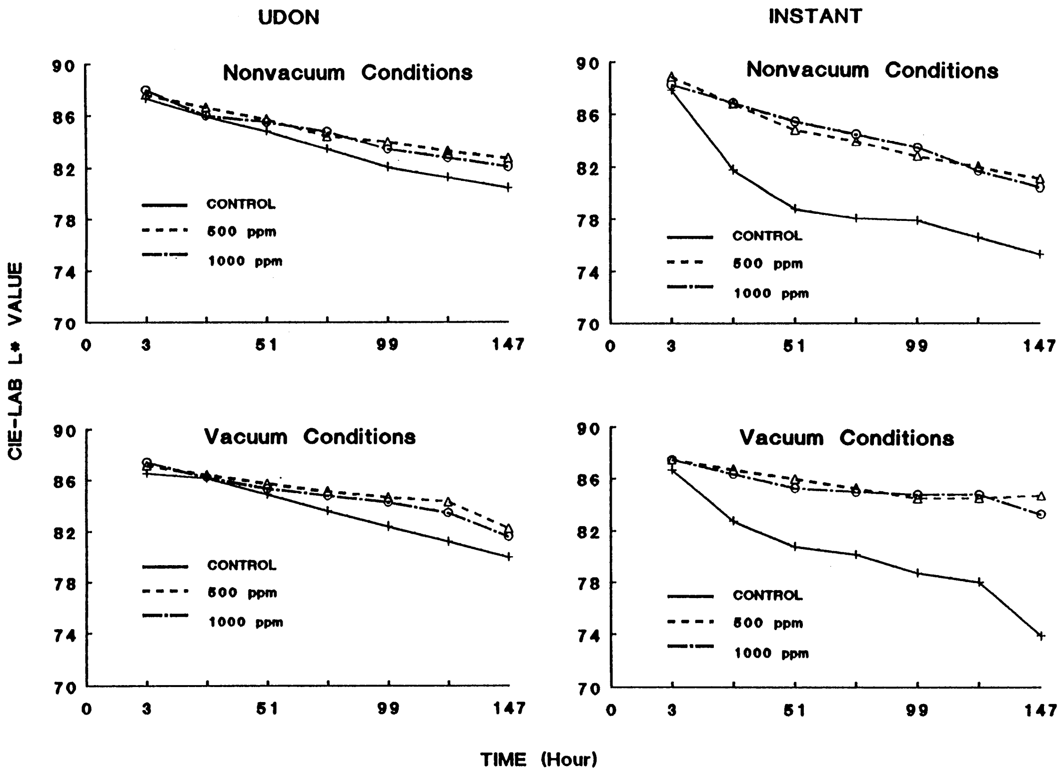

Fig. 2. CIE Lab L^* values in udon and instant noodle doughs made from hard white spring (Montana) wheat flour and treated with different levels of ascorbic acid and stored at 4°C under vacuum or nonvacuum conditions.

Cantonese noodle doughs (prepared from Chinese noodle flour, eight samples of the two HWS lines, Daws, and two Klasics grown in Reardon and Lind, WA) is consistent with the above assumption.

Retarding Discoloration of Noodle Doughs

Color changes in noodle doughs prepared with the HWS Klasic (grown in Davenport, WA in 1992) wheat flour and treated with several reducing agents were followed by L^* and ΔL^* values during 75-hr storage at 4°C (Table XIII). In udon noodle doughs (which showed less discoloration than did instant noodle doughs) (Table III), L^* values of ascorbic acid or ascorbic acid 2-phosphate supplemented samples, at both 3 and 75 hr, were significantly higher than those of others doughs, including the control (Table XIII). L^* values of instant noodle doughs, at both 3 and 75 hr, or ΔL^* values of untreated dough or doughs treated with sodium sulfite, 4-hexylresorcinol, and tocopherol were comparable. While ascorbic acid and ascorbic acid 2-phosphate treated doughs showed higher L^* values at both 3 and 75 hr in both udon and instant noodles, the ΔL^* values of ascorbic acid and ascorbic acid 2-phosphate treated doughs was lower in instant noodles only. The results pointed to the effectiveness of ascorbic acid and ascorbic acid 2-phosphate, albeit at high levels, in retarding discoloration of noodle doughs.

Effectiveness of ascorbic acid at a lower than 1,500 ppm level on retarding discoloration of udon and instant noodle doughs is shown in Figure 2. In udon noodle doughs, 500 and 1,000 ppm of ascorbic acid treatment slowed down to a similar extent L^* and ΔL^* values during 147-hr storage. Vacuum storage, per se, did not significantly affect the L^* values of udon noodle doughs. However, a combination of ascorbic acid treatment and vacuum storage slowed the ΔL^* values of instant noodle doughs. Differences in effectiveness of ascorbic acid between udon and instant noodle doughs may be due to differences in the dough pH or differences in the ΔL^* values of noodle doughs. The results indicate that ascorbic acid treatment at the 500 ppm level combined with vacuum storage can retard discoloration of noodle doughs and that their effectiveness is different among noodle types. It should be emphasized that the actual effect of ascorbic acid may be even larger than that reported here and that the effect may be masked, in part, by oxidation of ascorbic acid in dough to dehydroascorbic acid.

CONCLUSIONS

PPO activities and discoloration of noodle doughs were highly correlated for the 1992 samples from several wheat classes varying widely in protein contents. Cultivar was the dominant factor. The 1993 HWS wheat samples, from several locations varied widely in protein contents. PPO activities in those samples were relatively lower than in the 1992 samples and were not affected significantly by protein contents. Protein could be involved in dough discoloration at least in three ways: 1) as a marker for another (yet to be determined) component highly linked with protein; 2) through the effect of protein content on hardness-starch damage-particle size (the extent of this effect is yet to be determined); and 3) through the effect of rate of water binding (as measured by water activity) and textural changes during the period between mixing and sheeting. It should be noted that largest changes in discoloration took place shortly after dough mixing, when water activity in the incompletely developed dough was highest.

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