Measurement of Color, Gloss, and Translucency of White Salted Noodles: Effects of Water Addition and Vacuum Mixing

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ABSTRACT

Sensory evaluation showed panelists could detect small differences in gloss and translucency in boiled white salted noodles (WSN) but sensory evaluation requires significant resources. Methods for the measurement of noodle gloss and translucency in boiled WSN were developed and the effects of hardness, protein, water addition, and vacuum mixing on these visual sensory characteristics and color (as measured by CIE *L*, a*,* and *b**) were investigated. Noodles derived from hard wheats at low flour protein contents were more translucent than noodles from soft wheat flour at low protein. This trend changed at the highest flour protein contents observed. Translucency of the soft wheat noodles increased to levels equal to or exceeding the translucency of high protein hard wheat noodles. Translucency of all noodle varieties increased as flour protein increased. CIE *L** decreased, *a** increased, and *b** increased when water addition to dough increased from 30 to 35%, but there was no further effect on color when water addition was increased to >35% for raw soft and hard WSN. Boiled noodle translucency was significantly increased when water addition to the dough was increased from 35 to 38% and when noodles made from soft wheat flour were mixed under vacuum. Vacuum mixing significantly increased gloss of boiled noodles made from soft wheat flours.

The appearance of Asian noodles, in the form as sold (raw, dried, fried, boiled, or frozen) and after final cooking is an important consideration in the overall assessment of noodle quality. In thin white salted noodles (WSN) such as Japanese *kishimen* and the thick WSN such as Japanese *udon*, the appearance of raw noodles is usually judged by laboratory assessments of sheet color and color stability and often supported by measurements of Commission International de l'Eclairage (CIE) *L*, a*,* and *b**. Noodle researchers refer to *L** as lightness or brightness (Baik 1995; Park 1997; Kruger 1998; Wootton 1999; Hatcher 2000; Morris 2000), although CIE considers brightness to be a descriptor of lightness. The official Japanese method for the assessment of *udon* noodles incorporates visual sensory testing of the boiled noodles for color (including brightness, glossiness, and whiteness/yellowness (Crosbie et al 1991; Nagao 1996). Objective measurements of color, gloss, and translucency all rely on the use of reflected light in the form of specular light, scattered light, or diffuse light. Gloss, which relies on specular light, is seen when the angle of illumination equals the angle of reflection. Translucency is also a characteristic of starch pastes; Swinkles (1985) described wheat starch as opaque and waxy starches as translucent. Because partial waxy flour with an enhanced ratio of amylopectin to amylose in the starch is preferred for the manufacture of Japanese WSN (Seib 2000), it was considered that the measurement of translucency might also have a role in the assessment of boiled noodles. While researchers have observed variation in noodle gloss and translucency, little work has been done to develop appropriate analytical methods for these specific traits.

Earlier experiments associated with the measurement of color of raw noodle sheets emphasized the importance of using a standard background tile (Allen 1996) and a constant sheet thickness, or alternatively, conducting the tests at infinite optical thickness to eliminate effects of sheet thickness and background (Solah et al 1997). Infinite optical thickness was reached when *L*, a*,* and *b** measurements were the same when tests were conducted on either a black or white background.

While the thickness of raw noodles can be closely controlled by varying the sheeting roll gap in the final pass, the yield and, consequently, the thickness of noodles after boiling varies according to boiling time and the degree of starch swelling (Crosbie 1992). Accurate measurement of the color of boiled noodles necessitates the use of a method that minimizes the effect of variation on final noodle thickness; this can be resolved by conducting the tests at infinite optical thickness. Another consideration is raw noodle moisture content, which may not only affect raw noodle color but may also influence the rate of cooking and optimum boiling time. One approach in determining optimum boiling time is to judge the time when the uncooked central core of the noodle strands disappears. This is aided by compressing the strands between glass plates and viewing with a light box. An alternative approach is to boil the noodles until they reach a standard boiled noodle yield (or final moisture content). This approach is favored in the official Japanese method during sensory testing of the boiled noodles.

Whereas boiled noodle color may ideally be measured at infinite optical thickness, measurement of translucency necessitates the use of a thin sheet and both black and white backgrounds. Gloss is essentially associated with the noodle surface and is influenced by surface water and surface roughness but expected to be largely independent of noodle thickness. These were considerations in the development of methods in the present study. The aims of the study were to develop new and improved methods for measuring color, translucency, and gloss of boiled noodles, and to demonstrate the application of such tests on noodles prepared by both conventional and vacuum mixing.

MATERIALS AND METHODS

The translucency and gloss tests were developed in four stages (Experiments 1–4). Experiment 1 conducted sensory evaluation for translucency and gloss on boiled WSN disks made from Australian Standard White Noodle (ASWN) flour. Measurements were made on six noodle disks that varied in gloss and translucency due to addition of gelatin in varying amounts. Gelatin was dissolved in water and used to adjust a single ASWN sample. Experiment 2 was conducted to develop protocols for the measurement of translucency and gloss of thin, boiled noodle disks. The measurements were made on a group of samples that varied in grain hardness, protein, and flour swelling volume. Experiment 3 measured color of raw WSN disks and gloss and translucency of thin, boiled WSN disks. Experiment 4 assessed influence of dough water addition and vacuum mixing on color of noodles that were cooked to a constant boiled yield. This stage used pilot-scale vacuum mixing on the same sample as in Experiment 3 for thick WSN.

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Flour Samples

Experiments 1 and 4. Grain from the ASWN cultivar Cadoux was milled commercially at 60% extraction (9.0% protein and 0.40% ash).

Experiment 2. A total of 16 samples with a protein range of 7.0–11.5%, including four hard wheat samples with high flour swelling volume (FSV) (Crosbie 1992), four hard wheat samples with low FSV, four soft wheat samples with high FSV, and four soft wheat samples with low FSV were milled at 60% extraction using a laboratory-scale Buhler flour mill. Wheat cultivars were Cadoux, Kulin, Nyabing, and Cranbrook.

Experiment 3. Grain from ASWN and Australian Hard (AH) was milled commercially. ASWN flour was 9.0% protein and 0.40% ash, and AH flour was 10.7% protein and 0.50% ash.

Water Addition

Water addition with a conventional pin mixer with no vacuum applied was 30 and 35%; with vacuum mixing it was 35 and 38%. The aim in using the experimental vacuum mixing equipment was to maximize water addition while at the same time maintaining satisfactory dough sheeting properties. Vacuum mixing removes air during dough mixing. Dalbon (1996) reported that air bubbles in boiled pasta caused light to diffract, so the inclusion or exclusion of air during conventional or vacuum mixing of the noodle crumb or dough may affect translucency and whiteness of boiled WSN and surface characteristics, including gloss.

Mixing

Experiments 1 and 2. Flour (400 g) was mixed using a Hobart N50 dough mixer (without vacuum). Noodle formulas were 100 flour (on a 13.5% moisture basis), water (35 parts), and salt (2 parts). Each sample was mixed in triplicate. The mixing regime was 1 min on slow, 1 min on medium, and 3 min on slow (Crosbie 1992).

Experiment 3. Flour (400 g) was mixed using a Hobart N50 dough mixer (without vacuum). The main treatments applied in this study included mixing as in Experiments 1 and 2 with water additions of 30, 35, and 38%.

Experiment 4. Flour (3,000 g) was mixed using a TOM pilot-scale horizontal pin vacuum mixer with a maximum flour capacity of 5 kg and a maximum vacuum capacity of –100 kPa (at the Ball Noodle factory). The main treatments applied in this stage included conventional mixing (no vacuum) with water additions of 35 and 38% and vacuum mixing with 38% water addition and vacuum levels of –55 kPa and –90 kPa. The experiment was repeated three times (all treatments) on separate days. The formulation was 100 parts flour (13.5% moisture basis), 35–38 parts water, and 2 parts salt. The mixing regime involved the addition of water (with dissolved salt) to flour over a 30-sec period while mixing slowly. Then a further mix was conducted with the chamber closed for 7 min on high and 4 min on low at the required vacuum. After mixing, the WSN dough from each treatment was compressed into four blocks of similar weight. The compressed noodle blocks were rested in plastic bags for 3.5 hr before sheeting.

Sheeting

For all four stages, the noodle dough was sheeted using Ohtake noodle-making equipment. Thickness of raw noodle sheets and boiled noodle disks was measured with a micrometer thickness gauge (Peacock G2-257 digital thickness gauge; Ozaki, Japan) Two glass slides were used to hold the cooked noodle disk during measurement.

Experiments 1, 2, and 3. Noodle sheets were progressively reduced to a uniform final thickness of 1.30 ± 0.03 mm for thin WSN as in Konik (1993). Measurements for gloss and translucency were taken on sheets for raw noodle color and on disks or strands 3 mm wide (number 10 Ohtake cutter) for cooked noodles.

Experiment 4. Noodle sheets were progressively reduced to a uniform final thickness of 2.20 ± 0.01 mm for thick WSN as in Crosbie (1992) before cutting into disks 60 mm in diameter using a round metal cutter for translucency and gloss measurements.

Boiling of Noodles

The time for boiling the thin WSN was determined by sensory evaluation to assess the disappearance of the uncooked noodle core. The time for boiling of thick WSN (*udon*) was determined by sensory evaluation and apparent boiled noodle yield (ABNY). WSN (*udon*) was boiled for the determined time to give an ABNY of 310%. Optimum boiling time was established separately for each treatment. ABNY was calculated as the weight of boiled disks, that was expressed as a percentage of the weight of flour (at 13.5% moisture content) within the raw disks that were boiled as

ABNY* = Boiled noodle weight/raw noodle weight × 100
– 13.5/100 – moisture content** of raw noodle × 100

where * indicates ABNY is only an approximate value because of the loss of dry matter including salt during boiling; and ** indicates the moisture content of raw noodle includes moisture present in the flour plus added water, expressed as a percentage of the total weight of the dough (weight of flour + added water + salt).

Noodle disks were boiled for the determined time, removed, and drained for 10 sec, placed in water at room temperature for 30 sec, drained for 10 sec, placed in chilled water for 30 sec, drained for 10 sec to stop the cooking process, and then analyzed.

Measurement of Translucency and Gloss by Sensory Evaluation in Experiment 1

Panelists reported to the taste panel room at Curtin University of Technology, Perth, and were placed in individual booths to visually assess noodle disks. Samples were identified with a three-digit number. Two boiled WSN disk reference samples and four unknowns were presented to the panelists. New WSN disks were boiled every 10 min for assessment. Subjects were required to complete visual analogue scales, rating gloss and translucency (Meilgaard 1991). Panelists used a 150-mm visual analogue scale (VAS) for each sensation, anchored at each end with the opposing extremes of matte marked at one end and high gloss marked at the other end, to assess gloss. Panelists also used a visual analogue scale with opaque at one end (where black and white were not visible through the noodle disk) and translucent (80%) at the other to assess translucency. The distance from zero, marked on the VAS for each test sample was measured. Scores for all 32 panelists were averaged to calculate the gloss and translucency score. Panelists ranked noodle gloss and translucency on boiled noodle disks and strands from six WSN mixes of ASWN and gelatin, following standard procedures for sensory examination of foods (Standards Australia 1995).

Measurement of Color in Experiments 2, 3, and 4

A chromameter (Minolta CR-310, Konica Minolta Sensing) with D65 illuminant was used to measure CIE *L**(lightness), *a**, (greenness or redness), and *b** (yellowness) color values of disks. Measurements were made immediately after boiling and at 0.5 hr and 24 hr on raw noodle disks (1.3 mm thick, 8 layers). Color of raw noodle sheets was measured at infinite optical thickness, where CIE *L**, *a**, and *b** measurements on black and white tiles were the same. This meant that the color measurements were unaffected by background color and noodle sheet thickness (Solah et al 1997). Infinite optical thickness was achieved using sheets layered to a thickness of ≤10 mm. Color of boiled noodles was assessed at infinite optical thickness, where a black or white background gave the same boiled noodles values, using a method developed by Crosbie (1991). After boiling, 60 g of noodles were held in a covered plastic jar (internal diameter 60 mm at the top and 55 mm at the base) for 30 min and then compressed by force with an Agtron sample cup. Color measurements were taken through the optical glass base using a Minolta CRC-310 colorimeter.

Measurement of Gloss

Gloss was measured on boiled noodle disks using a BYK Gardner micro-TRI-gloss meter (Nick Harkness, Alexandria, Australia) at 60° and 85°. A standard black glass tile with a defined refractive index and a gloss of 100, supplied with the gloss meter, was used for calibration. Gloss units for test samples relate to the amount of reflected light from the black glass standard. Noodle disks were cut from raw noodle sheets and the noodle disks stored in a single layer inside a plastic bag and refrigerated (at 5°C) until required for boiling. The disks, in triplicate, were boiled together in a stainless steel pot to the optimum cook time determined for each treatment. Boiled disks were placed on a white standard backing tile (RACI Cereal Chemistry Division, Australia), which was tilted at 10° to prevent pooling of water and held for 3.5 min to stabilize the surface water. Gloss was measured at 60° (medium gloss) and 85° (low gloss). The boiled noodle disks were immediately and carefully transferred onto a Leneta opacity chart (Form 2C, Leneta, Mahwah, NJ) for translucency/opacity measurements.

Measurement of Translucency

The Minolta CR-310 was set to CIE *x, y, z* and used to measure CIE *Y* for the sample on a black and white Leneta opacity chart. Translucency percent was calculated as

$$100 - (\text{CIE } Y_{\text{black}}/\text{CIE } Y_{\text{white}}) \times 100$$

Statistical Analysis of Results

Experiment 1. The relationship between instrumental tests and sensory evaluation for gloss and translucency was determined using linear regression (Excel). Ranking of panelist scores for gloss and translucency were calculated according to Standards Australia, sensory examination of foods (AS 2542.2.6, 1995).

Experiment 2. The independent predictors of translucency and gloss were determined using multiple linear regressions. The effect of hardness category and FSV type were evaluated using ANOVA after adjusting for the effects of increased thickness due to cooking. Translucency was calculated as translucency %/mm, and all measurements were adjusted to a standard cooked noodle thickness of 1 mm.

Experiment 3. The effect of water addition and vacuum on color, gloss, and translucency for soft wheat WSN was also examined using ANOVA. Translucency and gloss results were adjusted to a standard cooked thickness as in Experiment 2.

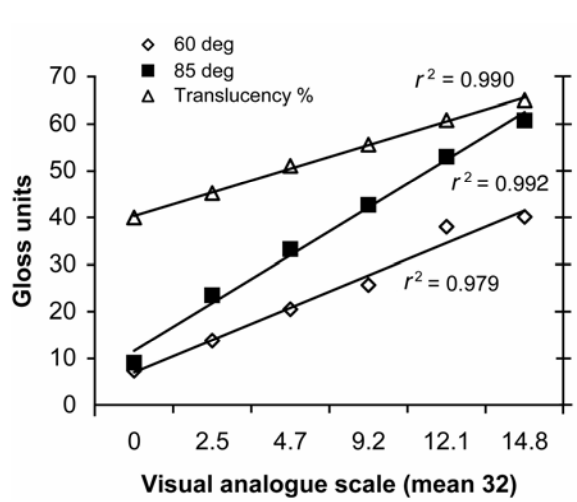

Fig. 1. Relationship between sensory evaluation panel score (n = 32) and instrumental measurements at 60 and 85° gloss and translucency% (n = 9).

Experiment 4. The independent predictors of translucency and gloss were determined using multiple linear regression. Effects of water addition and vacuum mixing were evaluated using ANOVA.

RESULTS AND DISCUSSION

Relationship Between Sensory Evaluation and Instrumental Tests in Experiment 1

The distance along the visual analogue scales (VAS) for each of the six samples was measured, the results of the 32 panelists were combined, and the mean scores were compared with instrumental gloss and translucency values. Twenty-one of the 32 panelists could discriminate between WSN gloss differences of 5 units (60°). Sensory evaluation showed that 32 panelists could detect differences in gloss of boiled white salted noodles; r^2 = 0.979 for 60° and r^2 = 0.992 for 85° (Fig. 1). Twenty-five of 32 panelists could discriminate translucency differences of 10%. The mean standard deviation of panelist scores for gloss was 2.4. Sensory evaluation showed that 32 panelists could detect differences in the translucency of boiled white salted noodles; r^2 = 0.990. The mean standard deviation of panelist scores for translucency was 3.1. There was a strong positive correlation (r = 0.900) between boiled WSN strands and disks for gloss and translucency as assessed by both the panelists and instruments (Table I). Instrumental tests matched human perception for gloss and translucency of WSN made from soft, high-FSV wheat flour.

Effect of Grain Hardness and Protein Content on Gloss and Translucency of WSN in Experiment 2

Translucency was affected by protein ($P < 0.001$) for Cadoux, Kulin, and Cranbrook. The mean levels of translucency of noodles made from the soft, low-FSV wheat flour and the soft, high-FSV wheat flour (9.25% protein) were 39.75 and 43.75%, respectively. The mean levels of translucency of noodles made from the hard, low-FSV wheat flour and the hard, high-FSV wheat flour (9.25% protein) were 42.0 and 44.50%, respectively. The most translucent noodle sheet tested was made from a soft, high-FSV soft wheat flour giving translucency of 47.50% at 11.50% protein (Fig. 2).

Translucency increased linearly with protein for the two soft and one hard wheat noodle samples but there appeared to be a varietal effect on this relationship, as the linear effect of protein

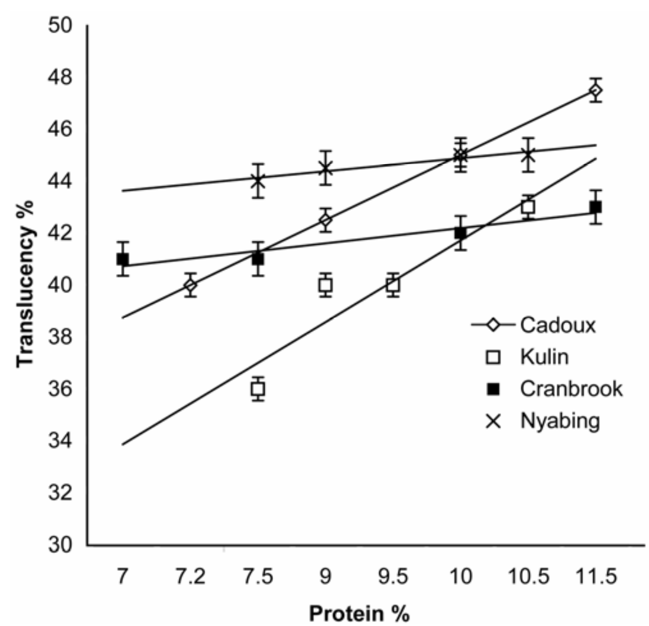

Fig. 2. Effect of protein on soft- and hard-grained wheat white salted noodles (WSN) translucency. Slope varies due to cultivar (n = 9). Translucency mean standard deviation was 0.9%.

differed for each of the four cultivars tested. The effect of protein on hard wheat translucency needs further investigation. At low flour protein contents, noodles derived from hard wheats were more translucent than noodles derived from soft wheats. But at the highest flour protein contents observed, translucency of the soft wheat noodles had increased to levels equal to or exceeding the translucency of high protein hard wheat noodles (Fig. 2).

The mean level of gloss for noodles from the soft wheat samples was 20.73 units (standard deviation 1.80) and 20.40 units (standard deviation 1.58) (60°); from the hard wheat sample, the mean level was 18.82 units (standard deviation 1.80) and 18.16 units (standard deviation 1.58) (60°).

Gloss was not affected by protein ($P = 0.216$). Starch quality (FSV) did not significantly affect gloss ($P = 0.268$) or translucency ($P = 0.266$) for these samples, although it was noticed that the sample with the highest translucency and gloss was a high-FSV type. Further research is needed to investigate effects of starch quality on gloss and translucency.

Influence of Water Addition on Color, Gloss, and Translucency of Thin WSN in Experiment 3

Color, gloss, and translucency are interrelated as they are all components of reflected light, so how water addition and vacuum affect color is important to the overall understanding of translucency and gloss. An increase in water addition to dough from 30 to 35% resulted in a decrease in lightness (L^*) and an increase in redness (a^*) and yellowness (b^*) values of raw WSN sheets from soft and hard wheat flour samples. Measurements of L^*, a^*, and b^* usually give low standard deviations (SD) using the method described and this study gave mean SD of 0.36 for L^*, 0.06 for a^*, and 0.39 for b^* (Figs. 3, 4, 5). Color stability was also affected by water addition. The 24-hr measurements showed a further loss of brightness for soft (–10 L^* units) and for hard samples (–5 L^* units). This finding agrees with the studies of Baik (1995) and Hatcher (1998), but previous research has not reported on dough with water additions >35%.

An increase in water addition to dough from 35 to 38% resulted in no change in L^* for 0 hr and a small increase in brightness/lightness at 24 hr. Redness (a^*) decreased for the soft wheat flour WSN sheets at 0 hr. There was no change for the hard wheat flour WSN sheets a^* for 0 hr and hard and soft WSN sheets a^* for the 24-hr results. There was no significant effect of water addition increase to dough from 35 to 38% on yellowness (b^*) values of raw WSN sheets (Figs. 3, 4, 5).

Translucency of thin noodles (1.3 mm thick) made from soft and hard wheat flour increased significantly ($P < 0.05$) from 55.70 to 56.90% for soft and 49.02 to 52.90% for hard, when water addition to dough was increased from 35 to 38%. There was no effect on gloss when water addition to dough was increased from 35 to 38% for soft and hard wheat flour noodles.

Influence of Water Addition and Vacuum Mixing on Thick WSN Characteristics in Experiment 4

The assessment of boiled noodle appearance and texture relies on the noodles being in the best possible condition after cooking and during consumption. Disintegration of noodles during boiling must be controlled; a rough surface is rated poorly for appearance and mouthfeel, and roughness will affect gloss by causing reflected light to scatter. The official Japanese method prefers a "fixed boiled condition" for making the sensory quality assessments of boiled noodles (MAFF 1985). In this study, it was important to assess the influence of the variables of water and vacuum on the boiled noodle condition.

ABNY increased with increased water addition and boiling time, but decreased with increased vacuum. Noodles made with higher water addition took less time to cook to a specific boiled noodle yield, while noodles processed with higher vacuum took longer to cook (Fig. 6). An optimum cooking time was determined for each combination to achieve a constant ABNY of 310%, which was considered ideal for this sample in relation to boiled noodle tex-

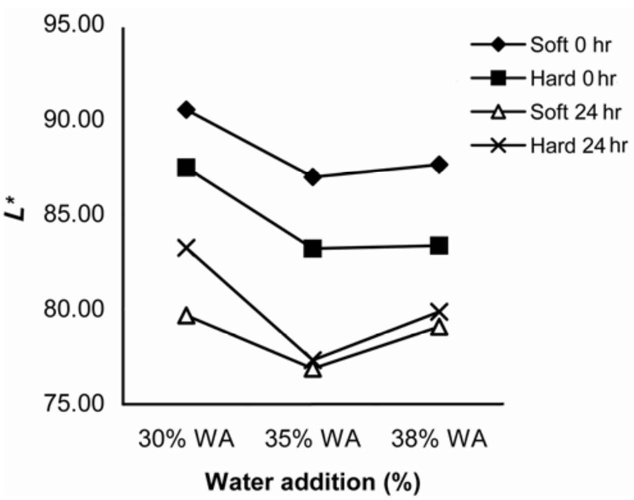

Fig. 3. Effect of water addition on color. CIE Lab L^* value at 0.5 and 24 hr of raw white salted noodle (WSN) sheets ($n = 9$).

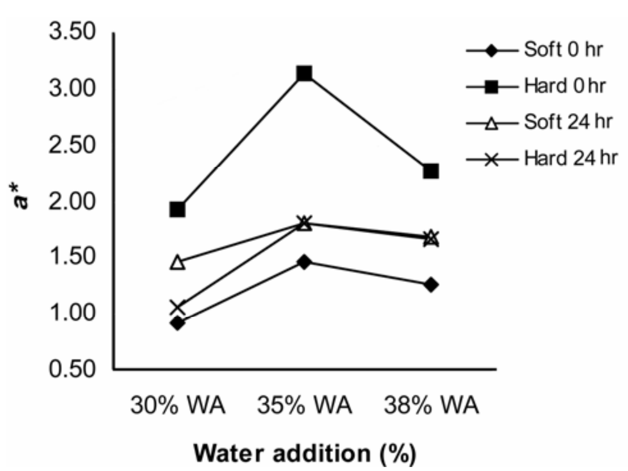

Fig. 4. Effect of water addition on color. CIE Lab a^* value at 0.5 and 24 hr of raw white salted noodle (WSN) sheets ($n = 9$).

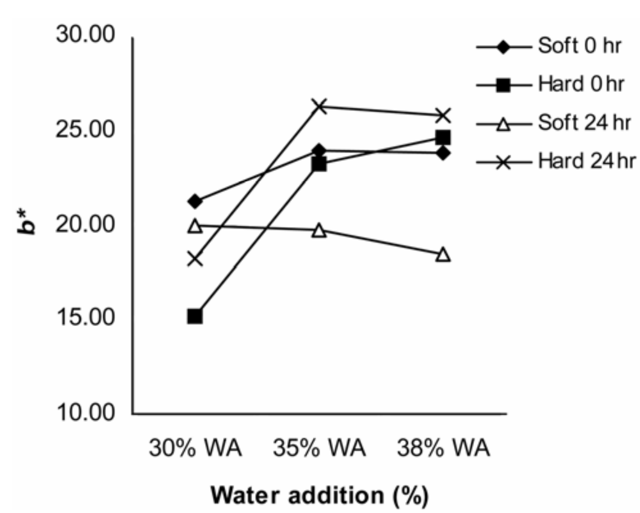

Fig. 5. Effect of water addition on color. CIE Lab b^* value at 0.5 and 24 hr of raw white salted noodle (WSN) sheets ($n = 9$).

ture as judged by sensory tests. The predicted cooking times were 16:36, 15:07, 16:24, and 17:41 for 35% WA/0 kPa, 38% WA/0 kPa, 38% WA/–55 kPa, and 38% WA/–90 kPa, respectively.

Vacuum mixing is mainly used where high moisture in raw noodles is an advantage such as in the manufacture of raw, frozen, and boiled noodles. Color stability is generally only an issue with raw noodles that are held for a period before cooking.

An increase in water from 35 to 38% resulted in an increase in lightness (L^*), a decrease in redness (a^*), and no effect on yellowness (b^*) values of raw WSN sheet. Also, color stability was not affected by water addition for this soft sample (Table II).

White salted noodle sheets made with vacuum mixing levels of –55 kPa pressure and –90 kPa pressure, produced sheets that were less light/bright (lower L^*), closer to 0 for red/green (higher a^*), and more yellow (higher b^*) than those made with the same moisture addition but with no vacuum mixing.

Similar to the effect of increased dough water addition on raw noodle color, boiled WSN L^* and a^* values were not significantly affected by increased water addition from 35 to 38% ($P > 0.05$). Although b^* increased in raw noodles, there was no effect of water addition on b^* of boiled WSN (Table III).

Again, in contrast to the effect of increased water addition on raw noodle color, boiled noodle lightness/brightness (L^*) and red/green (a^*) were not significantly affected by vacuum mixing. Vacuum mixing at –55 kPa and –90 kPa resulted in a significant increase in b^* values (Table III).

Variables of water addition and vacuum mixing change dough density by eliminating air and by adding water, or by increasing cohesion between protein and starch. Changes in dough density affect the appearance properties of gloss and translucency.

Boiled noodle disk translucency increased significantly ($P < 0.05$) from 32.92 to 34.78% when water addition was increased from 35 to 38% in the dough, but boiled noodle disk gloss was not affected (Figs. 7 and 8).

Although essentially a surface characteristic, noodle gloss was affected by cooked WSN thickness. A standard backing tile was used for this method as it was not practical to layer boiled WSN to achieve infinite optical thickness for the gloss measurement. The response at a 38% water addition to the dough showed that a change in vacuum mixing from –55 kPa and –90 kPa pressure resulted in a significant effect on boiled noodle gloss ($P < 0.001$) from 18.7 to 25.8 for 60° gloss, and 33.8 to 44.0 for 85° gloss. This approximately twofold increase in gloss was also obvious to the observer (Fig. 7).

Introducing vacuum mixing to dough increased translucency from 34.78 to 40.01% for boiled noodles. When vacuum changed

TABLE I
Relationship Between Gloss and Translucency and Rank Sum of Panelist Scores for Strands and Disks

Sample	Gloss (units) Instrument	Gloss Rank Sum Strands	Gloss Rank Sum Disks	Translucency (%) Instrument	Translucency Rank Sum Strands	Translucency Rank Sum Disks
1	9.1	32	32	40.0	33	32
2	23.5	65	68	45.2	66	64
3	33.3	90	94	51.0	92	96
4	42.7	130	129	55.6	125	128
5	53.0	160	158	60.8	160	160
6	60.7	187	191	65.0	190	192

TABLE II
Color and Color Stability of Noodle Sheets Processed by Conventional Mixing and Vacuum Mixing at –55 and –90 kPa (n = 12)[a]

Treatment	Mean	SD	Mean	SD
	L *** (0 hr)**		**Δ*L** (0–24 hr)**	
35% 0 kPa	84.26a	0.38	4.43l	0.50
38% 0 kPa	85.35b	0.22	3.03m	0.31
38% –55 kPa	83.43c	0.74	2.63m	0.84
38% –90 kPa	82.49d	0.24	1.35n	1.42
	***a** (0 hr)**		**Δ*a** (0–24 hr)**	
35% 0 kPa	–0.46e	0.04	–0.13o	0.07
38% 0 kPa	–0.62f	0.06	–0.16o	0.05
38% –55 kPa	–0.47g	0.16	–0.22o	0.05
38% –90 kPa	–0.35h	0.09	–0.21o	0.04
	***b** (0 hr)**		**Δ*b** (0–24 hr)**	
35% 0 kPa	25.30i	0.38	1.15p	0.31
38% 0 kPa	25.41i	0.18	0.19q	0.21
38% –55 kPa	27.74j	0.29	1.58p	0.75
38% –90 kPa	28.38k	0.93	2.08p	1.51

[a] Mean values with the same letter are not significantly different at P = 0.05.

TABLE III
Color of Boiled Noodle Strands Processed With and Without Vacuum (n = 6)[a]

Treatment	L^* Mean	L^* SD	a^* Mean	a^* SD	b^* Mean	b^* SD
35% WA 0 kPa	76.24a	0.24	–1.91b	0.14	18.56d	0.13
38% WA 0 kPa	76.14a	0.06	–1.93b	0.10	18.60d	0.35
38% WA –55 kPa	76.32a	0.18	–1.77b	0.08	19.14e	0.12
38% WA –90 kPa	76.39a	0.37	–1.64b	0.06	19.39e	0.10

[a] Mean values with the same letter are not significantly different at P = 0.05.

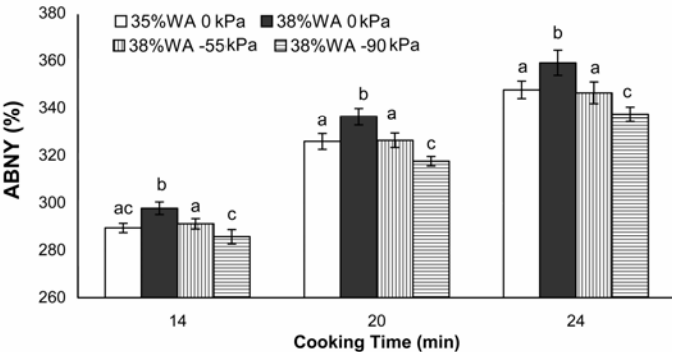

Fig. 6. Apparent boiled noodle yield (ABNY) values ± standard deviation for treatments after 14, 20, and 24 min of cooking ($n = 6$). Bars labeled with the same letter are not significantly different at $P = 0.05$. Error bars indicate SD.

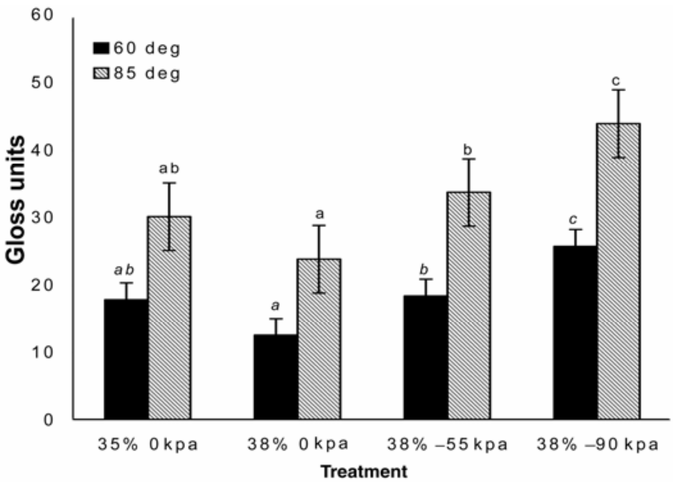

Fig. 7. Effect of water addition and vacuum at different pressures on boiled noodle gloss ($n = 10$) for *udon* soft wheat noodles. Bars labeled with the same letter are not significantly different at $P = 0.05$. Error bars indicate SD.

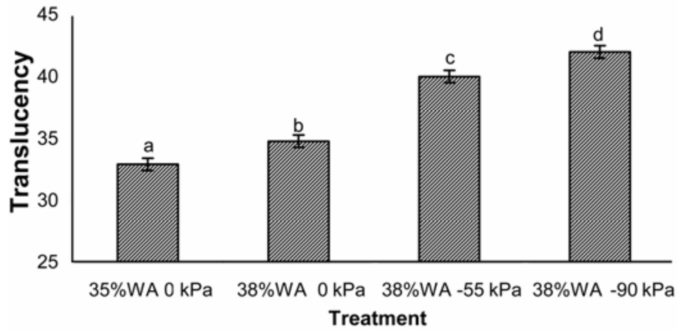

Fig. 8. Effect of water addition and vacuum at different pressures on boiled noodle translucency ($n = 10$) for *udon* soft wheat noodles. Bars labeled with the same letter are not significantly different at $P = 0.05$. Error bars indicate SD.

from –55 kPa to –90 kPa, translucency increased from 40.01 to 41.98% ($P < 0.01$) for WSN from soft wheat flour (Fig. 8). Multiple linear regression showed that adjustment of results due to increased thickness and due to cooking was not needed for this trial where raw thickness was carefully controlled to 2.20 ± 0.01.

CONCLUSIONS

Translucency and gloss are important quality traits that have a role in the assessment of white salted noodles. Gloss and translucency of WSN could be determined quickly using the methods described and using supporting methods in the assessment of WSN quality.

The instrumental methods developed in this study produced results that matched human perceptions of noodle gloss and translucency. Panelists and reflectance instruments were able to determine small differences in gloss and translucency, and the results were highly correlated.

Protein content in the boiled noodles had no effect on gloss, however there was a positive effect on translucency. Translucency increased as protein content increased for the WSN made from soft and hard wheat flour. The four wheat cultivars used in this study showed different responses to changes in protein content.

When water addition to dough was increased from 30 to 35%, color of the raw WSN disk was markedly affected: CIE L^* decreased and both a^* and b^* increased. This confirmed earlier results by others. However, when water addition was increased to 38%, there was no further effect on raw WSN color, although differences between samples were maintained. This indicated that assessments of raw WSN color in wheat breeding programs might be more reliable if tests were made on moist (>35% water addition) noodles. On the other hand, the application of vacuum at 38% water addition resulted in sheets with lower L^* and higher a^* and b^* values. Similarly, L^*, a^*, and b^* values of boiled WSN were not affected when water addition was increased from 35 to 38%, although b^* was increased if vacuum was also applied (at levels of either –55 kPa or –90 kPa).

Water addition increased boiled noodle translucency and reduced boiling time but had no significant effect on boiled noodle gloss. However, vacuum mixing increased boiled noodle gloss made from soft wheat flours significantly and produced a glossy, bright, creamy white noodle which is preferred in Japan.

Gloss and translucency is important for all WSN, including Japanese WSN, and the results of this research has implications for dumpling skins and other noodle types.

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