Assessment of Oriental Noodle Appearance as a Function of Flour Refinement and Noodle Type by Image Analysis

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ABSTRACT

Fresh alkaline and white salted noodle sheets prepared from patent and straight-grade flours of the western Canadian wheat class Canadian Prairie Spring White (CPSW), Karma and Vista, were visually characterized by image analysis over a 24-hr period. In both cultivars, the number of specks increased with time although the actual numbers were significantly influenced by both detection size and sensitivity. Maximum speck generation was observed in Karma's straight-grade *kansui* noodle sheets, increasing from 12.9 specks/cm^2 at 1 hr to 58.0 after 24 hr. Lowest speck numbers were observed in Vista's patent white salted noodle sheets with 4.5 specks/cm^2 at 1 hr increasing to 5.6 after 24 hr. The image analysis system was able to show that in combination with a significant cultivar effect, both flour refinement and noodle type significantly influenced the number of discolored specks detected over time. Straight-grade flours yielded more specks than the patent flours, while salted noodle sheets consistently had fewer specks compared with their *kansui* noodle sheets at all time intervals. No differences were detected in the average size of the specks due to cultivar or noodle type in the patent flour noodle sheets. Noodle sheets made from Karma straight-grade flour had significantly larger specks than noodle sheets made from Vista's straight-grade flour for both noodle types. Patent flour *kansui* specks were lighter than their salted counterparts. Straight-grade noodle specks were darker than their corresponding patent flours, but this difference was significant only in the *kansui* noodle sheets. Specks of all noodle sheets were characterized by darkness distribution profiles that highlighted key differences between the wheat cultivar samples due to noodle type and flour refinement.

The consumer's first critical assessment of noodle quality is based on subjective evaluation of the noodle sheet appearance. The degree of brightness followed by an absence of undesirable discoloration (specks) are essential to the consumer's acceptance of either raw alkaline or white salted noodle sheets. Most Asian markets prefer noodle products to be made from high-quality patent wheat flours producing bright noodle sheets with minimal discoloration (Miskelly 1984; Miskelly and Moss 1985; Moss et al 1986; Toyokawa et al 1989a,b). It is not uncommon for raw noodles, especially those that are alkaline-based, to be consumed 24 hr after production. This delay between manufacture and consumption allows discoloration. Discoloration, reduced brightness, and visual appeal are thought to involve the enzymes polyphenol oxidase (PPO), peroxidase (POD), phenolic compounds, and subsequent autooxidation products (Pierpoint 1969; Singleton 1987; Taylor and Clydesdale 1987; Hatcher and Kruger 1993, 1996). Enzyme levels and potential substrates associated with discoloration can be measured chemically (Marsh and Galliard 1986; Hatcher and Kruger 1993, 1996; Baik et al 1995) but do not provide a direct measure of the visual impact on the noodle that directly influences consumer acceptability. Color measurement of noodle sheets using a colorimeter and CIE L^*, a^*, b^* values are a normal laboratory procedure for the determination of brightness and discoloration of the noodle product. This method is limited in that it does not provide a means of quantitating or characterizing the visual impact that discolored spots have on consumer perception of overall noodle appearance and value.

Detection of bran specks in flour (Evers 1993, Whitworth 1994) and in durum wheat semolina (Harrigan 1995, Symons et al 1996) have been reported. Previous work (Hatcher et al 1999) has shown the preliminary application of computer imaging to assess the appearance of alkaline noodle sheets prepared from high-quality patent flour by detecting, quantitating, and characterizing the formation of regions of undesirable color on or below the noodle sheet surface over time. The objective of this study was to evaluate the ability of computer imaging to characterize and differentiate the visual appearance of two different types of noodle sheets prepared from flours of differing refinement. A secondary objective was to determine whether this discrimination could be used to discern differences in noodle sheets made from different cultivars within the same wheat class.

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MATERIALS AND METHODS

Flours

Wheat cultivars AC Karma and AC Vista from the Canadian Prairie Spring White (CPSW) class developed for the Asian noodle market were milled on the Grain Research Laboratory pilot mill using a commercial flow (Fajardo et al 1995). Individual streams were composited on the basis of increasing ash to yield two flours: a high-quality patent flour (60% flour yield) and a straight-grade flour. Characteristics of the flours used in this study are given in Table I.

Analytical Methods

Protein content (N × 5.7) was determined by combustion nitrogen analysis (model FP-248 Leco Dumas CNA analyzer) calibrated with ethylenediaminetetraacetic acid (EDTA). Ash content, farinograph, moisture, and starch damage were determined by Approved Methods 08-01, 54-21, 44-15A, and 76-30A, respectively (AACC 1995). Flour color was determined using a flour color grader (Simon Series IV, Satake UK, Stockport, UK) according to the Flour Testing

TABLE I
Proximate Analysis of Flour Samples Used for Noodle Preparation

	Vista		Karma	
	Patent	Straight-Grade	Patent	Straight-Grade
Protein (%)	10.9	11.6	10.4	11.0
Ash (%)	0.38	0.48	0.43	0.52
Color	–3.8	–2.3	–4.4	–2.5
Starch damage (AACC)	8.9	5.8	8.0	7.8
Moisture (%)	14.0	14.0	14.0	13.9
Farinograph				
Absorption (%)	61.8	62.4	60.0	60.1
Development time (min)	6.25	6.50	2.25	2.25
Mixing time tolerance (BU)	25	40	90	85
Stability (min)	22.5	8.5	2.5	2.0

Panel Method No. 007/4 (FMBRA 1991). The relative reflectance of the flour-water slurry is listed in Satake International units (the lower the number, the brighter the flour color).

Noodle Preparation

Noodle sheets were prepared on three separate days using the method previously described by Kruger et al (1994). *Kansui* reagent (9:1 potassium and sodium carbonate) or sodium chloride dissolved in water was added over a 30-sec interval to 200 g of flour to yield a 1% (w/w) composition at a final water absorption of 32%. A mixer (model N50, Hobart Canada, North York, ON) incorporated the ingredients over 5 min using a three-stage mixing regime. The crumbs were sheeted on a laboratory noodle machine (Ohtake, Tokyo, Japan) with an initial gap setting of 3.00 mm. Two passes were made at this setting with the noodle sheet being folded between passes to ensure homogeneity. A representative 25-cm section of the noodle sheet was used in the subsequent sheeting passes. Seven sheetings with gap settings of 3.00, 2.55, 2.15, 1.85, 1.57, 1.33, and 1.10 mm were used. Total work of individual sheetings was measured by a analog-digital board (Labmaster DMA ,Scientific Solutions, Solon, OH) interfaced to personal computer software (Labtech Notebook, Laboratories Technologies, Wilmington, MA) to ensure reproducibility between the triplicate preparations.

The final noodle sheet was cut into two portions with one undergoing spectrophotometric color measurements while the second piece was used for image analysis measurements.

Noodle Color Measurement

Noodle sheet color was measured with a spectrocolorimeter (Labscan II, HunterLab, Reston, VA) equipped with a D65 illuminant using the CIE 1976 L^*, a^*, and b^* color scale. Measurements were made in triplicate at two random locations on the sheet surface for each sample and averaged for each sample. Noodle sheets were stored in sealed plastic bags at room temperature until the timed readings.

Image Analysis

Noodle images were captured using a CCD color camera (model CD-950, Sony of Canada, Willowdale, ON) attached to a macroscope (model M-8, Wild Leitz Canada, Willowdale, ON) as previously described (Hatcher et al 1999). Illumination levels were controlled by adjusting the camera gain to a constant value from a Kodak #3 gray scale (Eastman-Kodak, Rochester, NY).

Images were captured from six different areas on each noodle sheet using a grid positioning system that ensured that the noodle was aligned exactly the same for each series of measurements at each time period. The camera-macroscope complex was located within a self-enclosed cabinet to prevent interference from overhead lighting. The noodle sheet was stored at 25°C in a sealed plastic box maintained at ≈95% rh except when being photographed. Each image represented a section 1.5 × 1.1 cm of the noodle surface for a total of 9.9 cm^2.

Two imaging variables were used during noodle sheet analysis. The Δgray level represents a threshold value of darkness. A discolored speck must exceed the background by this threshold value for it to be identified. ΔGray values of 2, 5, or 10 were selected during the formation of the binary mask when the image gray values were remapped. The other parameter for selecting discolored specks was based on a minimum threshold size of 5, 10, or 15

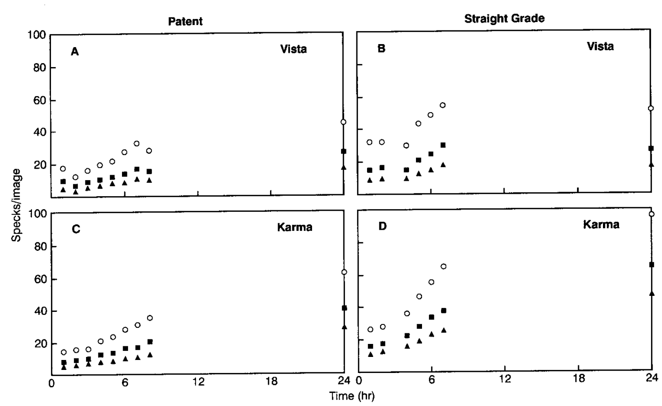

Fig. 1. Average number of specks/image (n = 3) detected over 24 hr (Δgray level = 2). **A,** Vista patent *kansui* noodle; **B,** Vista straight-grade *kansui* noodle **C,** Karma patent *kansu* noodle; **D,** Karma straight-grade *kansui* noodle. Minimum detection threshold size = 5 (○), 10 (■), and 15 (▲) pixels.

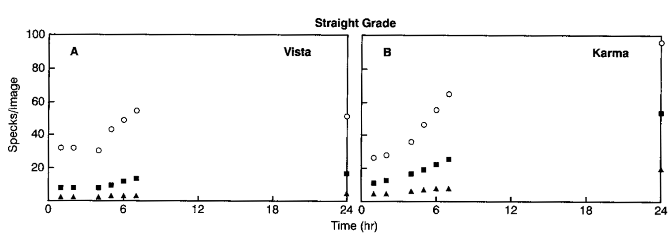

Fig. 2. Effect of varying the constrast detection limit (Δgray) while maintaining a constant minimum detection threshold (minimum threshold size = 5) on the mean (n = 3) of detected specks/image over time. **A,** Vista straight-grade *kansui* noodle; **B,** Karma *kansui* straight-grade noodle. ΔGray = 2 (○), 5 (■), and 10 (▲).

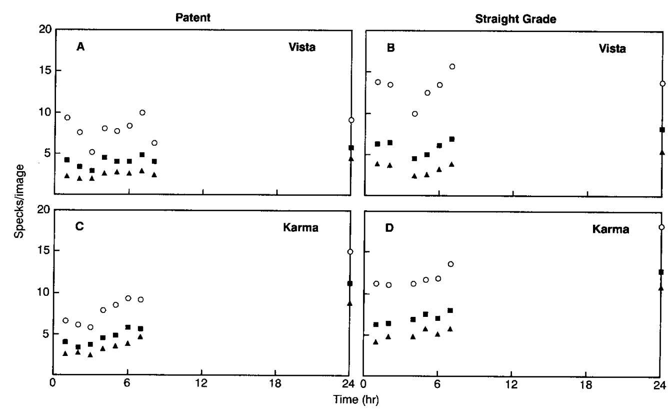

Fig. 3. Average number of specks/image (n = 3) detected over 24 hr. **A,** Vista patent salted noodle; **B,** Vista straight-grade salted noodle; **C,** Karma patent salted noodle; **D,** Karma straight-grade salted noodle. Minimum detection threshold size = 5 (○), 10 (■), and 15 (▲) pixels.

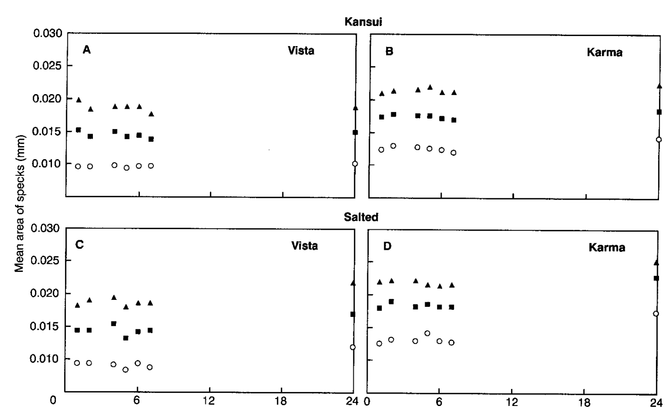

Fig. 4. Mean (n = 3) area of detected specks in straight-grade flours. **A,** Vista *kansui* noodle; **B,** Karma *kansui* noodle; **C,** Vista salted noodle; **D,** Karma salted noodle. Minimum detection threshold size = 5 (○), 10 (■), and 15 (▲) pixels.

pixels that correspond to 0.003, 0.0063, and 0.0094 mm^2 respectively Both parameters were applied to the binary measurement mask to identify areas of localized discoloration.

Statistical Analysis

The samples were prepared and analyzed using a completely randomized design that incorporated three replicates of each flour and noodle type. All statistical analyses, regression, analysis of variance, and frequency distributions were done with SAS statistical software (version 6.11, SAS Institute, Cary, NC). All statements of significance are at $P < 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Uneven hydration of flour particles due to the low water absorption level (32%) results in the initial noodle surface appearing mottled and required ≈1 hr for uniform hydration to remove this effect (Hatcher et al 1999). The image analysis software detects and quantitates specks based on a constant fixed difference (Δgray) between a discolored speck and the noodle surface. Uneven hydration caused exaggerated readings at 0 hr, forcing the initial readings to be excluded from statistical analysis as they contained a disproportionate amount of variance. Readings used in this study were made at 1, 2, 3, 4, 5, 6, 7, and 24 hr.

Effect of Flour Quality, Noodle Type, and Cultivar

In both Karma and Vista, the number of discolored specks detected increased with time in patent and straight-grade *kansui* noodles for the three Δgray levels (2, 5, and 10) examined (Fig. 1). The minimum difference between discolored specks and the noodle sheet background matrix required for the software to detect the speck is referred to as the Δgray level. The rate of increase was significantly influenced by both the Δgray level (Fig. 2) selected and minimum threshold detection size values (MS). These results are consistent with our preliminary findings (Hatcher et al 1999).

At the highest sensitivity (Δgray = 2, MS = 5), noodle sheets of Vista patent flour had 12.4 specks/image at 2 hr, which was not significantly different from noodle sheets of Karma patent flour with 15.5 specks/image. Straight-grade flours had a significantly greater number of specks, 31.9 and 28.3 specks/image, respectively, indicating that flour quality did influence the number of specks. No cultivar difference was detected within the straight-grade flours at 2 hr. At 6 hr, no cultivar differences were detected within either patent or straight-grade flours, although the significant influence due to flour quality continued.

When aged for 24 hr, noodle sheets from Karma patent flour had a significantly higher number of specks (61.9) than noodle sheets from Vista patent flour (44.5), indicating that with aging, wheat cultivar may influence noodle quality (Fig 1A, C). Because these two wheat samples were not grown on identical plot sites, the authors recognize that physical conditioning of the wheat may influence its subsequent milling performance and, as such, bran contamination. Both cultivars displayed a significant increase in specks/image when the noodle sheets were made from the higher ash straight-grade flours. Noodle specks for Karma increased >50%, (95.7) while for Vista they increased by a significant but lesser amount to 51.3 specks/image. This suggests differences between the two cultivars when using the straight-grade flours for noodle production, which is consistent with plant breeding evaluations.

As the measurement sensitivity was decreased (Δgray = 5, MS = 5), all samples displayed a decrease in the number of specks detected (Fig. 2). No cultivar difference was detected at 2 hr in *kansui* noodles from patent Karma and Vista flours with 6.9 and 4.9 specks/image, respectively. By 6 hr, a significant difference was observed in the speck count between Karma and Vista flours with 11.8 and 8.2 specks/image, respectively. This difference was increased by 24 hr to 37.5 and 19.1 specks/image, respectively. The *kansui* straight-grade noodle sheets from Karma and Vista flours were significantly different at 2 hr (12.6 specks/image and 8.1 specks/image, respectively), confirming that the poorer refined straight-grade flour may have been influenced by cultivar. This significant difference was maintained as the noodle sheets aged (Fig. 2).

A further reduction in measurement sensitivity (Δgray = 10, MS = 5) when only very dark specks were measured did not show any differences for *kansui* noodles prepared from patent flours for both Karma and Vista at any of the three time periods. Noodle sheets prepared from straight-grade Vista and Karma flours continued to display significant differences in the numbers of specks/image. At 2 hr, Vista had 2.4 specks/image compared with with Karma (5.1 specks/image). Aging for 24 hr enhanced this cultivar effect; Vista had only 4.8 specks/image detected versus 20.2 for Karma. Cultivar differences due to flour refinement continued to be reflected, even at this measurement sensitivity, as the number of specks detected in Karma straight-grade noodle sheets were significantly different from patent flour noodle sheets. Vista did not display a similar phenomena.

Salted Noodle Sheets

The most striking characteristic apparent when examining salted noodle sheets was the lower number of discolored specks detected. Salted noodle sheets had significantly fewer specks than those prepared with *kansui*, with the exception of noodle sheets made with Vista patent flour. With aging for 2 hr and at maximum measurement sensitivity (Δgray = 2, MS = 5), the noodle sheets prepared from straight-grade flours displayed only 42.3% (Vista) and 39.2% (Karma) of the total number of specks found in the corresponding *kansui* noodles.

At maximum sensitivity, the noodle sheets made from Karma patent flour displayed 6.1 specks/image at 2 hr while Vista had 7.4 specks/image. Similarly at 6 hr (9.3 vs. 8.3) or 24 hr (15.1 vs. 9.2), these values show no significant difference in speck formation between Karma and Vista in aging salted noodle sheets (Fig. 3A, C).

TABLE II
Influence of ΔGray Detection Parameter on Speck Count/Image

			Karma				Vista			
Time (hr)	ΔGray Level	Minimum Threshold Size	*Kansui* Patent	*Kansui* Straight-Grade	Salted Patent	Salted Straight-Grade	*Kansui* Patent	*Kansui* Straight-Grade	Salted Patent	Salted Straight-Grade
2	2	5	15.5	28.3	6.1	11.1	12.4	31.9	7.4	13.5
6	2	5	27.7	55.0	9.3	11.8	27.9	48.8	8.3	13.5
24	2	5	61.9	95.7	15.1	18.3	44.5	51.3	9.2	13.7
2	5	5	6.9	12.6	3.5	5.8	4.9	8.1	2.2	4.6
6	5	5	11.8	22.5	4.8	6.4	8.2	11.7	3.4	4.0
24	5	5	37.5	53.7	10.2	12.4	19.1	16.6	4.8	6.6
2	10	5	2.8	5.1	1.6	3.2	1.8	2.4	0.9	1.4
6	10	5	3.9	7.7	2.5	3.5	3.1	3.1	1.3	1.7
24	10	5	16.7	20.2	5.9	7.8	4.8	4.8	2.4	2.9

Noodle sheets made from straight-grade flours also showed no differences in speck numbers between the two cultivars at 2, 6, or 24 hr. Karma displayed 11.1 specks/image at 2 hr compared with 13.5 for Vista. Both cultivars remained relatively unchanged by 6 hr (11.8 and 13.5, respectively) and increased only minimally (18.3 vs. 13.7) by 24 hr (Fig. 3B, D). We noted that the number of specks detected in any of the four salted noodle sheets did not exceed 59.6% of those in the corresponding *kansui* noodle sheets at any of the time intervals. This confirms that speck development is directly related to noodle type, independent of varietal influence.

Although straight-grade noodle sheets displayed more specks than their patent counterparts at 2 hr, flour refinement did not significantly influence the number of specks detected in salted noodle sheets. This was maintained at 24 hr for both cultivars. Decreasing the measurement sensitivity (Δgray = 5 or 10) while maintaining a constant minimum threshold size (MS = 5) resulted in an ≈50% decrease in the number of specks detected in both the straight-grade and patent salted noodle sheets for both cultivars at each level (Table II).

Influence of Flour Refinement, Noodle Type, and Cultivar

At maximum measurement sensitivity (Δgray = 2, MS = 5), no cultivar or noodle type effects were detected within 2 hr for the patent flour noodle sheets speck size. Patent noodle speck size was restricted to a narrow range of 0.010–0.012 mm. Within a cultivar, no effect on speck size was detected on the basis of flour refinement. A significant difference was noted between Karma and Vista straight-grade flours, with Karma having larger specks for both salted and *kansui* noodles (Fig. 4). Karma specks for both noodle types were 0.013 mm, while Vista specks were 0.009 and 0.010 mm, respectively. For both cultivars, no difference was detected within the straight-grade flour speck size on the basis of noodle type.

Aging influenced speck size in all of the noodle sheets examined at the highest sensitivity. For both *kansui* and salted noodle sheets, regardless of the flour refinement or wheat cultivar, the 24-hr measurements (Δgray = 2, MS = 5) had the largest speck size. Salted noodle sheets of both patent and straight-grade Karma flour had significantly larger specks at 24 hr. This was not the case in *kansui* noodles. Salted noodle sheets of straight-grade Vista flour had a significantly larger speck size at 24 hr, however the patent flour showed no change in speck size with time. This suggests that the higher pH in the *kansui* noodles may be inactivating the enzyme PPO, thereby limiting the spread of discoloration over time. The higher speck count found in *kansui* noodle sheets may be due to the known phenolic autooxidation and discoloration that occurs in alkaline environments. Examination of the aging influence at lower sensitivity settings (Δgray = 5 or 10, MS = 5) showed no discernable aging pattern for noodle type or flour.

Effect of Flour Quality, Noodle Type, and Cultivar

Consumer preference for a noodle product is not only influenced by the number and size of visible specks but also by the contrast relative to the background matrix. The human eye and mind tend to exaggerate the size and darkness of a speck when there is a greater contrast to the background (Francis and Clydesdale 1975, Hutchings 1994). A standard method for assessing noodle color is to measure L^*, a^*, and b^* values with a colorimeter. These values reflect the noodle sheets' overall brightness, red, and yellow color components. They represent an average measurement determined over a large portion of the noodle. The color measurements for the different noodle sheets used in this study are listed in Table III. Image analysis offers the only means by which the actual darkness or density of the individual specks can be quantitated. The specks are measured on a gray level scale of 0–255; the higher the number, the lighter or brighter the speck. Because the speck is large enough to occupy several pixels, the mean darkness for each speck was calculated.

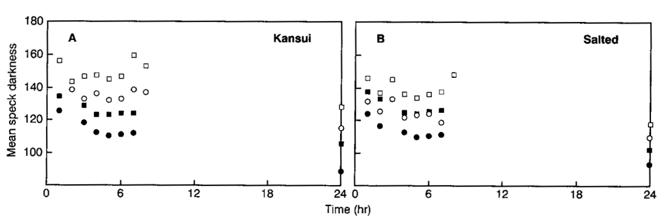

Fig. 5. Noodle speck mean darkness (n = 3) as a function of time and flour refinement for *kansui* noodle sheets (**A**) and salted noodle sheets (**B**). Karma patent flour (○); Karma straight-grade flour (●); Vista patent flour (□); Vista straight-grade flour (■).

Using maximum measurement sensitivity, the darkness of the individual specks was determined and averaged for each noodle at multiple time intervals (Fig. 5). At 2 hr, the lightest specks were found in the *kansui* noodles of Vista (141.9) and Karma (138.1) patent flours and were not significantly different. *Kansui* noodle patent flour specks were lighter than the corresponding salted noodle specks for each cultivar. Although no difference between Karma and Vista flours was found for *kansui* noodles, a significant difference was detected when comparing salted noodle sheets from Vista (138.3) and Karma (125.8) flours. Only for Karma was the difference between salted and *kansui* noodle speck darkness significant.

Noodle specks in either salted or *kansui* noodle sheets were darker for straight-grade flour than patent flour for both Vista and Karma. In salted noodle sheets, specks from Vista flour (130.8) were significantly lighter than those from Karma (116.1) flour.

It is a common practice for raw noodle sheets, particularly the alkaline *kansui* noodles where the high pH limits microbial action, to be stored for 24 hr or longer. Vista continued to display patent and straight-grade noodle specks lighter than Karma at 24 hr for both *kansui* and salted noodle sheets, although the differences were not statistically significant. Examination of flour quality showed that only Vista patent *kansui* noodle specks were significantly lighter than the straight-grade *kansui* or salted noodle specks.

Changing the Δgray parameter from 2 to either 5 or 10 to require greater contrast with the background matrix had minimal impact on discerning differences between the noodle specks. As seen previously (Hatcher et al 1999), the most noticeable effect was the anticipated darkening of detected specks. An example of

TABLE III
Color Analysis of Raw Asian Noodle Sheets Over Time[a]

	Vista			Karma		
	0 hr	2 hr	24 hr	0 hr	2 hr	24 hr
Kansui						
Patent						
L^*	87.47	83.60	78.70	86.32	82.19	76.93
a^*	–0.81	–0.82	–0.66	–0.49	–0.56	0.21
b^*	21.20	25.96	27.05	23.05	27.26	28.23
Straight-grade						
L^*	85.29	79.90	73.87	83.72	78.12	71.36
a^*	–0.84	–0.75	0.09	–0.40	–0.39	0.61
b^*	22.96	27.56	28.37	25.29	29.39	28.32
Salted						
Patent						
L^*	86.41	83.70	79.07	85.65	82.45	78.67
a^*	1.45	1.68	2.00	1.73	1.97	2.73
b^*	18.72	22.35	21.82	20.77	24.50	24.10
Straight-grade						
L^*	85.47	82.06	75.40	84.27	80.28	75.30
a^*	1.76	2.17	3.20	2.00	2.39	3.49
b^*	18.23	22.62	21.47	20.70	24.38	23.21

[a] Average standard deviation ± 0.44, 0.22, and 0.72 for L^*, a^*, and b^*, respectively.

this phenomena was observed in Vista straight-grade salted noodle specks that darkened from 130.8 (Δgray = 2) to 123.8 (Δgray = 5) and 111.6 (Δgray = 10).

Speck Darkness Distribution Profiles

While minimal differences were detected in mean speck darkness over time on the basis of cultivar, flour refinement, or noodle type, closer examination of the noodle specks on the basis of darkness distribution profiles highlighted key differences. Speck darkness can assume a value from 0 (black) to 255 (white), but for practical evaluation in this study a limit of 160 was used. The distribution profile of speck darkness was determined on the basis of eight divisions to ensure complete characterization of the specks over time. The distribution was divided equally into six divisions, on a 10 gray level unit basis, from 100 to 159. Two additional divisions, <100 and ≥160, were also included.

Mean density measurements of the noodle from Vista patent flour specks at 2 hr using maximum measurement sensitivity were not able to discern differences between *kansui* specks (mean darkness 141.9) and corresponding salted noodle specks (mean darkness 138.3). When these speck density profiles are compared (Fig. 6A, C), very distinct distributional differences were found. Analysis of the distribution profiles indicated that both noodle sheets had a similar distribution of light specks above the 130 gray level. The *kansui* specks had 94.6% above this level while the salted specks had 87.3%. This would account for the inability to distinguish the noodle sheets specks on the basis of average darkness. Closer examination, however, indicated that there were considerable differences within their respective speck darkness distribution profiles. The *kansui* patent Vista noodle had three separate speck distributions from 130 to 159 with 21.4% of the specks being extremely light, in the 150–159 range. The majority of its specks, 43.8%, lay within the 140–149 range, while 29.5% fell within the 130–139 range. The specks from the corresponding salted noodle sheets were mainly (68.7%) detected in the darker 130–139 range with <10% in either of the higher, lighter regions.

This skewed distribution at the 130–139 gray level would cause the consumer to rate the specks darker and larger in the salted noodle due to the contrast perception phenomena.

Mean speck density for salted noodle sheets of Vista straight-grade flour (130.8) was not significantly different from either *kansui* or salted patent flours. Analysis of the darkness distribution profile showed that only 62.1% of its specks were lighter than the 130 gray level, a reduction of 25% compared with the salted patent noodle sheets, and no specks fell within the brightest 150–159 division. The revealing character of the speck darkness distribution profile was evident for Vista straight-grade *kansui* specks. Although the mean speck darkness (128.6) was not significantly different from the salted samples (130.8), only 38.9% of its specks fell above the 130 gray level and entirely within the 130–139 range. The majority of specks (57.0%) were confined within the 120–129 division. These two divisions accounted for >95% of the specks within the *kansui* noodle. No other noodle displayed such a concentration of uniform specks.

For *kansui* noodle sheets of Karma patent flour, mean speck darkness (138.1) was similar to *kansui* or salted noodle sheets from Vista patent flour. Analysis of the distribution profile indicated that Karma *kansui* noodle specks were predominantly (74.6%) greater than the 130 level but well below the percentages of the corresponding patent Vista samples discussed previously (Fig. 6). For both Karma and Vista *kansui* patent noodle sheets, the major speck darkness distribution fell within the 140–149 division. The specks in Karma salted patent noodle sheets (mean darkness 125.8) displayed a much greater shift from their *kansui* counterpart in their distribution profiles than that observed in Vista. The percentage shift in Vista between kansui and salted patent flours represented a minimal 7.3% decrease in specks above 130. In the Karma salted patent noodle sheets, there was a dramatic decrease in the percentage (≈40%) of specks above the 130 level.

It was of particular interest to note that for noodle sheets of Karma straight-grade flour, kansui or salted, no specks were detected above the 130 level, while for similar noodle sheets of Vista, 38.9% of the specks were lighter than the 130 level. Thus visible specks are lighter for noodle sheets from Vista flour.

Analysis of the speck darkness distribution profiles at 6 hr indicated only minor changes in mean speck density for each sample with slight shifts in the distributional patterns.

Aging noodle sheets for 24 hr highlighted differences within cultivar samples due to flour refinement and noodle type as well as differences between cultivar samples (Fig. 7). Although no significant difference could be detected between the average darkness of specks in *kansui* noodle sheets of patent flour, 127.0 (Vista) and 115.2 (Karma), there were differences in the darkness profiles of their specks. Noodle sheets of Vista flour retained 36.8% of specks in the lighter region above the 130 gray level while no specks, 0%, were found in this region for noodle sheets of Karma flour.

Similar results were found for salted noodle sheets from patent flours. No significant difference in the average speck darkness was found between noodle sheets of the different cultivars (117.7 for Vista and 109.4 for Karma). Again, differences in speck profiles were evident. For noodle sheets of Karma flour, specks were predominantly (53.0%) located within the 100–109 range while for noodle sheets of Vista flour only a minimal portion (14.6%) of the

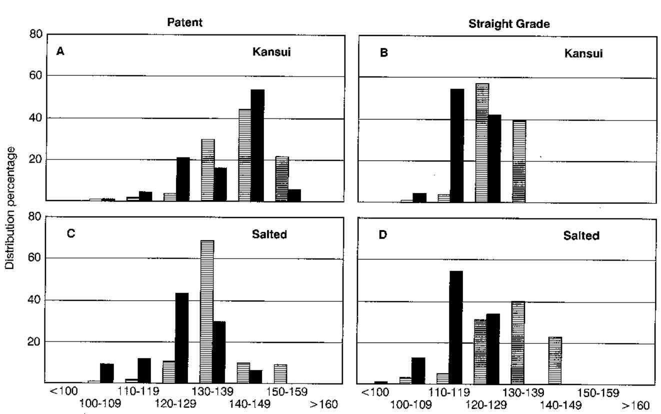

Fig. 6. Vista (shaded bars) and Karma (solid bars) noodle speck darkness profiles (n = 3) at 2 hr (Δgray level = 2, minimum detection threshold size = 5). **A,** *Kansui* patent noodle **B,** *kansui* straight-grade noodle; **C,** salted patent noodle; **D,** salted straight-grade noodle.

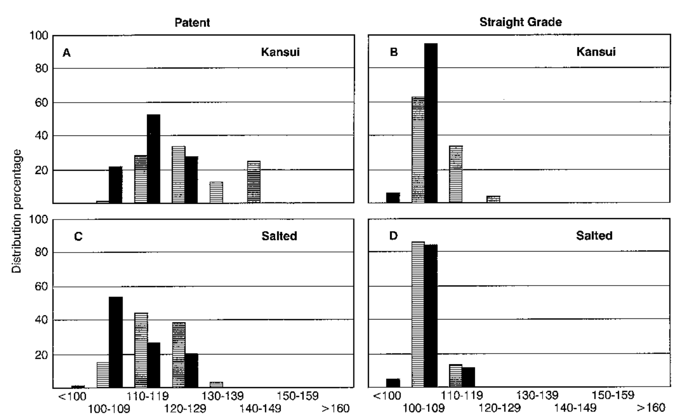

Fig. 7. Vista (shaded bars) and Karma (solid bars) noodle speck darkness profiles (n = 3) at 24 hr (Δgray level = 2, minimum detection threshold size = 5). **A,** *Kansui* patent noodle; **B,** *kansui* straight-grade noodle; **C,** salted patent noodle; **D,** salted straight-grade noodle.

specks were in this very dark region. This shows that for either noodle type, those made from Karma flour had specks that were always darker relative to the base noodle color than for those noodle sheets of Vista flour.

Differences between *kansui* and salted noodle specks were also evident after 24 hr of aging. Within *kansui* noodle sheets from patent Vista flours specks were distributed 36.8% above the lighter 130 gray level and only 1.1% in the dark 100–109 level. The corresponding aged salted noodle sheets had only 3.0% of the specks above the 130 level and 14.6% were in the 100–109 level. Noodle sheets from patent Karma flour had a similar pattern with specks in the salted noodle sheets tending to be much darker than those in the *kansui* noodle. While 53.0% of the specks fell within the 100–109 level for the salted noodle sheets, the majority of the specks in the corresponding *kansui* noodles (78.8%) were lighter than this.

Differences due to flour refinement were readily apparent after 24 hr. For either cultivar, all the specks were darker (<130) for straight-grade flours. The greatest differences in average speck darkness were observed within the *kansui* noodles. Differences between *kansui* noodle sheets of patent and straight-grade flours were 26.4 for Karma and 23.7 for Vista. In the salted noodle sheets, the differences were much smaller between the flours at 14.7 and 15.1, respectively.

The major distinguishing characteristic of the 24-hr straight-grade flour specks for either *kansui* or salted noodle sheets was the predominance of the specks in the 100–109 level. *Kansui* straight-grade noodle sheets of Vista flour had the lightest, with only 63.0% in this 100–109 level, while noodle sheets from the corresponding Karma flour had the maximum (94.3%).

As previously reported (Hatcher et al 1999), increasing the contrast between speck and noodle surface in the image analysis measurement system (Δgray = 2, 5, or 10) resulted in decreased speck detection and a shift in the darkness distribution profiles. The speck profile for *kansui* noodle sheets of patent Vista flour (Δgray = 2) shifted minimally from 94.6% above the 130 gray level to 84.3% (Δgray = 5), though a 60.6% larger shift (Δgray = 10) above 130 was observed at the highest contrast level. A similar pattern of changes was found for salted noodle sheets of straight-grade Karma flour. No light specks were found above the 130 gray level. The primary darkening shift was observed in the 100–109 level region. At 2 hr (Δgray = 2), this division accounted for only 12.1% of the specks, yet at Δgray = 5, it increased to 27.6% and at Δgray = 10, it was the predominant region accounting for 65.5% of the specks. Changing the contrast setting (Δgray) for measurement, although shifting the darkness distribution pattern, did not change nor diminish the cultivar or flour refinement differences previously observed.

CONCLUSIONS

The speck measurement method based on machine vision presented here is sufficiently sensitive to be capable of detecting differences in noodle appearance quality between *kansui* and white salted noodle sheets prepared from patent and straight-grade flour from samples of two CPSW cultivars. Differences were detected and quantitated in speck number and darkness distribution profiles within the CPSW class cultivars for both alkaline and fresh white salted noodle sheets. Changes in noodle appearance due to flour refinement were clearly detectable by image analysis. Although conventional colorimeters are an excellent means of evaluating noodle color, the key advantage of this method is its ability to characterize and quantitate the shifts in speck darkness profiles that best reflect critical consumer visual assessment of the product. The consistent measurement of noodle appearance in conjunction with the ability to analyze widely different noodle types prepared from flours of varying quality support the application of this technique in commercial noodle operations.

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