Image Analysis of Asian Noodle Appearance: Impact of Hexaploid Wheat with a Red Seed Coat

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ABSTRACT

Fresh alkaline (*kansui*) and white salted noodles (WSN) prepared from patent and straight-grade flour of the western Canadian wheat class Canadian Red Spring Wheat (CWRS) were visually characterizedby image analysis (IA) over a 24-hr period. In both *kansui* noodles, the number of spots increased over time, while minimal change was detected in the WSN prepared from either flour. Maximum spot generation was observed in the straight-grade *kansui* noodles, increasing from 53.1 spots per image at 1 hr to 76.2 by 7 hr before declining to 55.9 at 24 hr. Significant differences were detected in the number of detectable spots among the *kansui*, patent, and straight-grade noodles over the initial 7 hr, but by 24 hr no discernible differences were observed. Fewest noodle spots were observed in the patent WSN (10.1 spots per image at 1 hr rising to 13.3 at 24 hr). Hence, straight-grade flours yielded more spots than the matching patent flours, while WSN had consistently fewer spots relative to the *kansui* noodles at all time intervals. Minimal differences were detected in the average size of the spots due to noodle type or flour refinement, unlike the situation observed in white wheats investigated previously. Although discolored spots on the patent flour noodles were lighter than the straight-grade counterparts, no difference was observed on the basis of noodle type.

Noodle appearance is the first critical assessment of noodle quality made by a consumer and is based solely on subjective evaluation. Brightness and an absence of undesirable discoloration (spots) are essential to consumer acceptance of both raw alkaline and white salted noodles (WSN). For this reason, the majority of discerning Asian markets prefer noodle products made from high quality patent wheat flours producing bright noodles with minimal discoloration (Miskelly 1984; Miskelly and Moss 1985; Moss et al 1986; Toyokawa et al 1989a,b). The potential delay (≥24 hr) between the production and consumption of these noodles allows discoloration to occur. Discoloration, reduced brightness, and visual appeal are thought to involve the enzymes polyphenol oxidase (PPO) and 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 effect on noodle appearance, which directly influences acceptability to the consumer. Color measurement of noodle sheets using a colorimeter to determine chromaticity values (L^*, a^*, b^*) is a normal laboratory procedure for the determination of brightness and discoloration. This method does not provide a means of quantitating or characterizing the visual impact that discolored spots have on consumer perception of overall noodle appearance and, hence, value.

Previous work (Hatcher et al 1999, Hatcher and Symons 2000a,b) has shown that computer imaging can be used to assess noodles prepared from flours of differing refinement, cultivar, sprout damage, and noodle type by detecting, quantitating, and characterizing the formation of regions of undesirable color on or below the noodle surface over time. The previous findings were confined to the white seed coated Canadian Prairie Spring White (CPSW) wheat class. The objective of this study was to evaluate the appearance of fresh salted and alkaline noodles prepared from red seed coated wheat flours of differing refinement.

MATERIALS AND METHODS

Wheat, from the Canadian Western Red Spring (CWRS) class, was milled on the Grain Research Laboratory pilot mill (Multimax, Buhler AG, Uzwil, Switzerland) using a commercial flow (Fajardo 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 (Table I).

Analytical Methods

Protein content (%N × 5.7) was determined by combustion nitrogen analysis (CNA) (Leco model FP-248, Dumas CNA) calibrated with ethylenediaminetetraacetic acid (EDTA). Ash content, farinograph, moisture, and starch damage were determined by AACC Approved Methods 08-01, 54-21, and 44-15A, respectively (AACC 2000). Starch damage was determined using a starch damage assay kit (Megazyme, Wicklow, Ireland). Flour color was determined using a flour color grader (Simon Series IV, Satake UK, Stockport, UK) according to the Flour Testing Panel Method No. 007/4 (FMBRA 1991). The relative reflectance of the flour-water slurry is listed in Satake International units, where the lower the number the brighter the flour color.

Noodle Preparation

Noodles were prepared (Kruger et al 1994) on three separate days using *kansui* reagent (9:1 sodium and potassium carbonate) or sodium chloride dissolved in distilled water to yield a 1% (w/w) composition for a final water absorption of 32%.

The final noodle sheet was cut into two portions: one for spectrophotometric color measurements, the second for image analysis (IA) measurements.

Noodle Assessment

Noodle sheet color was measured in triplicate at two random locations with a spectrocolorimeter (Labscan II, HunterLab, Reston, VA) equipped with a D65 illuminant using the CIE 1976 L^*, a^*, and b^* color scale (Kruger et al 1994).

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 and Symons 2000a,b).

Individual noodle images were analyzed by in-house software developed in KS400 software (Carl Zeiss Vision, Hallbergmoos, Germany) using two imaging variables: Δgray and minimum threshold size (MS) (Hatcher et al 1999, Hatcher and Symons 2000a,b). ΔGray represents a threshold value of darkness by which a discolored spot must exceed the background for it to be identified.

Statistical Analysis

The samples were prepared and analyzed using a completely randomized design with three replicates for each flour and noodle type. All statistical analyses, analysis of variance, and frequency

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distributions were conducted using statistical software (vers. 6.12, SAS Institute, Cary, NC) All statements of significance are $P < 0.05$ unless otherwise stated.

RESULTS

Effect of Flour Refinement and Noodle Type on Spot Numbers

In the CWRS flour patent and straight-grade kansui noodle samples, the number of discolored spots detected increased over the initial 7-hr aging period (Fig. 1) at maximum sensitivity (Δgray = 2, MS = 5). At 1 hr, 53.1 spots per image were observed in the straight-grade flour noodles, which was significantly higher than the 34.8 spots per image detected in the corresponding *kansui* patent noodle. Aging for an additional hour resulted in no discernable change in the number of spots per image for either noodle flour (51.9 and 30.5, respectively). This initial slow increase in spot numbers was consistent with previous research (Hatcher and Symons 2000a), where no significant change was detected in *kansui* noodles prepared from the white seed coated Canadian Prairie Spring White (CPSW) class cultivars AC Karma and AC Vista over the same time period. Maximum spot generation for the CWRS flours was observed on aging the *kansui* noodles for 7 hr. The straight-grade *kansui* noodles displayed 76.2 spots per image and the *kansui* patent noodles displayed 60.0 spots per image.

Aging to 24 hr resulted in a decline from the maximum number of spots detected in the *kansui* noodles for both straight-grade and patent samples. In contrast, the number of spots per image for the white seed coated cultivars AC Karma and AC Vista patent flours increased significantly by 24 hr (Hatcher and Symons 2000a). Examination of L^*, at 2 and 24 hr (Table II) for both CWRS straight-grade and patent *kansui* noodles indicated a darkening in the overall noodle matrix, very similar to that observed previously for the two white seed coated cultivars; thus, there was no differential background effect between the samples. Furthermore, the AC Karma *kansui* straight-grade noodle also displayed a significant increase in the number of spots by the 24-hr reading although AC Vista was similar to the CWRS sample, with a slight decline in spot numbers as compared with the 7-hr reading.

TABLE I
Proximate Analysis of CWRS Flour Samples Used for Noodle Preparation

Flour Type	Patent	Straight Grade
Protein %	11.8	11.6
Ash %	0.40	0.49
Color	–3.7	–1.8
Starch damage %	6.0	6.3
PPO (nmol O_2/g/min)	nd[a]	31.8
Farinograph		
Absorption %	61.5	62.4
Developement (min)	3.50	3.75
Mixing time tolerance (BU)	25	30
Stability (min)	10.5	7.5

[a] Not detectable.

WSN prepared from either CWRS patent or straight-grade flours displayed no significant increase in the number of spots per image in either sample with aging (Fig. 1). The number of spots detected were significantly lower than the comparable *kansui* noodles. At 1 hr, the CWRS straight-grade WSN noodles had 17.7 spots per image, increasing minimally to 21.3 after 24 hr. The patent flour displayed 10.1 spots per image at 1 hr, 10.2 at 7 hr, and no significant difference (13.3) at 24 hr. No significant difference was detected in the number of spots detected in the CWRS patent or straight-grade WSN noodles with those previously studied for white (CPSW) cultivars.

As previously reported (Hatcher et al 1999; Hatcher and Symons 2000a,b) changing the sensitivity (Δgray = 2, 5, 10, or 15 gray levels) or altering the minimum size threshold limit for detection (MS = 5, 10, 15, or 20 pixels) decreased the number of spots detected in all of the noodles (data not shown) while maintaining the differences and relationships between treatments.

At maximum measurement sensitivity (Δgray = 2, MS = 5), flour refinement or noodle type minimally influenced the spot size within the CWRS patent or straight-grade flours. At 1 hr, no differences were detected in the patent or straight-grade *kansui* noodle spot sizes (0.0125 vs. 0.0123 mm^2, respectively). The straight-grade WSN noodle spots were not significantly different (0.0128 mm^2) from either of the previous samples, but the WSN patent noodle did display a significantly smaller spot size (0.0105 mm_2) than the other samples. This minimal discrimination was maintained at 2 hr, but no significant difference in spot size in any sample was detectable by 7 hr. Aging for 24 hr showed that only the WSN straight-grade noodle spots were significantly larger (0.0138 mm_2) than the others.

Effect of Flour Quality, Noodle Type, and Cultivar on Speck Darkness

The consumer's preference for a noodle product is not only influenced by the number and size of visible spots but also by the contrast relative to the background matrix. The human eye and mind tend

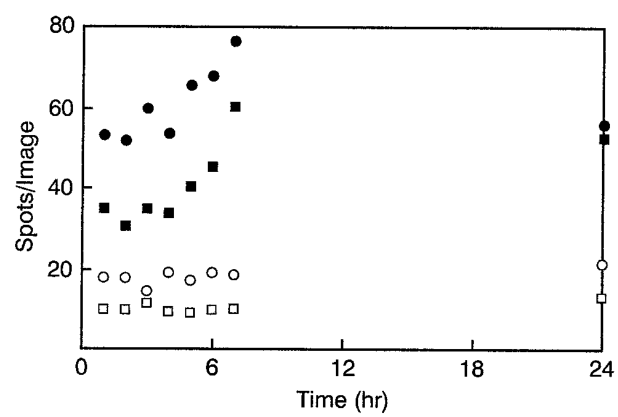

Fig. 1. Average number of spots per image ($n = 3$) detected in CWRS noodles over a 24-hr period (Δgray = 2, minimum threshold size [MS] = 5). Patent *kansui* noodle (■); straight grade *kansui* noodle (●); patent white salted noodle (□); straight grade white salted noodle (○).

TABLE II
Color Analysis of Raw CWRS Asian Noodles Over Time

	Patent			Straight Grade		
Color[a]	0 hr	2 hr	24 hr	0 hr	2 hr	24 hr
Kansui						
L^*	85.14	81.1	77.1	82.75	77.0	71.5
a^*	0.04	0.34	0.29	–0.29	0.40	0.89
b^*	22.83	29.8	30.2	25.75	31.5	30.9
White salted noodles						
L^*	84.75	81.2	77.2	83.78	80.1	74.4
a^*	2.37	2.83	2.71	2.58	3.05	3.65
b^*	21.02	25.6	25.9	21.40	25.7	25.8

[a] CIE color values (L^*, a^*, b^*). Average standard deviations: $L^* \pm 0.44$, $a^* \pm 0.22$, $b^* \pm 0.72$.

to exaggerate the size and darkness of a spot with increasing contrast to the background (Francis and Clydesdale 1975, Hutchings 1994). L^*, a^* and b^* values measured by a colorimeter represent an average measurement determined over a large portion of the noodle sheet. In this study (Table II), as previously (Hatcher and Symons 2000a), the noodle L^* declined rapidly over the first 2 hr with a slower decline thereafter. Comparison with the white wheats (AC Vista) indicated a significantly darker noodle for CWRS at all time intervals. This was not found for the AC Karma noodles.

Image analysis at present offers the only means by which the actual darkness or density of the individual spots can be quantitated. The spots are measured on a 0–255 gray level scale with the higher the number the lighter or brighter the spot. Because the spot is large enough to occupy several pixels, the mean darkness for each spot was calculated and hereafter simply referred to as darkness.

Using maximum sensitivity, the darkness of the individual spots was determined and averaged for each noodle at each time interval (Fig. 2). At 1 hr, the lightest spots were observed using the patent flour, although no differences were detected between the WSN noodles (135.3) and the *kansui* noodles (134.0). The straight-grade noodles were darker than their respective patent counterparts. The straight-grade WSN noodle spot mean darkness was 120.3, similar to that of the *kansui* spots (116.5). Aging for an additional hour resulted in a similar darkening in all noodle spots but did highlight the noticeable difference between red and white seed coat cultivars. The CWRS patent flour used in this study yielded *kansui* noodle spots with a mean darkness of 127.3 at 2 hr, which was significantly darker than either of the corresponding white seed coat cultivars AC Vista (141.9) or AC Karma (138.1) (Hatcher and Symons 2000a). Comparison of the corresponding WSN patent noodle spots (128.6) indicated that the CWRS noodles, while having significantly darker spots than the corresponding AC Vista (138.3) at 2 hr, were very similar to those previously reported for AC Karma (125.8) (Hatcher and Symons 2000a).

Examination of the 2-hr straight-grade noodles prepared from the CWRS flour indicated no differences in spot darkness for WSN (111.4) or *kansui* (109.6). These values support the concern over seed coat color effect on noodle appearance, as red seed coats are perceived by noodle manufacturers to produce darker spots than those from white coat cultivars. The white coated AC Vista *kansui* spots (130.8) were significantly lighter than the red seed coat CWRS sample, however the white coated AC Karma were not significantly brighter (116.1) (Hatcher and Symons 2000a). Thus, no clear evidence was found to suggest that noodle spots from red coated grains are always darker than those from all white seed coated cultivars.

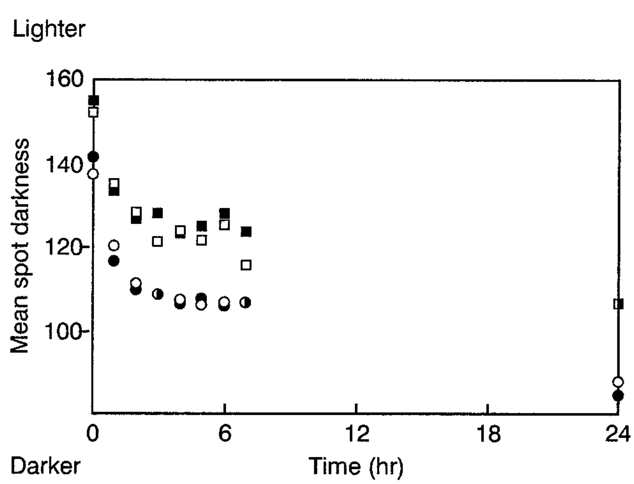

Fig. 2. CWRS noodle spot mean darkness (n = 3) as a function of time and flour refinement for *kansui* and salted noodles. Patent *kansui* noodle (■); straight grade *kansui* noodle (●); patent white salted noodle (□); straight grade white salted noodle (○).

Storage of the raw noodles for 24 hr before consumption is common for *kansui* noodles. Both the CWRS patent (106.6) and the straight-grade (84.6) *kansui* noodles displayed a very significant darkening in spot color by 24 hr and remained distinct from each other. This significant difference in *kansui* noodle spot darkness at 24 hr due to flour refinement was consistent with that observed for AC Vista and AC Karma. The CWRS patent *kansui* noodle spots were significantly darker than both AC Vista (127.7) and AC Karma (115.3) corresponding noodle spots.

No significant difference was detected between 24-hr CWRS WSN patent noodle spot darkness (106.8) or straight-grade (87.7) with corresponding *kansui* values. Although the aged CWRS WSN noodle spots showed significantly darker spots than AC Vista, no significant difference was detected in the comparable AC Karma spots, suggesting that apparent spot darkness is due to cultivar and not wheat type.

Previous research (Hatcher et al 1999, Hatcher and Symons 2000a) has shown the benefit of using spot darkness distribution profiles to highlight key differences due to noodle type, flour refinement, and varietal influence. The distribution profile of spot darkness was determined on the basis of eight divisions to ensure complete characterization of the spots over time and allow comparison with previous research. The distributions were divided equally into six divisions, on a 10 gray level unit basis from 100–159 with two additional divisions, <100 and >160 also being included.

Mean spot darkness measurements of CWRS patent flour were unable to discern any differences in spot darkness due to noodle type (128.6 WSN vs. 127.3 *kansui*) at 2 hr. However, when spot distribution profiles were compared (Fig. 3A), the CWRS WSN

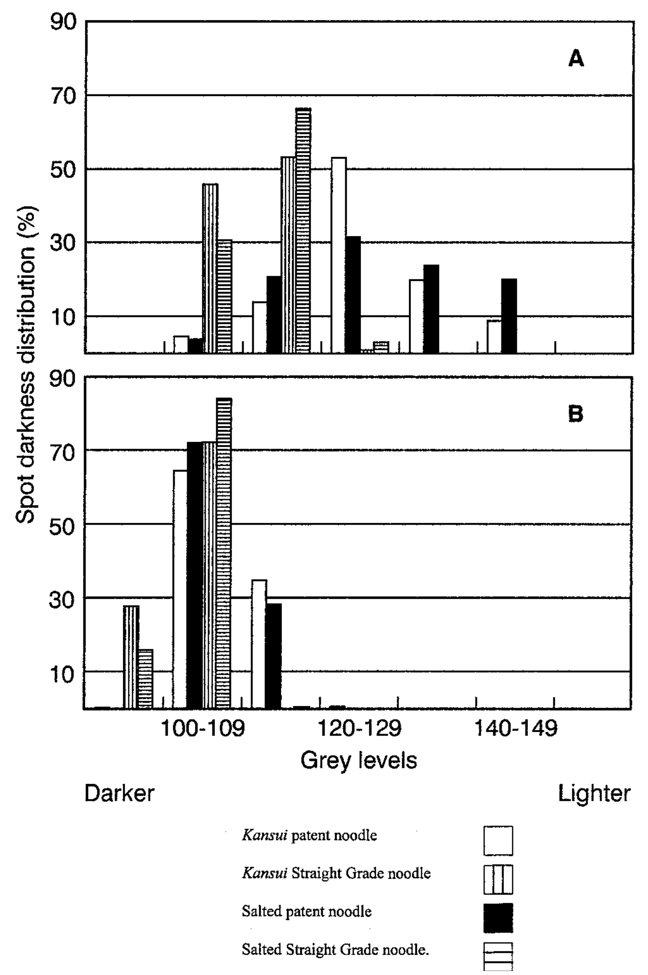

Fig. 3. Noodle spot darkness profiles (n = 2) (Δgray = 2, minimum threshold size [MS] = 5). **A,** 2 hr; **B,** 24 hr.

spots displayed 44.0% of spots in the light (>130) gray level, while the *kansui* noodle had only 28.7%. This difference in distribution profiles would cause the consumer to perceive differences between the noodle spots and rate the *kansui* noodle speckier and less desirable. Comparison with white seed coated AC Vista (Hatcher and Symons 2000a) highlights a major distributional shift as the corresponding patent noodles displayed 94.6% (*kansui*) of its spots above the 130 gray level and 87.3% for the WSN. It is of interest to note that, while AC Karma also displayed this significant distributional shift for patent *kansui* noodles (74.6% >130), analysis of its corresponding WSN noodles (34.8% >130) indicated it was comparable to the CWRS flour examined in this study.

In neither of the CWRS straight-grade noodle types at 2 hr were there any spots lighter than the 130 gray level and <3% (*kansui*) were found in the next lightest division (120–129). The corresponding AC Vista straight-grade noodles showed 38.9% (*kansui*) and 63.0% (WSN) above the 130 level, in contrast to AC Karma, which also did not have any spots above this level. The AC Karma straight-grade spots, however, did have a significant portion (41.6% *kansui* and 33.7% WSN) in the 120–129 division, reinforcing the differences in spot color due to seed coat at the earliest stage (2 hr).

Aging for 24 hr (Fig. 3B) increased the differences in noodle spot darkness distribution profiles due to flour refinement rather than noodle type. At 24 hr, the CWRS patent noodles had 34.8% (*kansui*) and 28.1% (WSN) in the 110–119 division, and no spots in the extremely dark (<100) region. The corresponding straight-grade noodles, however, had no spots within the 110–119 division or any of the lighter regions, but did have 27.8% (*kansui*) versus 15.8% (WSN) below the 100 gray level. Spots in the straight-grade flours were therefore darker than those in the patent flours of the same wheat and noodle type. In comparison, AC Vista straight-grade *kansui* noodles at 24 hr had 36.9% of spots above the 110 level, while the AC Karma remained similar to the CWRS flour with 0% above this level. Within the aged WSN straight-grade noodles, both AC Vista and AC Karma were similar (13.4 and 11.6% respectively) above the 110 gray level, validating the concern over red seed coated wheat in noodle production.

CONCLUSIONS

The IA-based noodle assessment method has sufficient sensitivity to detect differences in noodle appearance quality between cultivars within the same wheat class over time, regardless of noodle type or flour quality (Hatcher and Symons 2000a). It also provides valuable quantifiable data on differences due to seed coat color when wheats are milled under similar conditions. Spot number and darkness distribution profiles for both alkaline and fresh WSN noodles from patent and straight-grade CWRS wheat flours were compared with our previous results for two CPSW cultivars. Changes in noodle appearance due to flour refinement were consistent in both wheat classes. This method to characterize and quantify the shifts in spot darkness profiles emulates consumer visual discrimination of the product. Significant shifts in the distribution of spot darkness were detected based on flour refinement as well as seed coat color. The issue of cultivar influence was observed, indicating generalizations about seed coat color on spot darkness are cultivar-dependent. The ability of this technique to discriminate appearance and widely different noodle types prepared from flours of varying quality and wheat class support its application in commercial noodle quality control.

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