Influence of Sprout Damage on Oriental Noodle Appearance as Assessed by Image Analysis

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ABSTRACT

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Fresh alkaline (*kansui*) and white salted noodles prepared from sound and sprout damaged patent flours of the western Canadian wheat class Canadian Prairie Spring White (CPSW) cv. Vista were characterized by image analysis (IA). In all samples, the number of discolored spots increased with aging <24 hr (24 ± 1°C), although the number of spots per sample was significantly influenced by the degree of sprout damage. Alkaline *kansui* noodles made from severely sprouted wheat (Day 5) flours had the greatest number of spots per image at 1 hr (114) and increased to 256 spots per image by 7 hr. This represented an approximate fivefold greater number of spots as compared with the sound flour *kansui* noodle at 7hr. No further increase in spot numbers was detected in the severely sprouted sample with aging for 24 hr. Significantly fewer spots were observed in the white salted noodles (WSN) prepared from heavily sprouted wheat with 29 spots per image at 1 hr increasing to only 54.5 after 24 hr. The IA system was able to detect a significant difference in the size of the discolored spots over time due to sprout damage. The largest spot size was measured in the *kansui* noodles prepared from heavily sprouted wheat. All sprouted flours used to prepare both *kansui* and WSN had significantly larger spot sizes as compared with sound control flours. The mean darkness values for the noodle spots prepared from the heavily sprouted flours were significantly darker than the control flours for both WSN and *kansui* noodles. Spots of all noodles were characterized by darkness distribution profiles that highlighted key differences between noodle type and the degree of sprout damage. Addition of sodium metabisulfite to the *kansui* noodles at 1,000 ppm significantly decreased the number of spots formed, minimized the size, and lightened the spots over the first 7 hr, but they subsequently darkened after 24 hr.

Noodle appearance is the first critical judgment made by the consumer when evaluating noodle quality. Visual discrimination is based upon noodle color, brightness, and the impact of undesirable discoloration (spots). Asian consumers prefer noodle products to be 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). Few studies on the effect of sprout damage (Kruger 1994, Kruger et al 1995) have been conducted relative to the numerous references on quality assessment. Noodle color measurement, using a colorimeter and chromaticity values (L^*, a^*, b^*) are normally reported as an indication 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, hence, value.

It is not uncommon for raw noodles, especially alkaline-based, to be consumed up to 24 hr after production. Discoloration and reduced brightness occurring over this period reduce noodle visual appeal and is thought to involve the enzyme polyphenol oxidase (PPO) (Hatcher and Kruger 1993, 1996). PPO levels increased by >35 fold in wheat (Kruger 1976) with the onset of germination. Canadian Western Red Spring Wheat (CWRS) noodles showed minimal changes in noodle color using L^*, a^*, and b^* values (Kruger et al 1995), but no method was available to address the issue of undesirable discolored spots. Computer imaging has been used to assess the appearance of *kansui* and white salted noodles (WSN) by detecting, quantitating, and characterizing the formation of regions of undesirable color on or below the noodle surface over time (Hatcher et al 1999, Hatcher and Symons 2000). The objective of this study was to characterize and differentiate the visual appearance of two different types of noodles prepared from flours of increasing sprout damage, using the imaging method.

MATERIALS AND METHODS

Wheat grain, cv. AC Vista, from the Canadian Prairie Spring White (CPSW) class, developed for the Asian noodle market, was thoroughly mixed to ensure homogeneity and divided into five equal 2-kg samples with one as a control. Four samples were surface sterilized with a 1% hypochloride solution for 10 min, thoroughly rinsed for 10 min under running distilled water, drained, and immersed in a covered aerating steeping container. Each sample was allowed to steep for 16 hr at 20°C before being removed, rinsed with fresh distilled water, and transferred to sterile plastic containers fitted with moist, sterile germination pads. A sample of wheat after steeping was retained for analysis while the remaining three samples were placed in a sterile container, sealed with plastic wrap, and stored in the dark at 20°C. The kernels in the containers were kept moist by daily misting with water, and the samples were removed after one, three, and five days (D1, D3, D5) of germination. All samples were bench-top dried on blotter paper under a stream of continuously moving air until dried. Dried rootlets and broken seeds were removed by hand before each sample was milled (Black et al 1980). Individual streams were composited on the basis of increasing ash to yield a patent flour (60% flour yield). Characteristics of the flours used in this study are found in Table I.

Analytical Methods

Wheat falling number (FN) was determined according to AACC Approved Method 56-81B (AACC 2000). AACC Approved Method 22-07, modified as described previously (Kruger and Tipples 1981) was used to determine α-amylase activity. Flour protein content (%N × 5.7) was determined by combustion nitrogen analysis (CNA) (Leco model FP-248, Dumas CNA analyzer) calibrated with ethylenediaminetetraacetic acid (EDTA). Ash content and moisture were AACC Approved Methods 08-01 and 44-15A, respectively.

Noodle Preparation

Noodles were prepared on three separate days using the method previously described by Kruger et al (1994). *Kansui* reagent (9:1 sodium and potassium 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 for 5 min before 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 seven sheeting passes.

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The final noodle sheet was cut into three portions: one undergoing spectrophotometric color measurements, the second for textural analysis of cooked noodles, the third for image analysis measurements.

Noodle Color and Texture Measurements

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 (Kruger et al 1994). Noodle sheets were stored in sealed plastic bags at room temperature (24 ± 1°C) until timed readings. Measurements were made at 0 hr, then at 1-hr intervals to 7 hr and finally at 24 hr.

Noodles were optimally cooked, cooled for 1 min under running distilled water, drained, and stored for exactly 10 min at 25°C as described by Kruger et al (1994) before textural analysis.

Texture measurements were made on cooked noodles using a universal testing machine (IUTM model 4201, Instron, Canton, MA) with fixtures and procedures similar to those described by Oh et al (1983, 1985) and Kruger et al (1994). Analyses were made on five sets of three noodles and data was averaged for cooking replicates.

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).

Images were captured from six different areas on each noodle sheet using a grid positioning system that ensured 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 of the six images represented a 1.5- × 1.1-cm section of the noodle surface for a total of 9.9 cm^2. Measurements were made at 0 hr, then at 1-hr intervals to 7 hr and finally at 24 hr.

Individual images were analyzed by in-house software developed in KS400 software (Carl Zeiss Vision, Hallbergmoos, Germany). Each image before analysis was corrected for minor variations in the image capture system using the white background image captured daily (Hatcher et al 1999).

Statistical Analysis

Noodle samples were prepared using a completely randomized design incorporating three replicates. All statistical analyses, regression, analysis of variance, and frequency distributions were obtained using statistical software (vers. 6.11, SAS Institute, Cary, NC) All statements of significance are $P < 0.05$, unless otherwise stated.

RESULTS

Decreasing wheat FN values yielded flour with increased maltose values with a concurrent elevation in α-amylase activity (Table I). Protein level in the flour decreased significantly with sprouting, as did the corresponding ash levels. Decrease in protein content is important as it is positively correlated with noodle texture attributes (Miskelly and Moss 1985, Shelke et al 1990, Huang 1996).

Noodle Color

Raw alkaline noodles prepared with *kansui* ideally should be yellow in color and undergo minimal discoloration over time. This corresponds to high *L** (brightness) and *b** (yellowness) values using the colorimeter. Nonsprouted (control) noodles were equivalent in noodle brightness (*L** = 85.4) to those of the steeped samples (*L** = 84.07), and both were significantly brighter than the three sprouted samples (83.7–77.9) immediately (0 hr) after preparation (Fig. 1A). By 2 hr, each of the noodles prepared from the sprouted sample flours were significantly different from each other and displayed decreased brightness with increasing sprout damage. These differences were maintained through the 24-hr period examined.

The WSN displayed a similar pattern, although the significant difference detected between the control and steeped samples in the first 6 hr was lost by 7 hr. For all samples examined, the raw salted noodle brightness was significantly greater than the corresponding *kansui* noodle. As was the case for the *kansui* noodles, increasing sprout damage resulted in decreased brightness (*L**) at each time interval examined (Fig. 1B).

Addition of alkaline *kansui* causes the endogenous flavanoids within the flour to turn yellow. Immediately after sheeting, no significant difference was detected between the sound control noodle yellowness (*b** = 24.9), and either the steeped or D1 sprouted sample (Fig. 1C). This was due to increased variability among replicates caused by nonuniform hydration. The severely sprouted samples, D3 and D5, however, displayed an immediate significant reduction in *b** values (21.8 and 21.3, respectively) as compared with the sound flour. Aging for 1 hr allowed for full flavanoid yellow color development. Sprouting for as little as one day reduced noodle b* color (at 1 hr) development, causing the noodles to be significantly different from both the sound and steeped samples. No difference was observed between the sound and steeped sample in yellowness (*b**) over the entire 24-hr period, but each sprouted sample became and remained different from 4 hr onward.

An ideal WSN should have a pale creamy color. This is reflected in lower *b** values for the salted noodles in contrast to the yellow *kansui* noodles (Fig. 1D). It was of interest to note that the fresh raw salted noodles (0 hr) prepared with the severely sprouted samples, D3 and D5, displayed significantly yellower noodles (*b**) than the sound sample. However, by 2 hr, *b** had increased in the sound sample and was significantly higher than all but the steeped samples. This significant difference in *b** values was maintained between sound and sprouted samples for the 24-hr period examined. Significant reductions were observed in the raw salted noodle *b** values with increasing sprout damage at 24 hr for D1, D3, and D5 samples.

Discoloration on a noodle surface is most often seen as reddish-brown spots. These spots are formed through the reaction of labile

TABLE I
Proximate Analysis of AC Vista Flour Samples Used for Noodle Preparation[a]

			Duration of Sprouting		
Sample	Control	Steeped	1 Day	3 Day	5 Day
Falling number (sec)	385	220	70	60	60
α-Amylase[b]	3.5	22.5	269	5,270	50,267
Maltose value[c]	1.8	1.8	4.3	8.1	11.6
Protein %	10.1	10.1	9.7	9.5	9.0
Ash %	0.44	0.41	0.35	0.38	0.36
Moisture %	14.2	14.1	14.6	14.2	14.1

[a] 14% flour moisture basis.
[b] Maltose (mg) × 10^{-3}/g/min.
[c] Maltose (mg) /10 g/hr at 30°C.

quinones, phenolic oxidation products, with the free amines, and sulfhydryls of proteins (Pierpoint 1969). At 0 hr, examination of the red-green scale (a^*) of the *kansui* noodles indicated no color differentiation on the basis of sprouting. With the exception of the severely sprouted sample (D5), aging (Fig. 1E) shifted from green to red color development in the noodles slowly over the initial 7 hr. Only by 24 hr were the noodles significantly ranked according to the degree of sprout damage. The severely sprouted material (D5) had the maximum a^* value (3.28), while the sound control had an a^* value of only 0.00. The remaining samples displayed increasing a^* values with sprout damage within this range.

The influence of sprout damage on a^* values of salted noodles was not as clearly defined as all were significantly redder than the *kansui* noodles and displayed minimal change over the 24-hr period (Fig. 1F). Maximum a^* values were observed in the severely sprouted sample (D5) over each time period, but no discernible pattern was observed on the basis of sprouting in the remaining samples. Aging for 24 hr confirmed the significantly greater a^* value for the D5 sample. No difference was detected between sound, D3, or steeped noodles while the D1 noodle (Fig. 1F) was the least red sample.

Influence of Sprout Damage on Noodle Spot Numbers

Previous research (Hatcher et al 1999, Hatcher and Symons 2000) examined the number of detectable discolored spots observed in *kansui* and WSN made from other sound patent (60% extraction) and straight-grade CPSW Vista samples. Greatest discrimination was observed at a Δgray value of 2 with a minimum size (MS) threshold of five pixels.

In the current study, significant differences were observed between samples in the number of detectable spots (Δgray = 2, MS = 5) at the 1 hr reading, with a maximum of 114 spots per image for the severely sprouted (D5) *kansui* noodles compared with a minimum of 11 spots per image for the steeped sample (Fig. 2A). No statistical difference was detected between the sound (control) sample (26 spots per image) and the steeped sample. The number of spots in the severely sprouted samples, D3 and D5, increased rapidly as the noodle aged. There was no significant difference between the number of spots (D3 vs. D5) at any time interval. While D1 sprouted samples had a rate increase in spot appearance similar to the severely sprouted samples, it remained significantly different in terms of actual spot numbers. After 2 hr, the number of spots on the noodles prepared from sprouted wheat D1 became significantly higher than the control and steeped samples and remained separate from the all other samples for the remaining time periods.

Altering the detection sensitivity (Δgray), that is, requiring a greater difference between the background matrix and the discolored spots, resulted in a dramatic decline in the number of spots detected (Fig. 2B). Within the severely sprouted noodle (D5), the decrease in spots per image had a range of 113.6–8.5 spots per image at 1 hr to 265.3–35.6 spots per image at 7 hr as the Δgray level was increased from 2 to 20, respectively.

Increasing the minimum spot size threshold setting (5–20 pixels) allowed significant discrimination of sprout damage to be determined as early as 1 hr. Using the largest spot threshold size (MS = 20) the maximum number of spots (50 spots per image) were found in the severely sprouted *kansui* (D5) noodle, which was distinct from the D3 sample (39 spots per image). The D1 sample (10 spots per image) was distinct from all other samples. The control (5 spots per image) and steeped (3 spots per image) samples were not distinguishable from each other but remained distinct from all of the sprouted samples at this setting.

Examination of raw WSN over a 24-hr period, at maximum sensitivity (Δgray = 2, MS = 5), indicated a trend similar to the *kansui*

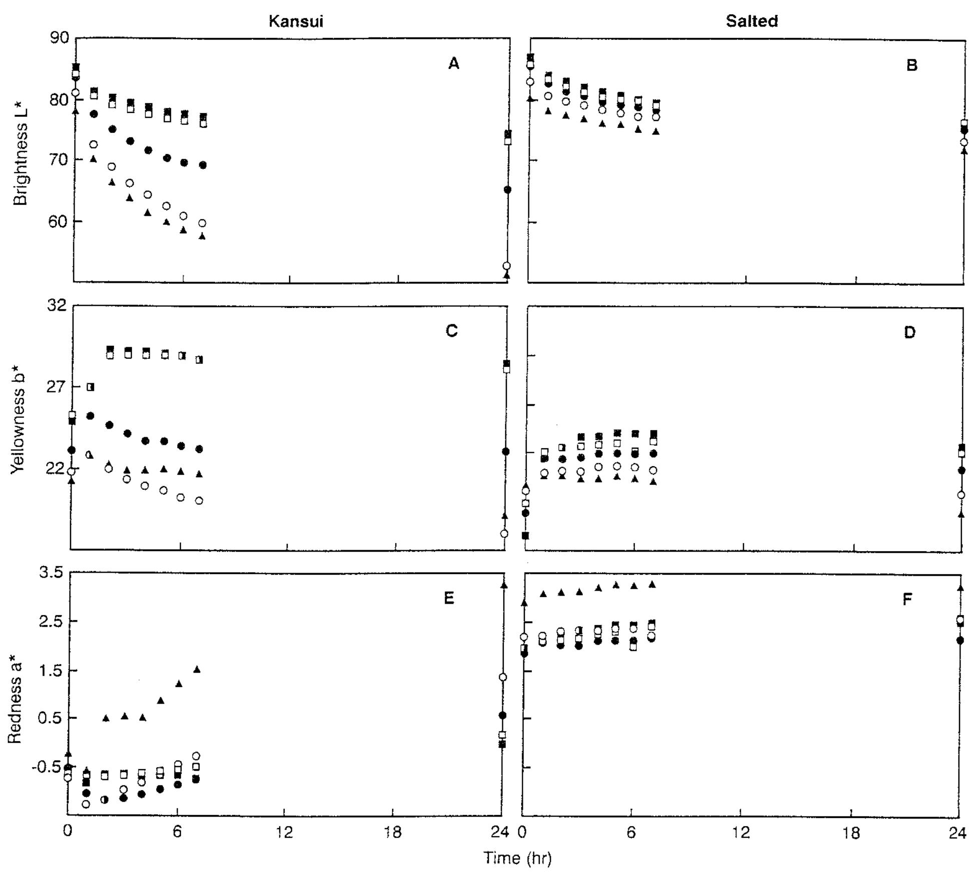

Fig. 1. Influence of aging on noodle development of chromaticity values (L^*, a^*, b^*). **1A,** *Kansui* noodle brightness (L^*); **1B,** salted noodle brightness (L^*); **1C,** *kansui* noodle yellowness (b^*); **1D,** salted noodle yellowness (b^*); **1E,** *kansui* noodle redness (a^*); **1F,** salted noodle redness (a^*). Control (■); steeped (□); sprouted day 1 (●); spouted day 3 (○); sprouted day 5 (▲).

noodles as marked differences in the number of spots per image due to sprout damage were evident (Fig. 3). At 1 hr, a significantly lower number of spots per image were observed in the WSN as compared with the *kansui* noodle counterparts, with the exception of the noodle prepared from the steeped wheat flour. These comparisons were consistent with previous observations (Hatcher and Symons 2000). After 1 hr, the WSN from severely sprouted wheat flour (D5) had the maximum number of spots per image (29), significantly higher than all other samples, which showed no significant difference. The D5 sprouted wheat flour noodle had significantly higher spots per image until 4 hr, at which time it was not distinguishable from the D3 sprouted sample. Aging for 24 hr showed three distinct segregations on the basis of noodle spots. Maximum spots were found with the D3 and D5 samples (59.0 and 54.5 spots per image, respectively) which, while indistinguishable from each other, were significantly higher than the D1 noodle (33.3 spots per image). The lowest number of spots were observed in the control (sound) salted noodle (16.6), which did not differ from the steeped sample (19.8 per spots per image).

Changing the detection sensitivity (Δgray) resulted in a dramatic decrease in detected spots for the salted noodles. This agreed with the results for the *kansui* noodles. At the maximum (Δ gray = 20), neither noodles prepared from the control, steeped, or D1 sprouted wheat flour noodles had more than one spot per image over the initial 7 hr. The number of spots per image in noodles prepared from sprouted wheat flour (D3 and D5) were significantly different from the other noodles, but no differentiation was detected between them over the entire 24-hr period at this setting (data not shown).

Influence of Sprout Damage on Spot Size

Previous examination of changes in spot size over time for both *kansui* and WSN using sound (sprout free) CPSW patent Vista or Karma flours, had indicated no change in size over 24 hr for either noodle type at sizes of 0.010–0.012 mm^2 (Hatcher and Symons 2000). The IA measurement of spot size of the sound (control) *kansui* and WSN flour noodles in this study (Fig. 4A,B) are consistent with previous findings. While no discernible difference was observed with the steeped samples for either noodle type, a very significant increase in spot size was detected in the severely sprouted D3 and D 5 samples over the 24-hr period. The D5 sample spots in the alkaline *kansui* noodles increased almost threefold, while the salted noodles displayed a twofold increase in size. In sprouted wheat, the increase in proteolytic enzymes associated with germination increased the supply of free amino acids and peptide chains. These undergo condensation reactions with the labile quinones, thus expanding the size of the discolored spots. Degradation by proteolytic enzymes is limited in sound wheat, limiting the reaction with quinones, and thus limiting spot size. Autooxidation of endogenous phenolics in the alkaline environment of the *kansui* noodles, forming larger numbers of reactive phenolic quinones, is the probable cause of the differences in size between *kansui* and salted noodles from the sprouted samples.

Influence of Sprout Damage on Spot Darkness

Unlike normal colorimeters, IA has the ability to analyze the noodle sheet, discern spots, and subsequently analyze each spot on a pixel-by-pixel basis. This provides an accurate assessment of spot darkness and is independent of the larger noodle matrix in which the spot is embedded. The darkness of the spot is of particular importance to consumers as it affects their visual perception of the product and, hence, its associated monetary value (Francis and Clydesdale 1975).

Darkness of the spots falls on a 0–255 gray level scale, with the lower the number, the darker the spot. Each discolored spot was broken into component pixels, and darkness was assigned on this gray level scale. An average darkness value was then calculated for each spot, and a mean value was calculated for each noodle sheet replicate. The mean darkness density reported summarizes the data of each sheet replicate and represents the average darkness density of the spots for a particular noodle type at a specific time interval (Fig. 5A,B).

At 1 hr and maximum sensitivity (Δgray = 2, MS = 5), the *kansui* noodles prepared from D5 sprouted wheat displayed the darkest spots (76.4), which were significantly darker than those of the D3 sample (107.0) (Fig. 5A). The lightest spots were observed in the steeped samples (129.6). Generally, the spots darkened significantly over the first 3–4 hr after which darkening slowed.

At 24 hr, maximum noodle spot darkness was observed in the D5 sample (26.7), becoming significantly lighter with decreasing sprout damage for D3 (55.6) and D1 (78.3). The noodles prepared from the control and steeped flour samples were not significantly different from each other (103.8 and 102.4, respectively), but were significantly lighter than the other samples.

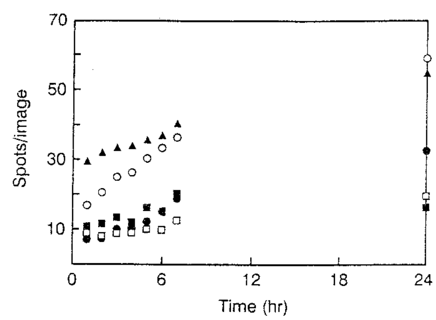

Fig. 3. Mean number (n = 3) of detectable spots per image at maximum image analysis sensitivity in raw white salted noodles prepared from sprout-damaged flour. Control (■); steeped (□); sprouted day 1 (●); spouted day 3 (○); sprouted day 5 (▲).

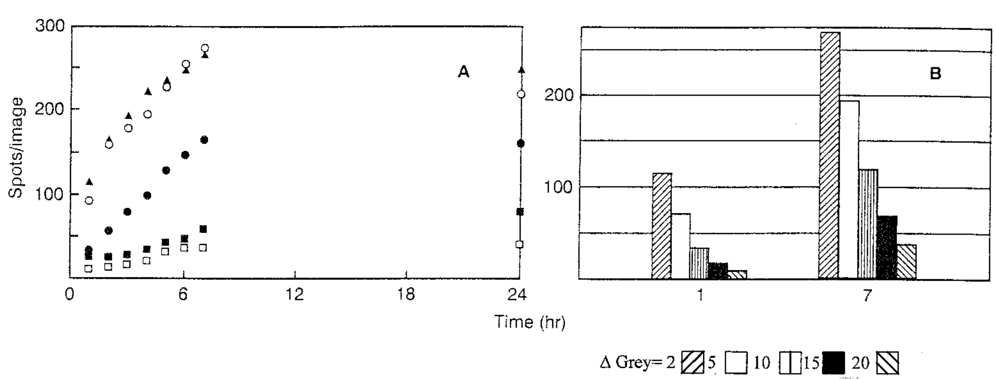

Fig. 2. A, Mean number (n = 3) of detectable spots per image at maximum image analysis sensitivity in *kansui* noodles prepared from sprout-damaged flour. Control (■); steeped (□); sprouted day 1 (●); spouted day 3 (○); sprouted day 5 (▲). **B,** Impact of changing sensitivity (Δgray) value on mean number (n = 3) of detectable spots per image in severely sprouted (day 5) *kansui* noodles at 1 and 7 hr.

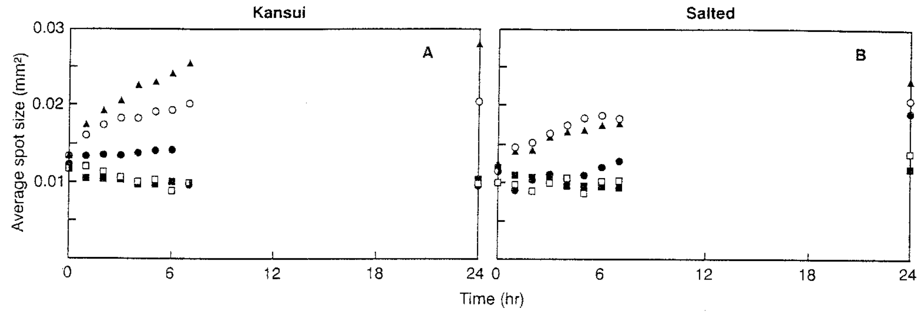

Fig. 4. Changes in mean value (n = 3) of discolored spot size over 24 hr using sprouted flour in *kansui* (**A**) and white salted noodles (**B**). Control (■); steeped (□); sprouted day 1 (●); spouted day 3 (○); sprouted day 5 (▲).

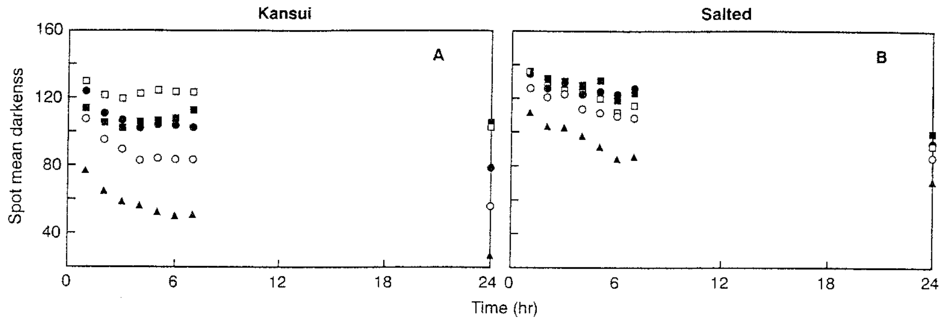

Fig. 5. Mean value (n = 2) of noodle spot darkness as a function of time and sprout damage (Δgray = 2 minimum size = 5) in *kansui* (**A**) and white salted noodles (**B**). Control (■); steeped (□); sprouted day 1 (●); spouted day 3 (○); sprouted day 5 (▲).

Examination of the raw WSN spots at 1 hr revealed that they were significantly lighter than comparable *kansui* noodles and had a smaller range in darkness (Fig. 5B). The severely sprouted (D5) WSN noodle sample continued to have the darkest spots (111.8), which were significantly darker than those of D3 (126.8). The lightest spots were detected in the control flour (136.0), but no discernible differences were found with those of the steeped (134.8) or D1 (134.5). Aging for 24 hr resulted in a general darkening of all sample spots, but unlike the *kansui* noodles the only significant difference was detected between the severely sprouted (D5) sample and the other samples. The lightest spots, found in the sound control flour (99.4) were comparable to the *kansui* noodles (103.8), while the darkest spots, D5 (70.5) were considerably lighter than the *kansui* noodles (26.7). The aged raw salted noodles displayed a range of only 28.9 gray level units between noodle spot darkness extremes, as compared with 77.1 for the *kansui* noodles.

The ability of our custom in-house image analysis software to provide a complete darkness density distribution profile of the discolored spots allowed further characterization of the differences due to sprout damage. Examination of the *kansui* noodle spots at 1 hr highlighted immediate differences between the samples due to sprout damage (Fig. 6A). The sound (control) noodle had 81.6% of the spots located in the lighter region (above the 110 gray level), while the corresponding D3 sample was reduced to 21.4% in the lighter region. The noodles prepared from the severely sprouted wheat (D5) had no spots this light, as all were below the 100 gray level.

Aging the *kansui* noodles for 7 hr resulted in further darkening of the discolored noodle spots (Fig. 6B). While the control (sound) flour noodles still maintained 73.5% of the spots in the lighter region (above 110) the profile distribution had darkened with the majority of spots (62.2%) found in the 110–119 range. A similar darkening was observed for the D3 sprouted sample, as all spots were darker than the 110 cutoff limit. The D5 sample displayed a further darkening of discolored spots. By 7 hr, the majority of the spots (87.8%) were located in the 50–59 gray level distribution range.

After 24 hr, significant differences were observed within the spot darkness profiles of the samples (Fig. 6C). The sound control *kansui* noodle spots were normally distributed, with 19.9% still above the 110 gray level, while the sprouted D3 samples were primarily (75.5%) located in the darker 50–59 division. In the severely sprouted (D5) samples, spots darkened significantly with 94.1% below the 50 gray level.

Examination of the darkness density distribution profiles of the raw salted noodles highlighted some key differences. The initial sound control noodle spots were lighter than the corresponding *kansui* noodles at 1 hr, with 98.4% above the 110 gray level (Fig. 7A). Unlike *kansui* spots, the majority (80.7%) were located in the lighter 130–139 region. The D3 salted noodle samples also displayed light spots with 98% above the 110 gray level, although unlike the control sample, the majority of the spots (57.4%) were located in the 120–129 region. The lighter salted noodle spots were also evident in the severely spouted (D5) sample, as 45.6% of the spots were above the 110 gray level 1 hr after production. As observed in the *kansui* noodles, aging for 7 hr significantly reduced salted noodle spot brightness (Fig. 7B), with only 82.2% of the sound control noodle spots at above the 110 gray level. A similar phenomena was observed for the D3 sample with 51.2% above this level and solely confined to the 110–119 range. Few (0.2%) of the severely sprouted (D5) WSN spots fell above the 110 level after 7 hr.

The lighter salted noodle spots, as compared with the *kansui* counterparts, remained consistent after 24 hr of aging (Fig. 7C). The sound salted noodle had spots at a gray level range of 70–119. These spots were generally lighter than the *kansui* counterparts, as 28.1% were located above the 110–119 gray level, although the greatest distribution was located in the 80–89 division (35.2%). The sprouted D3 sample had 50.6% of spots in the 80–89 division, while no spots were found above the 110 level. It was of particular interest to note that the severely sprouted D5 salted noodle sample showed a broader and lighter spot distribution profile than the corresponding *kansui* noodle. Unlike the *kansui* noodle where 94.1% of the spots were extremely dark (below the 50 gray level), only 0.2% of the salted spots fell within this range. A relatively broad and equal distribution was observed over the four divisions from 50–90 with the maximum (30.6%) being found in the 80–89 grouping.

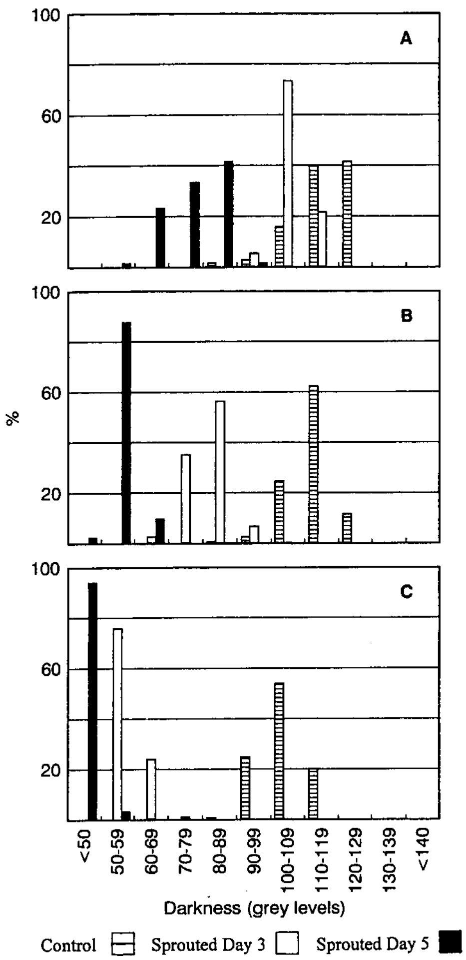

Fig. 6. AC Vista *kansui* noodle spot darkness profiles at 1 hr (**A**), 7 hr (**B**), and 24 hr (**C**).

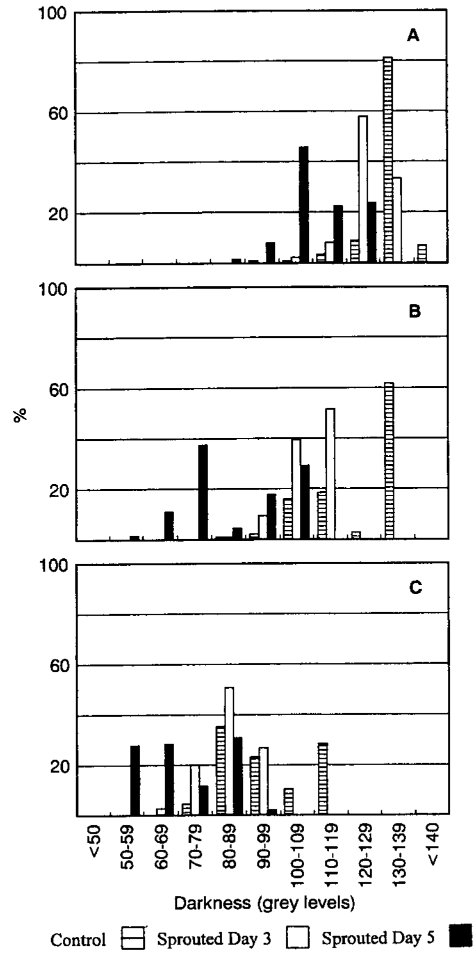

Fig. 7. AC Vista white salted noodle spot darkness profiles at 1 hr (**A**), 7 hr (**B**), and 24 hr (**C**).

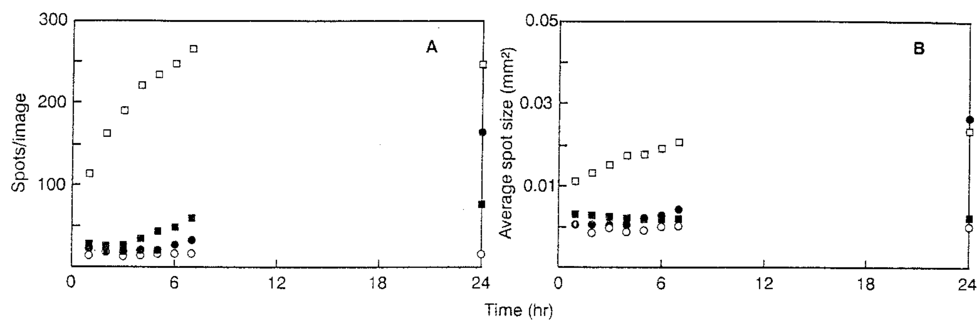

Fig. 8. A, Influence of inhibitor (1,000 ppm of sodium metabisulfite) on mean number (n = 2) of detectable spots per image in *kansui* noodles over 24 hr. **B,** Influence of inhibitor (1,000 ppm of sodium metabisulfite) on mean size (n = 2) of detectable spots per image in *kansui* noodles over 24 hr. Sound (■); sound + inhibitor (○); sprouted day 5 (□); sprouted day 5 + inhibitor (●).

These findings are of particular interest as previous research from this laboratory (Hatcher and Symons 2000) on sound patent flours had found that spots in WSN were darker than the *kansui* counterparts. Using sound AC Vista samples (Hatcher and Symons 2000), both *kansui* and salted noodles had <6% of spots below a 100 gray level after 24 hr. The current data, with >70% below the 100 gray level at 24 hr (Figs. 6C and 7C) was based on a AC Vista sample from another growing location and would suggest that there may be a significant environmental effects on spot darkness. McCallum and Walker (1990) found a significant environmental effect on enzyme activity which would be consistent with our findings. In the sprouted samples, the reason for this difference may be attributed to the abundance of simple sugars and free amino acids or small peptides present in the sprouted samples. The same cascading condensing reactions that resulted in the sprouted noodle spots increasing significantly in size over time and previously unobserved in sound noodle samples (Hatcher and Symons 2000) may be causing the *kansui* spots to darken more than the salted noodles. The results from this study for *kansui* and WSN does indicate that the sprouted wheat flour results in significantly darker spot generation.

Influence of Sodium Metabisulfite Addition

The problem with discoloration of fruits, vegetables, and other food products due to the presence of the enzyme polyphenol oxidase (PPO) has been well documented (Mayer and Harel 1991, Zawistoski et al 1991, Osuga et al 1994). One of the initial solutions to this problem was the incorporation of sulfite inhibitors as

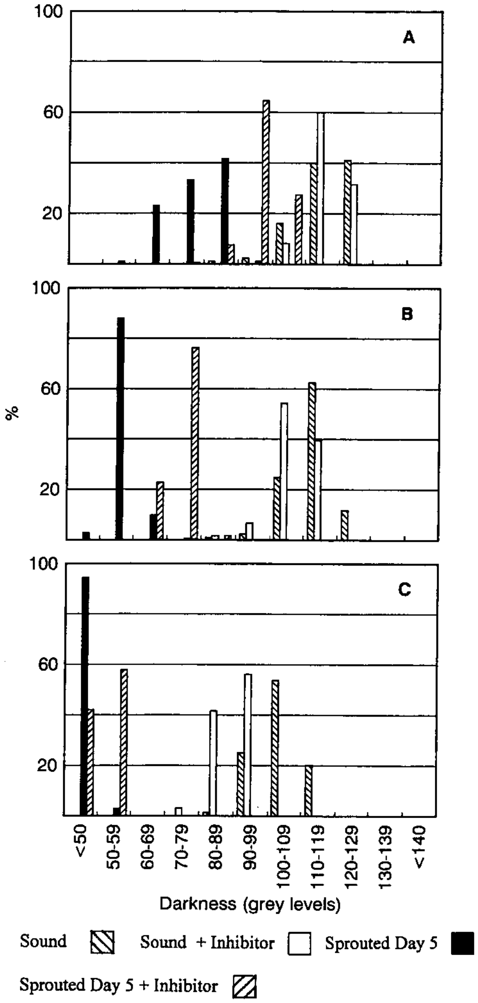

Fig. 9. Influence of inhibitor (1,000 ppm of sodium metabisulfite) on darkness profiles ($n = 2$) of detectable spots per image in *kansui* noodles over 24 hr.

either a wash or for direct incorporation into the food product to retard this form of discoloration (Lambrecht 1995). The use of sulfite has raised many health concerns (Taylor et al 1986) but it continues to be used within the industry.

Sodium metabisulfite was incorporated into the flours at a 1,000 ppm level in the preparation of *kansui* noodles. Even at the highest sensitivity, a dramatic decline in the number of spots per image detected was observed in the severely sprouted D5 sample over the first 7 hr (Fig. 8A). Aging for 24 hr resulted in a significant increase in the number of spots per image (170) but this was significantly lower than the inhibitor-free sample (248). The inhibitory influence of sodium metabisulfite was also observed on the sound flour where the inhibitor repressed the number of spots per image. By 6 hr, the number of spots was significantly lower than the sound, noninhibited flour whose spot number had increased with time. After 24 hr, there were only 18 spots per image in the inhibitor-sound *kansui* noodle as compared with 78 spots per image for the comparable sound flour alone.

Addition of the metabisulfite at the 1,000 ppm level also significantly influenced the size of the spots that formed over the 24-hr period examined. No difference was detected in the metabisulfite treated severely sprouted (D5) *kansui* noodle spot size with that of either the sound or the sound plus inhibitor noodles over the initial 7 hr (Fig. 8B). It was only after 24 hr that the influence of the inhibitor disappeared and size of the inhibitor-treated severely sprouted (D5) *kansui* noodle spots were significantly larger (0.0306 mm^2) from the sound noodle spots. No difference was detected in the average spot size for either treated or nontreated *kansui* sound noodles. Addition of the metabisulfite significantly influenced the darkness distribution profile of both the control and severely sprouted (D5) *kansui* noodle spots (Fig. 9A). A slight lightening of the control spots was observed as the portion of spots displaying above the 110 gray level increased from 81.6 (control) to 91.8% (control + metabisulfite) at 1 hr. A more dramatic and significant change was observed within the severely sprouted (D5) *kansui* noodle when treated with the inhibitor. The nontreated sample had no spots lighter than a 100 gray level and had only 1.3% of spots in the 90–99 gray level division at 1 hr. In the presence of 1,000 ppm metabisulfite, 27.1% of the spots were above the 100 gray level with a combined total of 91.4% above the 90 gray level at 1 hr.

Aging for 7 hr resulted in a detectable darkening of the control-inhibitor noodle spots, as only 39% remained above the 110 gray level, while the severely sprouted inhibitor-treated sample became significantly darker with 75.8% of spots falling within the 70–79 division (Fig. 9B).

Examination of the spots on the treated and nontreated sound (control) *kansui* noodles after 24 hr revealed no significant improvement in the darkness distribution as the metabisulfite noodles were actually slighter darker (Fig. 9C). The reason for this darkening in the sound control + inhibitor noodle is not understood at this time. Although the spots were extremely dark, a significant lightening effect was still observed with the metabisulfite on the severely sprouted *kansui* noodles (D5). The majority of the spots (57.8%) resided in the 50–59 gray level, whereas the nontreated noodles had 94.1% below the 50 gray level.

CONCLUSIONS

Image analysis is an effective tool for characterizing the changes in noodle appearance due to sprout damage over time. Significant differences due to sprout damage were detected and quantitated in both *kansui* and WSN in terms of spot number, size, and darkness profiles. The addition of the PPO inhibitor sodium metabisulfite (1,000 ppm) was effective in reducing discolored spot number, size, and darkness. The IA system was able to characterize and quantitate the influence of the inhibitor, particularly on the severely sprouted flour samples over time. This study supports the application of the IA technique for commercial noodle production.

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