



Noodle-making quality from Australian standard white wheat and Montana wheat and barleys
by Xianzhong Han

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Agronomy

Montana State University

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Abstract:

The influence of machining on the color of Chinese noodle dough was examined in this study. When sheets of noodle dough were prepared, it was noted that the L* (lightness/darkness) value and the b* (yellow/blue) chromaticity value were different for the top and bottom of the dough sheets. When the doughs were subsequently passed through the rolls of the noodle machine, the L* and b* values increased after each passage for at least 3 hr after the doughs were made. Interestingly, if identical dough sheets were compared, the dough sheets which passed through the reduction rolls at 1, 2 and 3 hr respectively after initial preparation maintained higher L* and b* color value over dough sheets which were passed through the reduction rolls after initial preparation and stored.

In the first part of study, we compared the color changes in response to machining using Australian Standard White wheat and Nuwest, a Montana hard white winter wheat.

In the second part of the study, Nuwest, a Montana hard white wheat was compared to Australian Standard White (ASW) wheat for Asian noodle and breadmaking quality parameters. Noodles made from these two wheats were stored under environmental conditions similar to the climatic conditions found in South East Asia. The color and texture of the noodles were monitored for a period of 96 h. Nuwest produced noodles which were equal to or superior to those produced from ASW. Nuwest and ASW also had similar breadmaking quality.

In the third part of the study, four Montana barleys, Merlin, Glacier, high amylose Glacier, and high amylose hull-less Glacier were added into two wheat flours, Nuwest and ASW. This study showed that incorporation of barley flours into noodles increased the insoluble fiber, soluble fiber, insoluble P-glucan and soluble β -glucan content of the product but resulted in an undesirable color change.

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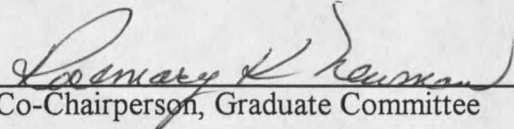
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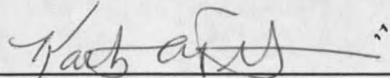
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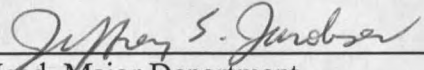

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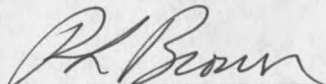
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ABSTRACT

The influence of machining on the color of Chinese noodle dough was examined in this study. When sheets of noodle dough were prepared, it was noted that the L* (lightness/darkness) value and the b* (yellow/blue) chromaticity value were different for the top and bottom of the dough sheets. When the doughs were subsequently passed through the rolls of the noodle machine, the L* and b* values increased after each passage for at least 3 hr after the doughs were made. Interestingly, if identical dough sheets were compared, the dough sheets which passed through the reduction rolls at 1, 2 and 3 hr respectively after initial preparation maintained higher L* and b* color value over dough sheets which were passed through the reduction rolls after initial preparation and stored. In the first part of study, we compared the color changes in response to machining using Australian Standard White wheat and Nuwest, a Montana hard white winter wheat.

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CHAPTER 1

LITERATURE REVIEW

Introduction

Noodles originated in China and are still a popular food throughout Asia. Fifty percent of wheat consumed in Asia is in the form of noodle products which may vary in their ingredients, degree of cooking before sale, and degree of drying (Hoseney, 1992). They may be white (Japanese type) or light yellow (Chinese type). Chinese noodles are commonly consumed in South-East Asia and Japan. The essential ingredients of Chinese noodles are flour, water and alkaline salts called Kansui. Kansui can be sodium or potassium carbonate or bicarbonate - or even sodium hydroxide (Moss et al., 1986). Kansui raises the pH of the raw noodles to between 9 and 11 and is responsible for the yellow color of Chinese noodles which develops under alkaline condition. Kansui confers a unique characteristic of Chinese noodles.

Noodle Color

Carotenoids and flavonoids are two types of pigments in wheat flour which are related to the yellow color of Chinese noodles. Carotenoid pigments are found in the endosperm and give flour its creamy-yellow color. These pigments can be bleached rather easily and are destroyed by bleaching agents added to flour. Flavonoid pigments, which come mostly from bran contamination of flour, are not bleached by the normal bleaching agents. The flavonoids are relatively stable and are colorless at acidic pH but give a yellow color at high pH. Alkaline solutions detach flavones from the polysaccharides, allow the yellow color to become manifest (Hoseney, 1992). Different formulations of Kansui affect noodle brightness and yellowness. Using sodium hydroxide instead of potassium carbonate or sodium carbonate produced substantially increases yellowness in noodle sheets (Kruger et al., 1992).

Darkening of the noodles during storage is mainly caused by polyphenoloxidase located largely in bran (Kruger et al., 1992). Tyrosinase is involved in the oxidation of phenols to quinones which are subsequently converted to dark colored melanins by polymerization and interaction with protein. Tyrosinase activity is found to be an inherited characteristic (Miskelly, 1984). Enzymatic browning in noodles increases with increasing extraction rate of flour, presumably since bran particles contain a high concentration of oxidative enzymes, phenolics, and pigments (Oh et al., 1985a).

Flour protein content is strongly associated with color. Moss (1971) found that

brightness was inversely proportional to flour protein content. As protein content increases, the color become less attractive. Discoloration is associated with gluten washed from the samples (Miskelly and Moss, 1985).

Miskelly (1984) found the brightness and yellowness of the noodle sheet was highly correlated with milling yield. The yellowness of the noodle sheets increases while the brightness of the noodle sheets decreases with increased yield. An increased flour extraction rate results in a higher level of germ, and hence more flavone compounds are available for reaction with Kansui to produce more yellowness; the decrease in brightness of the product is due to discoloration from bran and other components high in minerals. The granularity may also influence the color of dry flour; a flour with finer particle size is brighter and whiter.

Hunter $L^*a^*b^*$ color values have been used to measure noodle color. In the $L^*a^*b^*$ color space, L^* indicate brightness and a^* and b^* are the chromaticity coordinates. The a^* value is a measure of red (+a)/green (-a) and b^* value is a measure of yellow (+b)/blue (-b). In general, L^* and b^* values are inversely related (Miskelly, 1984). L^* values should be as close to 100 as possible. The higher the value, the brighter the noodle. b^* values must be approximately 30 or above and a^* values should be as close to 0 as possible for acceptable noodle color.

Noodle Texture

Wide variations exist in the type of noodle preferred by different people. In China and Korea, noodles with a "chewing" texture are preferred. In Japan, a soft texture is desired. The eating quality of cooked noodles depends largely on their firmness, resilience, and surface characteristics besides flavor (Oh et al., 1985b).

Protein quantity and quality are important in noodle making. A high levels (10-14%) of strong protein produce noodles with a chewy, elastic texture. Flours with a low protein content give noodles with poor cooking tolerance and the noodles are mushy and sticky when overcooked (Hoseney, 1992). Strong flours (those with high resistance and extensibility in the extensograph) give firmer and more elastic noodles than do weaker flours, in fact, no flour with protein content below 9.5% gives noodles of satisfactory eating quality (Miskelly and Moss, 1985). Increases in flour protein levels and strengths from different classes of wheat are accompanied by increases in the values of textural properties of the cooked noodles. Flour protein might produce a tight noodle structure resulting from a strong adherence between starch and protein. Such a tight structure might cause uncooked noodles to appear translucent, resulting in less reflected light in high-protein noodles. The tight structure of a high protein noodle retards moisture penetration into its core during cooking, so the cooking time of hard wheat noodles increases linearly with protein content.

Starch is the predominant component in flour. It changes from the raw granular

form to the gelatinized form during cooking (Hoseney, 1992). Oda et al. (1980) found that the amylose level in wheat starch from 13 commercial flours was negatively correlated with the eating quality of noodles. Miskelly and Moss (1985) prepared noodles from over 150 wheat flours from all over Australia, and the eating quality of the Chinese noodles was correlated with starch that showed a low pasting consistency. Crosbie (1991) isolated starch from 13 flours milled from Australian wheats that varied in quality for the production of Japanese salt noodles and found positive correlations between starch swelling power (at 92.5 °C), peak viscosity in the amylograph, and the overall texture score of the cooked noodles.

Enzymes also influence the quality of noodles. Excessive amounts of α -amylase in flour cause rapid breakdown of the noodle structure (Hoseney, 1992).

Alkaline salts toughen the dough and affect pasting properties (Terada et al., 1981). Enzyme activity such as enzymatic darkening is inhibited under alkaline conditions. Alkaline treatments also cause isomerization of amino acids, desulfuration of cysteine and a decline in the biological availability of lysine and dehydroalanine.

Resting dough before sheeting is known to improve dough sheeting properties by allowing uniform moisture distribution and mellowing of wheat gluten. Increasing resting time increases surface firmness (Oh et al., 1985b). The speed of the noodle machine rolls also affects the firmness of the dough. The surface firmness of noodles increases as the roll speed decreases or as reduction percentage increases at a constant roll speed (Oh et al.,

1985c).

Water absorption also influences the characteristics of a noodle dough. Too much water results in a sticky dough that stretches excessively during handling, but too little water results in a stiff dough that resists sheeting (Oh et al., 1986).

Cooked noodle textural properties are not affected greatly by different flour refinements. The relative ranking of wheats in terms of raw noodle color or cooked noodle texture is mainly independent of flour refinement (Kruger et al., 1994).

Several instruments have been used to measure noodle texture, including the General Foods Texturometer (Chang and Lee 1974, Cheigh et al., 1976), Autograph S-100 (Lii and Chang 1981), Texturecorder (Nielson et al., 1980), Viscoelasticity Meter (Okada 1971), and Instron Universal Testing Instrument (Oh et al., 1983).

Objectives

The objectives of this study were to: (I) identify machining influences on the color changes in noodle dough sheets, (ii) determine the suitability of the Montana hard white winter wheat, Nuwest, for noodle-making, (iii) establish a Chinese noodle standard from Australian Standard White wheat which is well recognized in the Asian market, and (iv) incorporate Montana barley flours into noodle-products and identify the potential value added nutritional benefits of these products.

CHAPTER 2

THE EFFECTS OF MACHINING ON COLOR CHANGES IN CHINESE NOODLE
DOUGHIntroduction

Color is one of the most important considerations in the assessment of the quality of Chinese noodles. The final product may be raw, lightly boiled and coated with oil, dried, steamed and fried or steamed and dried. However, when various flours for noodlemaking quality are evaluated, the color of the uncooked noodle dough provides the critical predictive factors (Kruger et al., 1992). Most consumers prefer a clear, pale, yellow product free from specks and discoloration (Shelke et al., 1990). Hunter Lab color values have been used to evaluate noodle color characteristics, with high L^* (brightness) and b^* (yellowness) values being desirable (Kruger et al., 1992, Miskelly, 1984). Chinese noodles depend on the development of the natural yellowness of the flavones under alkaline conditions for their final color (Miskelly and Moss, 1985). Noodles prepared by a variety of different methods have been shown to decrease in brightness (L^* values) over time and increase in yellowness (b^* values) rapidly during the first half hour after processing. Subsequently the L^* and b^* values changed at a much slower rate (Kruger et al., 1992). Changes in noodle dough color are caused by a variety of factors. The large

shift in the total reflectance spectrum during the first hour of dough resting is quite different from that in the later period and may be indicative of factors such as changes in water distribution that alter the surface characteristics of the dough (Kruger et al., 1992). Tyrosinase, located in the bran layer of the wheat, may affect noodle dough color as it may become involved in the oxidation of phenols to quinones which are subsequently converted to dark colored melanins by polymerization and interaction with protein (Miskelly, 1984). Polyphenol oxidase (PPO) has also been implicated in undesirable color changes in noodles (Kruger et al., 1992). As the PPO activity increases, the rate of change in brightness (L^*) values and yellowness (b^*) values increases. The brightness and yellowness values of dried Chinese noodles have been shown to be governed by protein content, cultivar and environmental conditions affecting the wheat from which the noodles were produced (Moss, 1971). The brightness (L^*) values of noodles have been shown to decrease as the flour protein content increased (Miskelly, 1985). Brightness (L^*) and yellowness (b^*) values decrease with increasing flour refinement since PPO is located predominantly in the bran, and high-extraction milling exacerbates this time-dependent browning (Hatcher and Kruger, 1993, Kruger et al., 1994). Starch may also influence the color of noodle products. Color differences between noodle doughs produced from several wheat varieties are highly correlated with differences in starch characteristics (as measured by gelatinization, differential scanning calorimetry, or amylose-amylopectin parameters) (Baik et al., 1995).

The objective of this study was to investigate machining influences on the color of noodle dough. L^* and b^* values change greatly during the first hour after processing, but these changes may not be simply a result of enzymatic activity. In this study, the effects of re-machining the doughs after various periods of resting time were examined to determine the physical effects of machining the dough on color attributes.

Materials and Methods

Materials

'Nuwest', (reg. no. CV-812, PI 586806), a hard white winter wheat (*Triticum aestivum* L.) cultivar, was developed and released by the Montana Agricultural Experiment Station in 1994 (Bruckner et al., 1996). Nuwest was kindly provided by Dr. Biggerstaff, Western Plant Breeders Inc., Bozeman, MT. Australian Standard White (ASW) was kindly provided by M. Kruk, Wheat Marketing Center, Inc. Portland, OR.

Noodle Preparation

During all procedures, laboratory conditions were maintained at 25°C and 50% relative humidity. Flour (300g) was pre-mixed at a low speed in a Hobart mixer for 1 min, the mixing speed was then increased to medium and a solution containing 3 g sodium chloride, 3 g sodium carbonate and 114 ml distilled water was poured into the flour within a 20 to 30 second period of time. Mixing continued for a total mixing time of 5 min. The

dough was rested in a plastic bag for 10 min. After resting, the dough was folded lengthwise and passed through a noodle machine (Otake Mfg. Co. Ltd., Tokyo, Japan) six times at a gap size of 8 mm (compression series). The temperature of the noodle machine rolls was maintained at 30°C. The dough was rested in a plastic bag for 10 min, and then passed through the gradual reduction series until a final dough thickness of 1.6 mm was achieved. Noodle dough sheets were stored in sealed bags at 85% relative humidity and 30°C throughout the color analyses.

Dough Color Analyses

The doughs were cut into circular pieces (6 cm in diameter) and color values were measured by the Minolta CR-310 Chroma Meter using the L*a*b* color system.

Statistical Analyses

All the doughs were repeated three times and each dough was measured twice at different point. Color measurements of noodle doughs are the averages of 6 individual determinations. Data were analyzed by analysis of variance using the General Linear Model Procedure (SAS, 1986). The error bars in the graphs show the standard deviation.

Results and Discussion

Machining Influences on Dough Surface Color Values

The differences in the color of the two surfaces of the dough sheets made from Australian Standard White (ASW) and Nuwest are reported in Figs. 1 and 2 with "top" and "bottom" referring to the orientation of the dough surfaces as the dough sheet emerges from the noodle machine. Initially, the top surfaces of the doughs had higher L^* values than the bottom surfaces, while the bottom surfaces of the doughs had higher b^* values than the top surfaces. The differences in the L^* and b^* values diminished during the first hr, and after the first hr of resting, the L^* and b^* values for the top and bottom surfaces were similar. It is likely that the initial differences were caused by uneven force angles exerted on the two surfaces of the dough from the rolls of the noodle machine. These differences allowed for uneven distribution of water on the two surfaces of the dough (Oh et al., 1986). It is also possible that differences in the temperatures of the atmosphere (25°C) and the noodle machine rolls (30°C) affected the distribution of water on the surfaces of the doughs.

Influence of the Number of Times Dough Passes through Machine Rolls on Color Values

The number of times a dough was passed through the noodle machine rolls had a great effect on the color of the doughs made from both ASW and Nuwest (Figs. 3 and 4).

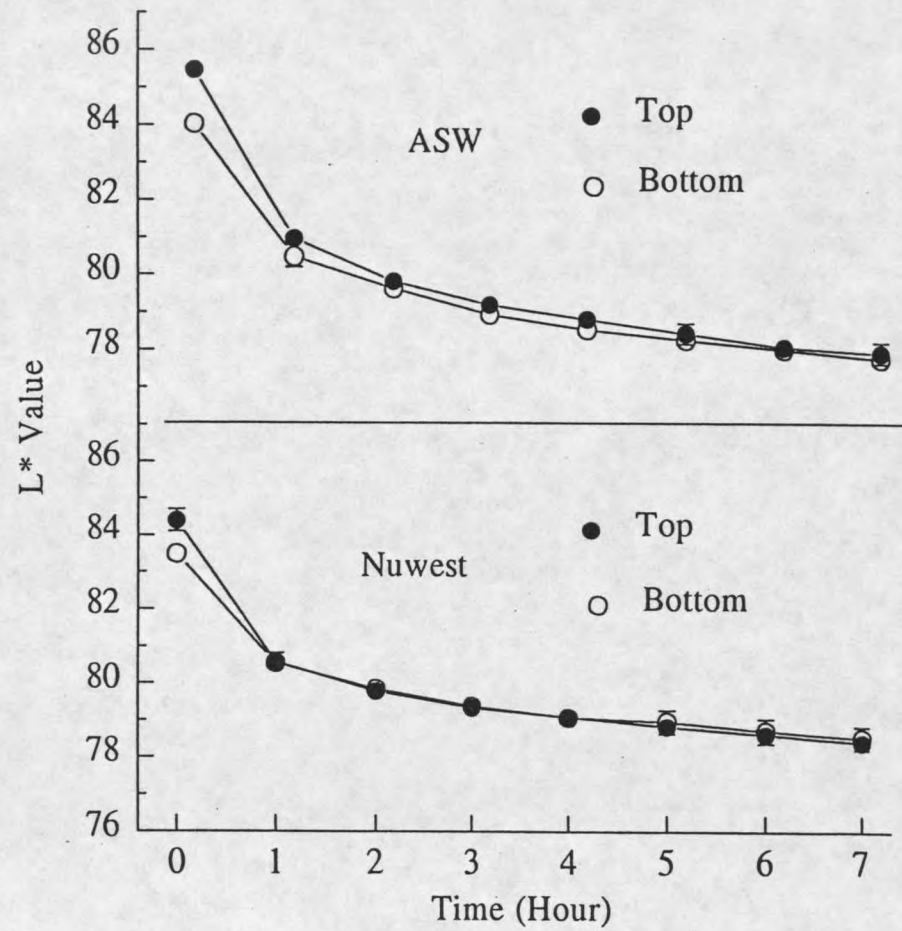


Fig. 1. Change in L* values on top and bottom surfaces of the dough during storage.

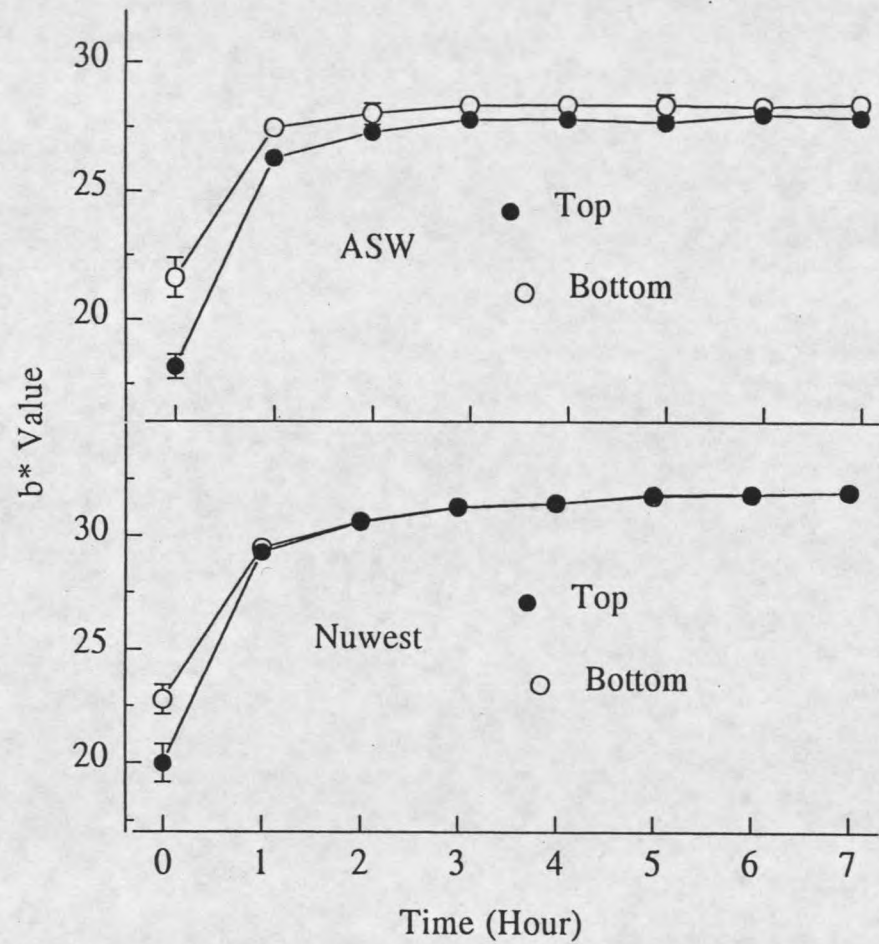


Fig. 2. Changes in b^* values on top and bottom surfaces of the dough during storage.

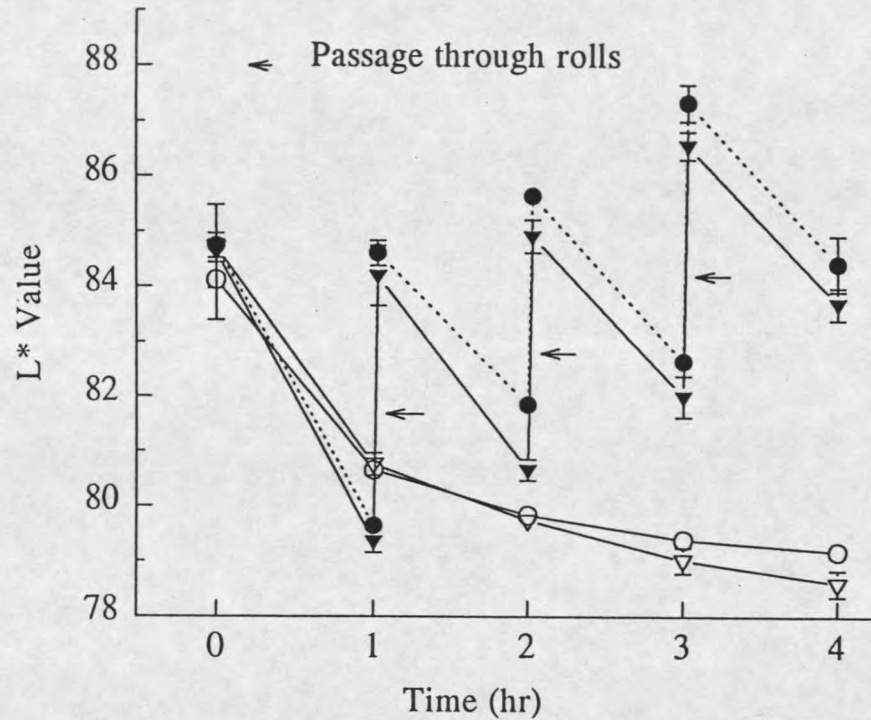


Fig. 3. Changes in L* values of doughs produced from Nuwest (○) and ASW (▽) during storage (control) and changes in L* values of doughs produced from Nuwest (●) and ASW (▼) which occurred as a result of repeated passage through the rolls of the noodle machine during storage.

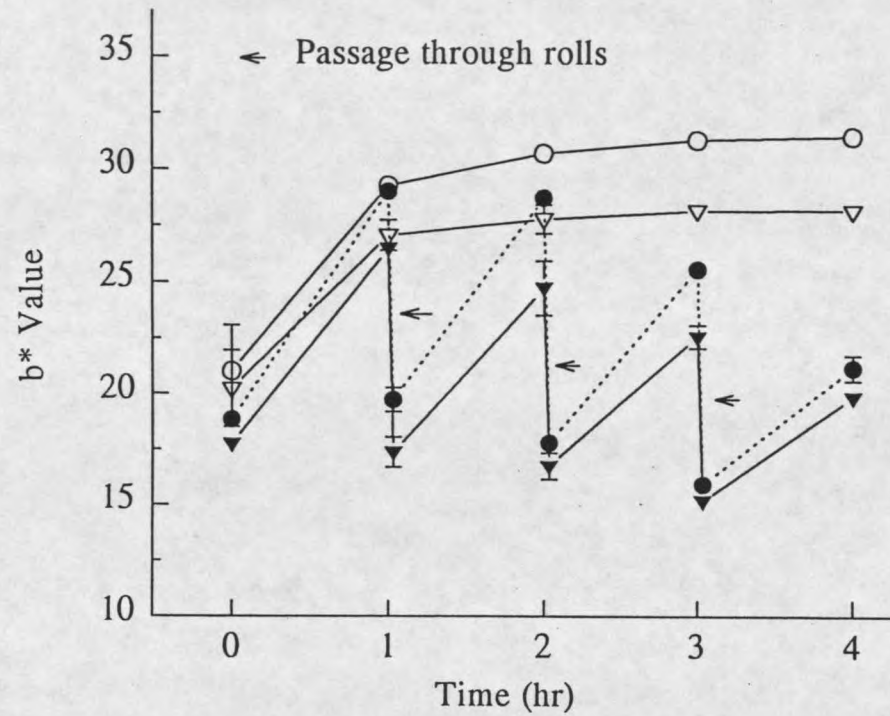


Fig. 4. Changes in b^* values of doughs produced from Nuwest (○) and ASW (▽) during storage (control) and changes in b^* values of doughs produced from Nuwest (●) and ASW (▼) which occurred as a result of repeated passage through the rolls of the noodle machine during storage.

The initial L^* and b^* values of the doughs were recorded immediately after the doughs were made (Fig. 3). The L^* values decreased quickly after 1 hr but increased after doughs were folded lengthwise, passed through the rolls at a gap size of 6 mm (Fig. 3.). The L^* values of the same doughs decreased during the second hour of storage but increased after the dough was again folded and passed through the rolls at a gap size of 6 mm. The same phenomenon was observed during the third hour of storage. The b^* values, on the other hand, increased during first hr of storage and decreased after the dough was passed through the rolls of the noodle machine (Fig. 4). The same phenomenon held true during the second and third hr of storage. The b^* values of the same doughs increased during the second and third hr of storage but decreased after the doughs were folded and passed through the noodle machine rolls. Both ASW and Nuwest produced similar results.

Color Changes during Storage

To examine the influences of color changes occurring within the dough during the resting period, a dough piece (8 mm thick) formed after the initial compression series in the noodlemaking process was cut into four equal size pieces. The first piece was passed through the reduction series of the noodlemaking process to a final thickness of 1.6 mm at 0 hr and the L^* and b^* values were recorded for the resulting dough sheet. The second dough piece was allowed to rest in a sealed bag at 30°C and 85 % rh for 1 hr and was then passed through the reduction series to a final thickness of 1.6 mm. The L^* and b^* values

were recorded for the resulting dough sheet. The third and fourth dough pieces were passed through the reduction series at 2 and 3 hr respectively and their L^* and b^* values recorded (Figs. 5 and 6). The L^* and b^* values for the first dough piece (control) recorded each hr (Figs. 5 and 6) indicate the changes in those values which occur over the 3 hr after the dough is made if no further machining takes place. The color changes in both L^* values and b^* values decrease if the dough is passed through the rolls of the noodle machine during the resting period. The color differences between dough pieces which were passed through the rolls of the machine during the resting period and the control were caused by unknown reasons, but these changes are not likely related to enzymatic activity. If the changes in color were caused by enzymatic activity, all doughs would exhibit the same color changes over time. These results indicate that surface color changes which take place during the first hr after the dough is made are not due to enzymatic activity occurring throughout the dough. Rather, the surface color changes appear to be related to physical phenomenon which are influenced by the machining of the dough.

To determine the length of time the color changes caused by machining would persist, a big single dough piece which had been processed through the compression series in the noodlemaking process was cut into three equal size pieces. The first piece was passed through the reduction series to a final dough thickness of 1.6 mm at the 0 hr. The dough was then placed in a plastic bag and rested for 7 hr at 30°C and 85% rh. The L^* and b^* values were recorded hourly (Figs. 7 and 8). The other two dough pieces were placed in plastic bags and rested at 30°C and 85% rh. After 1 hr of resting, the second

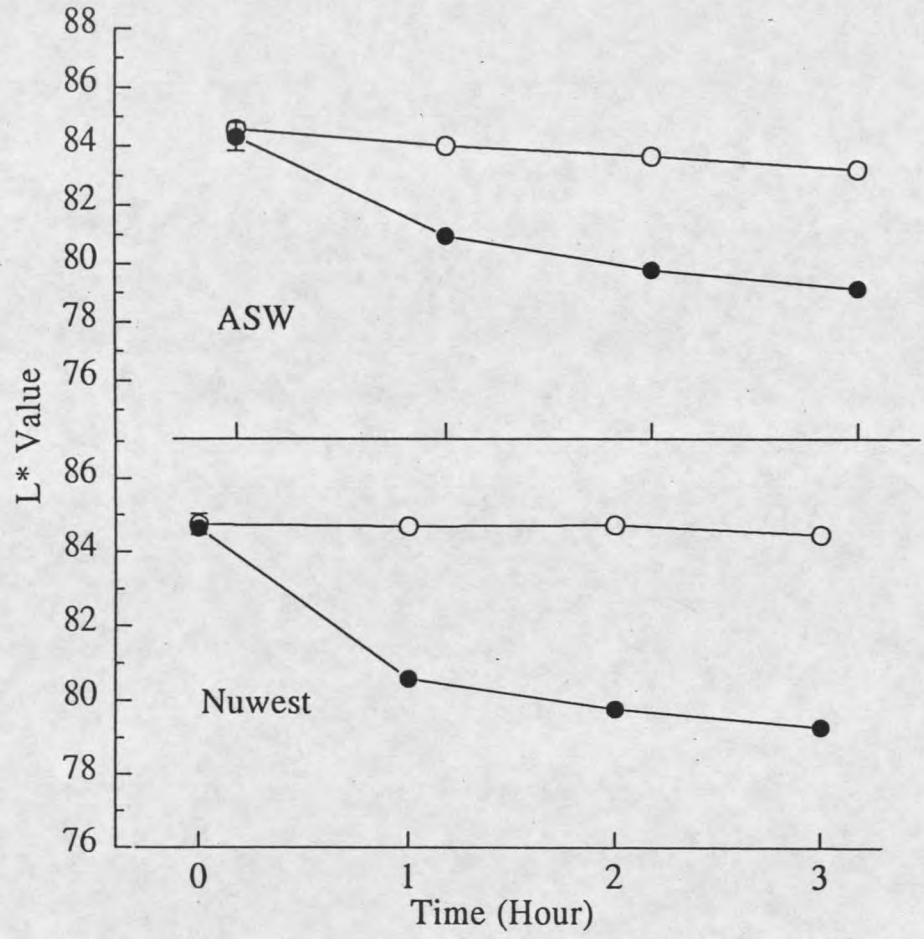


Fig. 5. Changes in L* values of doughs prepared at the same time but passed through the reduction series in the noodlemaking process at different stages. Each point on the graph represents a separate piece of the original dough passed through the reduction series at that particular time point (○). Changes in the L* values of a control dough passed through reduction series immediately after being made (●).

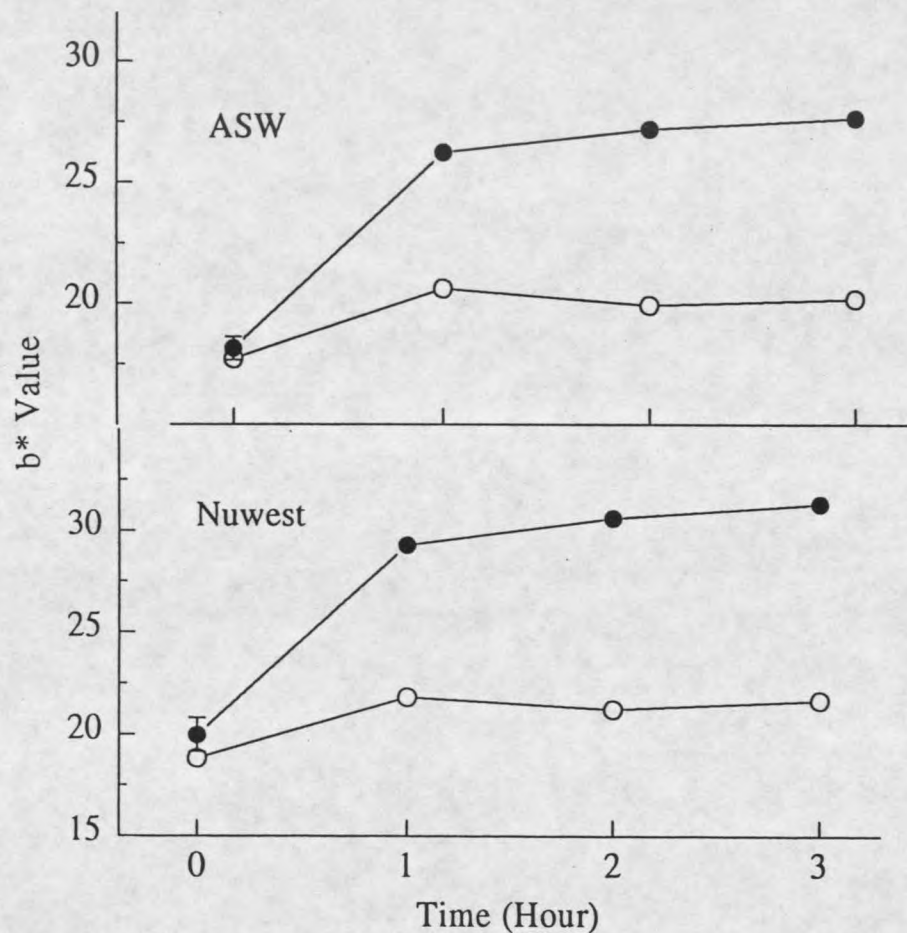


Fig. 6. Changes in b^* values of doughs prepared at the same time but passed through the reduction series at different stages. Each point on the graph represents a separate piece of the original dough passed through the reduction series at that particular time point (○). Changes in the b^* values of a control dough passed through reduction series immediately after being made (●).

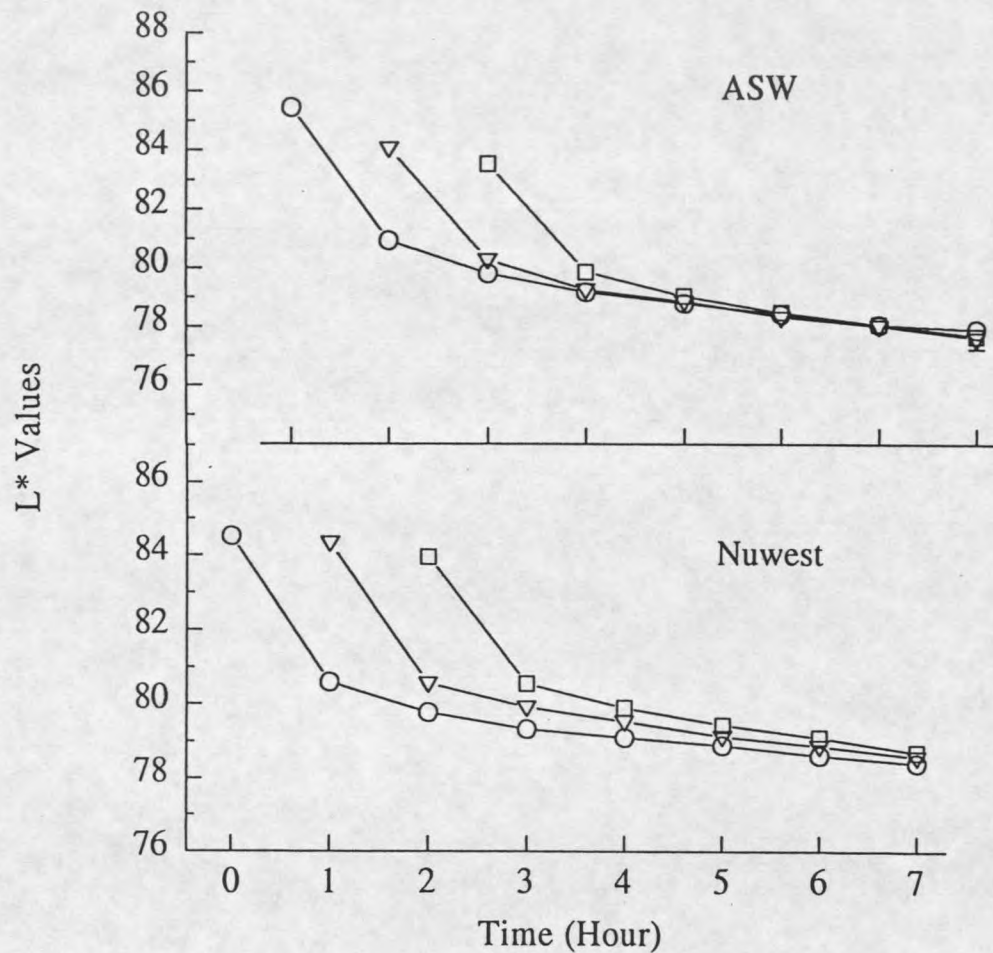


Fig. 7. Changes in L* values of doughs passed through the reduction series of the noodlemaking process at different time points but stored under similar conditions. Dough passed through the reduction series immediately after preparation (\circ); dough stored 1 hr and passed through the reduction series (∇); dough stored 2 hr and passed through the reduction series (\square).

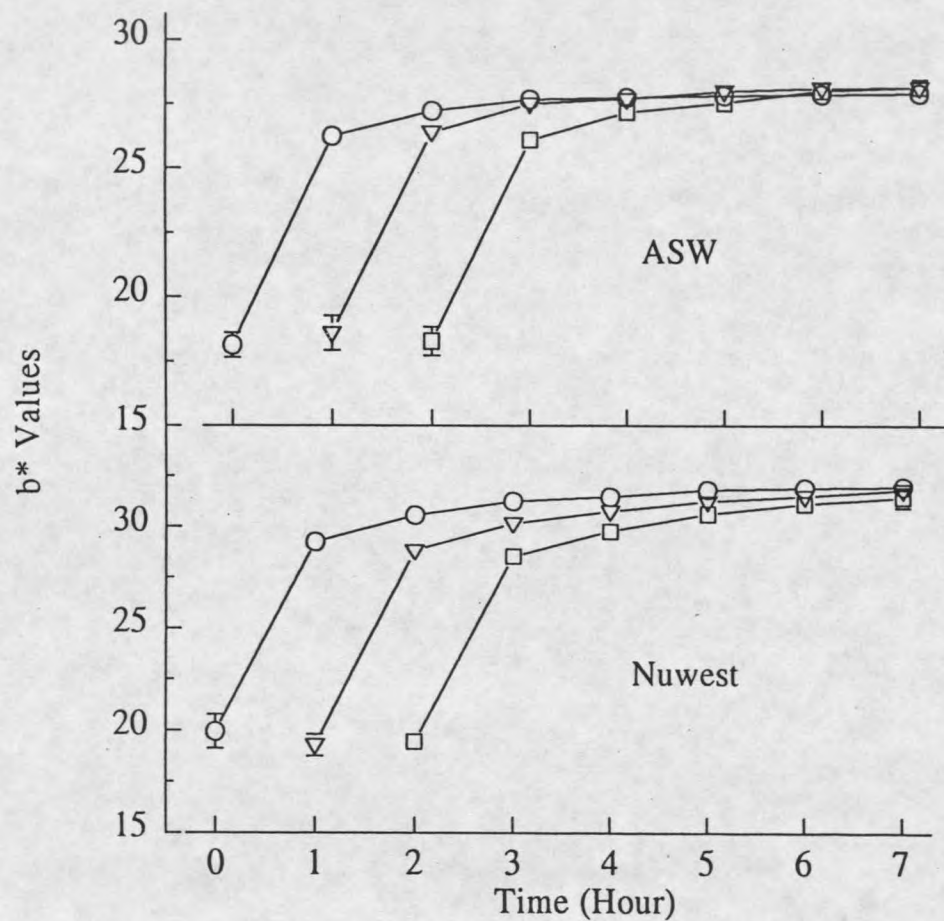


Fig. 8. Changes in b^* values of doughs passed through the reduction series of the noodlemaking process at different time points but stored under similar conditions. Dough passed through the reduction series immediately after preparation (\circ); dough stored 1 hr and passed through the reduction series (∇); dough stored 2 hr and passed through the reduction series (\square).

dough piece was passed through the reduction series to a final thickness of 1.6 mm and rested for 6 hr. The L^* and b^* values were recorded hourly (Figs. 7 and 8). After 2 hr of resting, the third piece was passed through the reduction series to a final thickness of 1.6 mm. The dough was placed in a plastic bag and rested for 5 hr. The L^* and b^* values were recorded hourly (Figs. 7 and 8). For dough sheets made from Nuwest, the L^* and b^* values of the first dough sheet after 1 hr of resting were expected to be similar to the L^* and b^* values of the second dough piece after it was passed through the reduction series because both doughs had been resting under similar conditions for the same period of time. However, the L^* values remained higher for the second dough piece for 3 hr and the b^* values remained lower for the same period of time. The same phenomena was observed in the third dough piece. Differences in L^* and b^* values in these dough sheets remained for several hours. After 7 hr, all dough pieces produced from Nuwest had similar L^* and b^* values. For dough sheets made from ASW, the L^* and b^* values became similar after 4 hr. This phenomenon is likely due to factors affecting water absorption in the doughs. Nuwest flour had a water absorption (determined during mixograph analyses) which was approximately 2% lower than ASW flour (Han et al., Table 2, unpublished data). It is likely that water distribution throughout the Nuwest doughs occurs after 7 hr and after 4 hr in ASW doughs (Figs 7 and 8) accounting for the differences in L^* and b^* produced upon re-machining the doughs.

Conclusions

In this study, three interesting phenomena were observed. First, Chinese noodle doughs produced on the Ohtake noodle machine had different L^* and b^* values for the tops and bottoms of the dough sheets during the first hr after they were made. The differences appear to be due to the uneven distribution of water at the surfaces of the doughs. The difference in water distribution may be due to the temperature difference between the top and bottom of the dough sheet or differences in forces exerted on either side of the dough sheet during machining. Secondly, L^* values decreased and b^* values increased during the time the dough rested. Passing the dough through the rolls of the machine a second and third time caused a subsequent increase in the L^* values and decrease in the b^* values of the doughs. Thirdly, the changes in the L^* and b^* values which occurred during the first hour after the dough had been passed through the reduction series appeared to be directly related to distribution of water in the dough. After 7 hr, the L^* and b^* values for all dough sheets produced from the same original dough were similar regardless of machining differences. This is significant in that researchers examining various flours for noodlemaking quality should bear in mind that the dramatic differences in L^* and b^* values seen between the initial time the dough is prepared and 1 hr after the dough has rested is dependent upon distribution of water to the surface of the dough and not upon enzymatic activity occurring throughout the dough. The present study suggests that the surfaces of the doughs appear to become evenly hydrated after 1 hr of resting and then the affects of other phenomena which may affect

the color of the dough can be accurately measured. However, it appears to take approximately 7 hr for all doughs to become fully hydrated and completely accurate color analyses can be performed. However, this time period will vary depending upon the absorption of the flours being studied.

Re-machining doughs which are not completely hydrated appeared to affect the L^* and b^* values due to mechanical reorientation of incompletely hydrated particles of flour at the surface of the doughs. All doughs which exhibited this phenomenon eventually produced identical L^* and b^* values after complete hydration of the dough occurred. Therefore, accurate color analyses cannot be performed on noodle doughs until complete hydration of the doughs has taken place. An accurate profile of color changes which are controlled by intrinsic factors in the flour itself can only be obtained after complete hydration of the dough. The first color data should be taken at the point of complete dough hydration and not immediately after the dough is produced for the first accurate representation of the intrinsic color attributes contributed to noodle doughs by a particular flour.

CHAPTER 3

NUWEST, A MONTANA HARD WHITE WHEAT IS COMPARABLE TO
AUSTRALIAN STANDARD WHITE WHEAT FOR NOODLE AND BREAD
MAKING QUALITYIntroduction

Over 50% of wheat consumed in Asia is in the form of noodle products.

Australian Standard White (ASW) accounts for the largest portion of the wheat utilized in the noodlemaking industry in South East Asia and is considered the quality standard with which other wheats are compared. The color and texture of the noodles are two of the critical quality factors associated with Asian noodles. Ideally, the cooked noodle product should be a bright, pale yellow noodle which has a clean bite and is not sticky. It is also critical that the uncooked noodles maintain a suitable color for at least 48 hr in Asian countries due to the time lapse which may occur between the manufacturing of the noodles and the time a customer purchases them from a hawker. Hunter Lab color values have been used to measure noodle color (Miskelly, 1984). In the $L^*a^*b^*$ color space, L^* indicates brightness and a^* and b^* are the chromaticity coordinates. The a^* value is a measure of red/green and the b^* value is a measure of yellow/blue. In general, L^* and b^* values are inversely related (Miskelly, 1984). Kruger et al. (1994) showed that the L^*

value (brightness) of raw noodles decreased, while the b^* value (yellowness) increased with time and decreased with flour refinement. Red-green chromaticity ($\pm a^*$), on the other hand, was class dependent and the color in raw noodles either increased (became redder) or decreased (became greener) at 4 hr after preparation. Differences in brightness (L^* values) and yellowness (b^* values) are attributable to a multitude of factors including wheat cultivar, milling extraction rate, protein content, starch damage, brown and yellow pigments contained in the flour, and the time elapsed after making noodles. Changes in brightness and yellowness of the noodles were greatest during the first hour after they were prepared and leveled off thereafter (Baik et al., 1995). Some studies suggest that gray discoloration of noodles may be caused by the oxidation of tyrosine with consequent melanin formation (Moss, 1971), while others have shown that polyphenol oxidase, located largely in bran, may also produce a deleterious dull brown color in raw Cantonese noodles (Kruger et al., 1992).

Texture is also a critical characteristic of oriental noodles, and both starch and protein play major roles in governing textural properties (Baik et al., 1994). Although preferences vary from country to country, and even from region to region within a country, sufficient firmness of the noodle to give a clean bite without being tough is required for good quality (Miskelly and Moss, 1985).

In this study, we compared Nuwest, a Montana hard white winter wheat with

ASW for Chinese noodle making quality and in breadmaking quality. The noodles were stored at 30°C and 85% relative humidity in this study in an effort to mimic the climatic conditions of South East Asian countries.

Materials and Methods

Materials

'Nuwest', (reg. no. CV-812, PI 586806), a hard white winter wheat (*Triticum aestivum* L.) cultivar, was developed and released by the Montana Agricultural Experiment Station in 1994 (Bruckner et al., 1996). Nuwest was kindly provided by D. Biggerstaff, Western Plant Breeders Inc., Bozeman, MT. Australian Standard White (ASW) was kindly provided by M. Kruk, Wheat Marketing Center Inc., Portland, OR.

Noodle Preparation

During all procedures, laboratory conditions were maintained at 25 °C and 50% relative humidity. Flour (300g) was pre-mixed at a low speed in a Hobart mixer for 1 min, the mixing speed was then increased to medium and a solution containing 3 g sodium chloride, 3 g sodium carbonate and 114 ml distilled water was poured into the flour within 20 to 30 seconds, mixing continued for a total mixing time of 5 min. The dough was rested in a plastic bag for 10 min. After resting, the dough was folded length wise and passed through a noodle machine (Otake Mfg. Co. Ltd., Tokyo, Japan) six times at a gap size of 8 mm (compression series). The temperature of the noodle machine rolls was

maintained at 30°C. The dough was rested in a plastic bag for 10 min, and then passed through a gradual reduction series until a final dough thickness of 1.6 mm was achieved. Noodle dough sheets were stored in sealed plastic bags at 85% relative humidity and 30°C throughout the duration of the color analyses. The noodle strands used for texture analyses were cut with a 1.6 mm cutter (Otake Mfg. Co. Ltd.) and boiled for 1 min prior to analysis.

Breadmaking

AACC method 10-10B (AACC, 1983).

Dough Color Analysis

The doughs were cut into circular pieces (6 cm in diameter) and color values were measured with a Minolta CR-310 Chroma Meter using the L*a*b* color system. The error bars in the graphs show the standard deviation.

Noodle Texture Analyses

The hardness or "bite" of the noodles was measured using a modification of the AACC pasta hardness method provided by Texture Technologies Corp (Texture Technologies Corp., Scarsdale, NY). A TA-XT2 Texture Analyzer was set to the following settings: force measured of compression, speed of 1 mm/sec, distance of 9.7 mm, and post test speed of 10 mm/sec. A lexan knife was installed and the probe was calibrated at a return distance of 10 mm. Fresh noodles were boiled for 3 min, collected in

a wire basket, rinsed in cold tap water for 1 min and the basket containing the noodles was tapped on a cotton towel for 1 min. Four strands of noodles were placed on the lexan plate of the TA-XT2 Texture Analyzer perpendicular to the pasta blade. The noodles were immediately covered with plastic wrap and allowed to rest for 8 min. The plastic wrap was removed and the hardness tests were conducted. The peak force measurement obtained indicated the hardness ("bite") value of the noodle.

The adhesiveness of noodles was measured using a modification of the pasta adhesiveness method for the TA-TX2 Texture Analyzer provided by the Texture Technologies Corp. A rectangular probe and aluminum plate were used in the adhesiveness test. The speed was set to 1 mm/sec, distance to 15 mm, force applied to 300 g, time to 1 sec, and post test speed to 10 mm/sec. The noodles were prepared as they were for the hardness test. Six strands of noodles were cut to the length of the rectangular probe and were placed on the aluminum plate parallel to the rectangular probe. The noodles were immediately covered with plastic wrap and allowed to rest for 8 min. The plastic wrap was removed and the adhesiveness tests were performed. The peak of withdrawal force was the measurement which indicated adhesiveness.

Analytical Methods

Moisture and ash were determined by AACC approved methods 44-15A and 08-1, respectively (AACC, 1983). Total starch and resistant starch content were determined by the Megazyme method (McCleary et al., 1994). Protein (Kjeldahl N x 5.7), ether extract (AOAC 1990), dietary fiber (Prosky et al., 1988) and insoluble and soluble β -glucan

(McCleary and Codd, 1991) were also determined.

Statistical Analyses

All the doughs were repeated three times and each dough was measured twice at different point. Color measurements of noodle doughs were determined from the average of six individual analyses. Data were analyzed by analysis of variance using the General Linear Model Procedure (SAS, 1986).

Results and Discussion

Chemical Composition of ASW and Nuwest Flours

The results of the chemical analyses are shown in Table 1. Nuwest had a higher protein content, ether extract and resistant starch content than ASW, while ASW had a higher total starch, and insoluble and soluble fiber contents. Nuwest had a notably low ash content.

TABLE 1
Chemical Composition of Flours^a

Ingredients	Australian Standard White	Nuwest
Moisture	10.67 ^b	11.09
Ash	0.52	0.42
Protein	11.61	13.19
Ether Extract	1.16	1.24
Total Starch	79.25	75.68
Insoluble Fiber	0.77	0.65
Soluble Fiber	0.94	0.65
Insoluble β -glucan	0.20	0.17
Soluble β -glucan	0.03	0.04

^aAll results reported on a % dry basis, except moisture.

^bProtein and fiber contents are average of duplicated measurements, others are average of four measurements.

Flour, Baking Quality and Moisture Content of Nuwest and ASW

Flour and baking quality data are shown in Table 2. Nuwest and ASW were similar in breadmaking quality with bake water absorption, mixing times and loaf volumes being similar. Crumb grain scores were also comparable (data not shown).

Table 2
Flour and Baking Quality Data

	Flour Quality				Baking Quality		
	Flr Yld ^a (%)	Ash (%)	Mixograph		Water Abs (%)	MT (min)	Loaf Vol. (cc)
			Abs ^b (%)	MT ^c (min)			
Nuwest	72.0	0.42	62.6	3.2	74.8	5.3	870
ASW	72.0	0.52	64.3	3.5	74.2	4.0	830

^aMilling flour yield

^bAbsorption

^cMixing time

The moisture contents of noodle doughs made from Nuwest and ASW are shown in Fig. 9. The moisture content of uncooked and cooked doughs decreased during the 96 hr storage due to the exposure of doughs to the air during the color measurements. The moisture contents of cooked and uncooked noodle doughs made from Nuwest and ASW were similar.

Color Changes of the Doughs During Storage

L* values, the index of brightness/darkness, in Chinese noodles should be as high as possible. L* values were consistently higher in the doughs produced from Nuwest than those produced from ASW over a period of 96 hr (Fig. 10). The most dramatic changes in

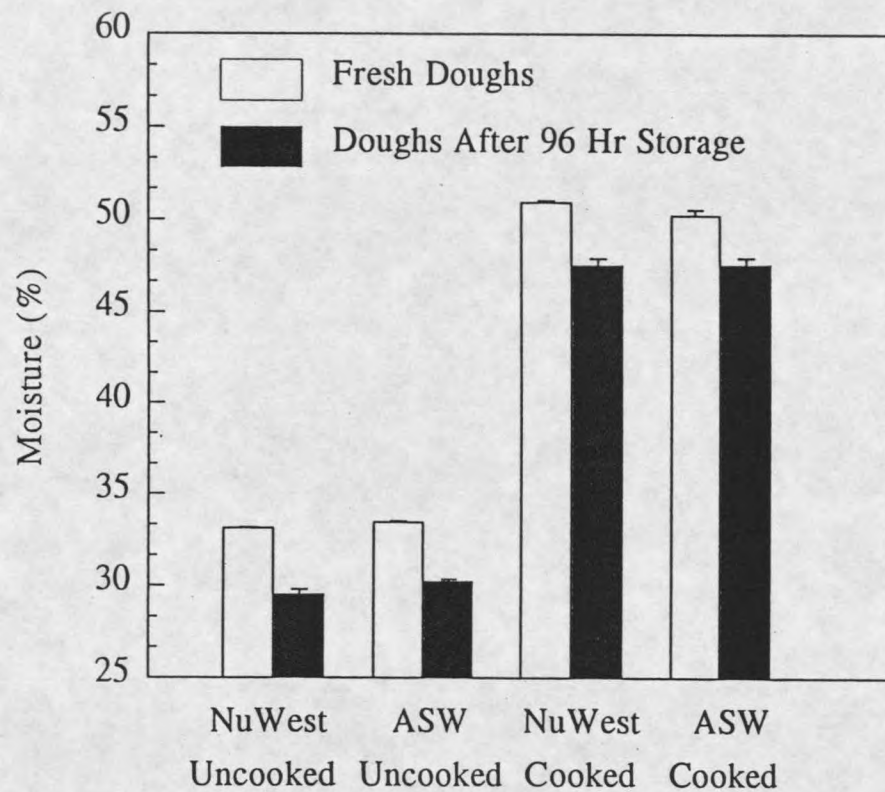


Fig. 9. Moisture contents of fresh doughs (uncooked and cooked) and doughs (uncooked and cooked) after 96 hr storage at 30 °C and 85 % relative humidity in sealed bags.

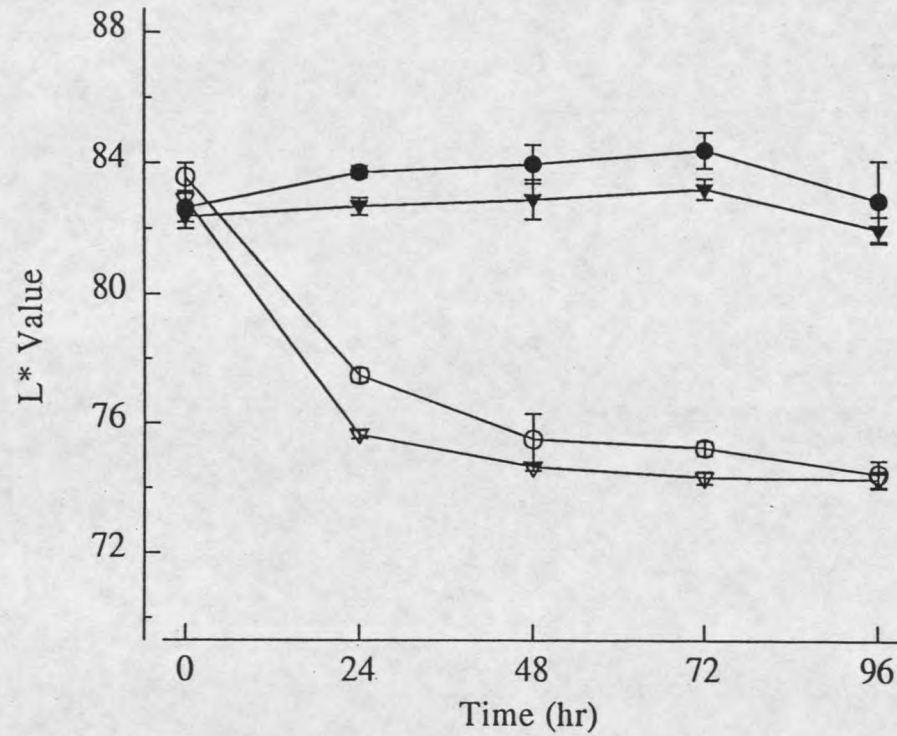


Fig. 10. Changes in L* values during 96 hr storage at 30 °C and 85% relative humidity in sealed plastic bags. Cooked Nuwest dough (●), cooked ASW dough (▼), uncooked Nuwest dough (○), and uncooked ASW dough (▽).

the L^* values of the uncooked noodles occurred over the first 5 hr (Fig. 11). L^* values of the uncooked noodle dough decreased in both ASW and Nuwest, with a substantial decrease occurring in the first two hr (Fig. 11). L^* values of the cooked noodle doughs increased during storage and decreased only after 72 hr (Fig. 10).

The b^* value is an index of yellow/blue with the target value for Chinese noodles being at least 28. The b^* values of uncooked Nuwest doughs were consistently higher than those of uncooked ASW dough (Figs. 12 and 13). The changes which occurred in b^* values during storage were dramatic (Figs. 12 and 13). Again, most of the changes in the b^* values of the uncooked doughs occurred during the first two hr (Fig. 12). The b^* values of the uncooked doughs increased during the first 24 hr but decreased thereafter with a slight increase after 72 hr (Fig. 13). The b^* values of the cooked doughs decreased during the first 48 hr but fluctuated slightly after 48 hr. The irregular changes in b^* values after 48 hr were probably caused by microorganisms present in the dough although no attempts to substantiate this were made in the present study.

The a^* value is an index of red/green with the target value for Chinese noodles being 0. The a^* values of Nuwest doughs were less than or equal to those of ASW over a period of 96 hr (Fig. 14). The a^* values did not change noticeably during the first 5 hr (Fig. 15). The a^* values for uncooked doughs and cooked doughs increased over a period of 96 hr (Fig. 14) and the a^* values for uncooked Nuwest doughs remained lower than those of uncooked ASW doughs over the total period of time (Fig. 14). The a^* values for

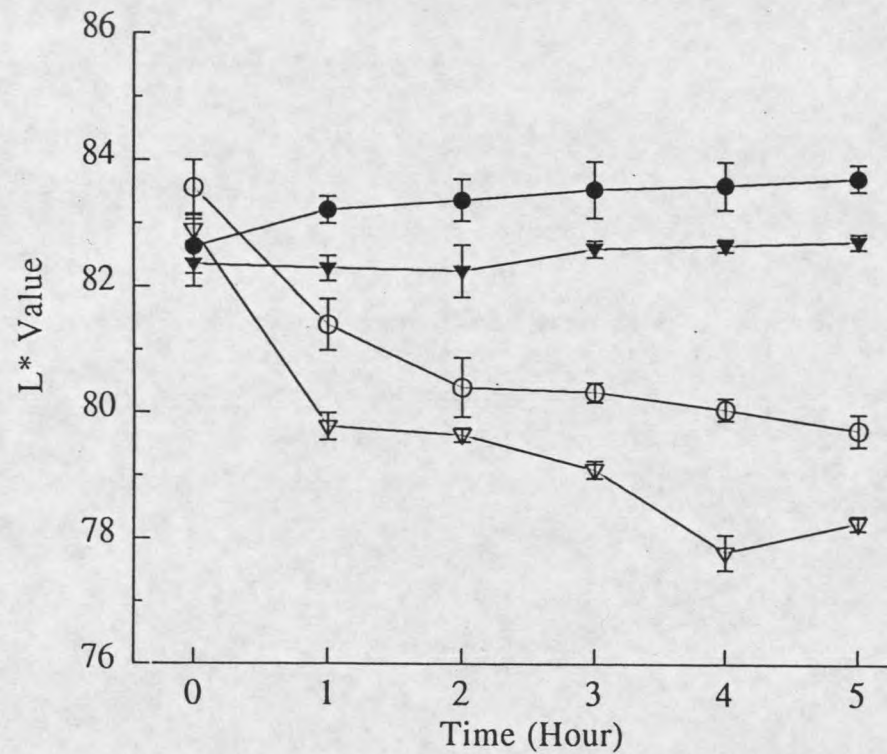


Fig. 11. Changes in L* values during 5 hr storage at 30 °C and 85% relative humidity in sealed plastic bags. Cooked Nuwest dough (●), cooked ASW dough (▼), uncooked Nuwest dough (○), and uncooked ASW dough (▽).

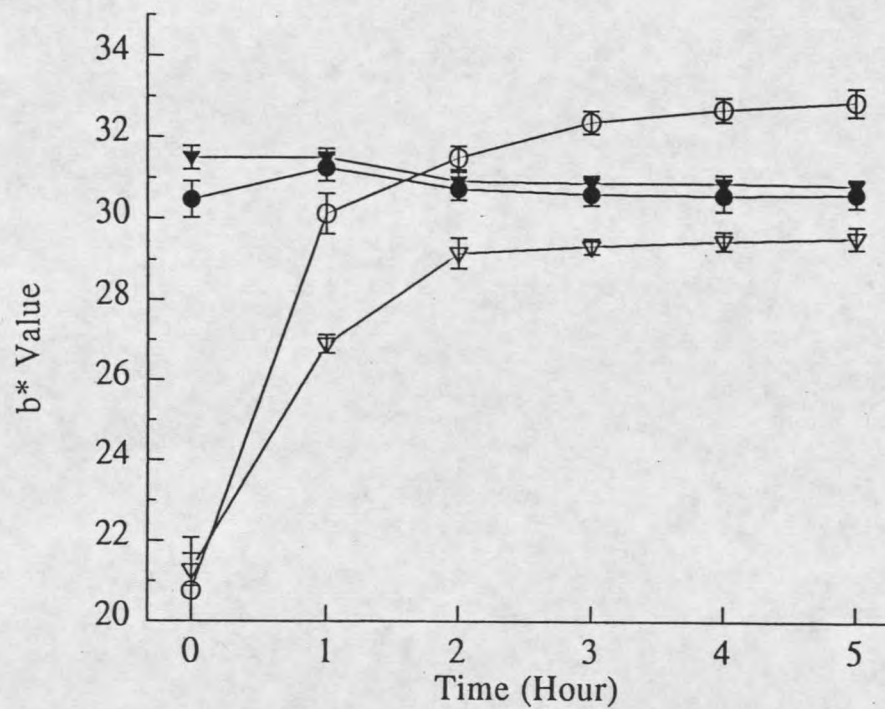


Fig. 12. Changes in b* values during 5 hr storage at 30 °C and 85% relative humidity in sealed plastic bags. Cooked Nuwest dough (●), cooked ASW dough (▼), uncooked Nuwest dough (○), and uncooked ASW dough (▽).

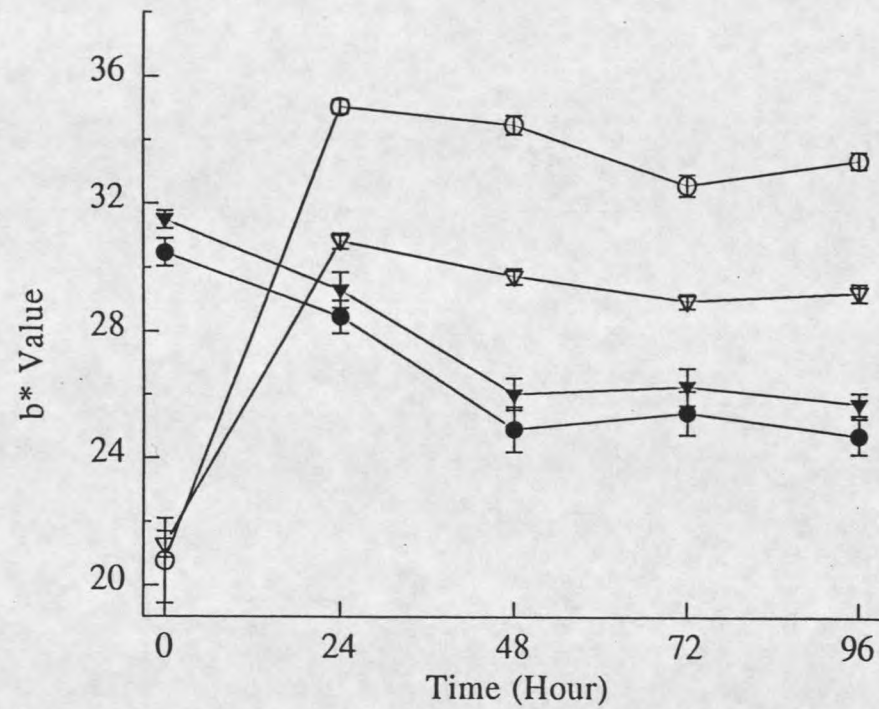


Fig. 13. Changes in b* values during 96 hr storage at 30 °C and 85% relative humidity in sealed plastic bags. Cooked Nuwest dough (●), cooked ASW dough (▼), uncooked Nuwest dough (○), and uncooked ASW dough (▽).

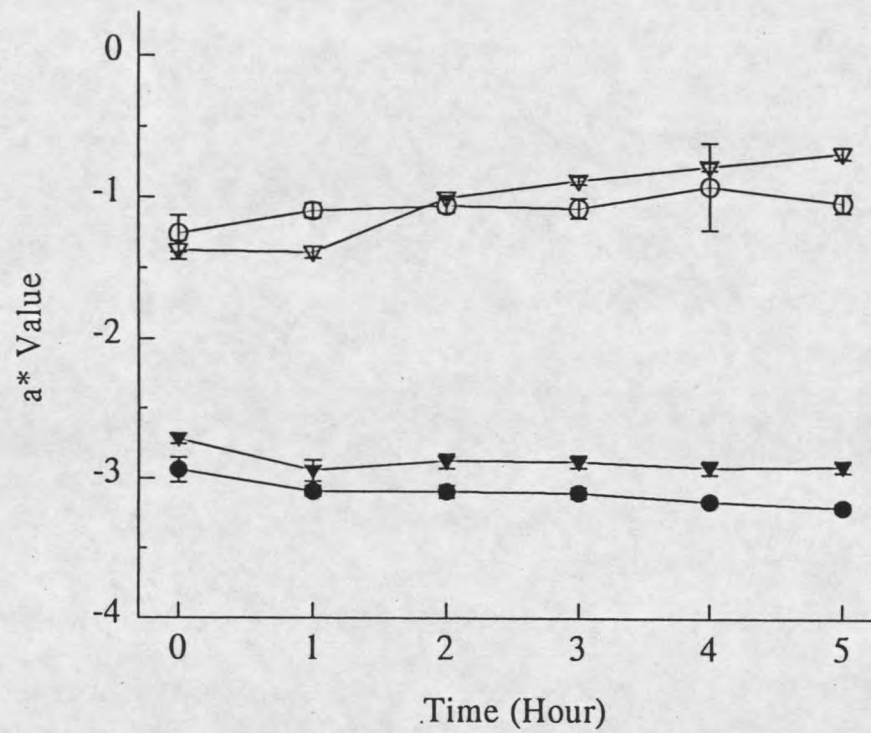


Fig. 14. Changes in a* values during 5 hr storage at 30 °C and 85% relative humidity in sealed plastic bags. Cooked NuWest dough (●), cooked ASW dough (▼), uncooked NuWest dough (○), and uncooked ASW dough (▽).

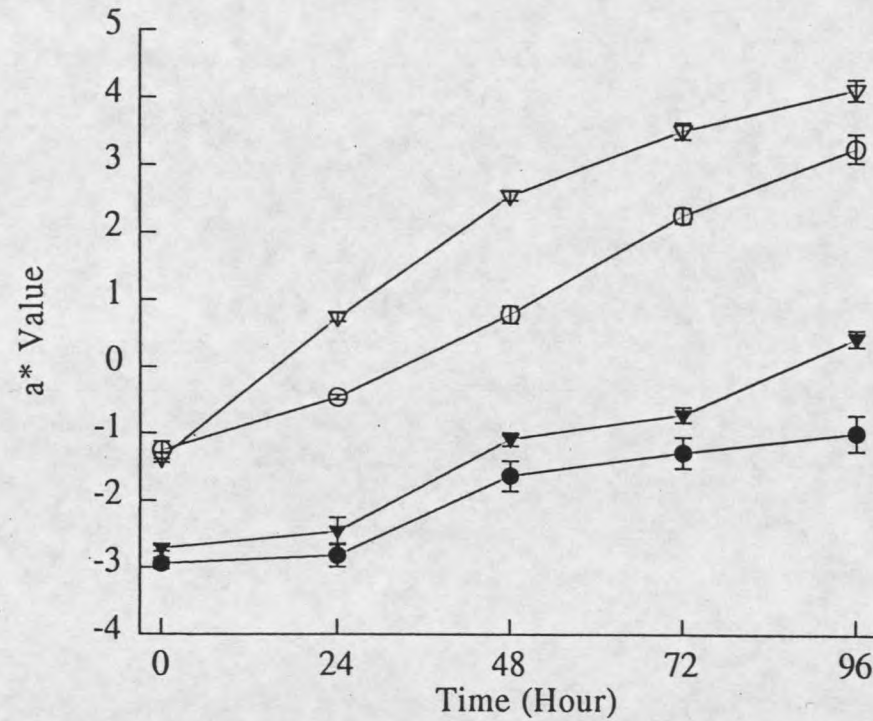


Fig. 15. Changes in a* values during 96 hr storage at 30 °C and 85% relative humidity in sealed plastic bags. Cooked NuWest dough (●), cooked ASW dough (▼), uncooked NuWest dough (○), and uncooked ASW dough (▽).

uncooked Nuwest dough at 24 and 48 hr were very close to zero.

Texture of the Cooked Noodles

The texture of the noodles is important with particular attention to hardness, or noodle "bite" characteristics and adhesiveness which provides an indication of the "stickiness" of the noodles. The hardness value (peak force measurement) determined for noodles made from Nuwest was 170.99 ± 2.20 and the hardness value (peak force measurement) determined for noodles made from ASW was 161.66 ± 2.07 . These values represent the averages of six replicate measurements. The greater hardness value of noodles made from Nuwest is likely due to the higher flour protein content although both protein content and protein quality are responsible for influencing the texture of noodles (Baik et al., 1994).

The adhesiveness value (peak of withdrawal force) determined for noodles made from Nuwest was 255.24 ± 18.91 , while the adhesiveness value (peak of withdrawal force) of noodles made from ASW was 314.20 ± 13.10 g. These values represent the average of eight replicate measurements. This data indicates that noodles made from Nuwest were less adhesive than those made from ASW.

Conclusions

Nuwest, a Montana hard white wheat produced Asian noodles which were

comparable in quality to those produced from Australian Standard White Wheat (ASW). Most notably, the color and color stability of the noodles produced from Nuwest were closely correlated to the color and color stability of noodles produced from ASW even under conditions which mimicked the environment of South East Asia. Because of its higher flour protein content, Nuwest produced noodles which had a harder "bite" than the noodles produced from ASW. Additionally, the noodles produced from Nuwest were shown to be less adhesive than the noodles produced from ASW. Nuwest also has comparable breadmaking quality to ASW. Nuwest produces a high quality flour suitable for producing excellent Asian noodles as well as performing well in the breadmaking process.

CHAPTER 4

INCORPORATION OF BARLEY FLOURS INTO NOODLE PRODUCTS

Introduction

Barley is an important agricultural crop in the world. There is a growing interest in barley for food and industrial use (Åman and Newman, 1986). Barley consumption has been shown to have a hypocholesterolemic effect in humans (Newman et al., 1989; McIntosh et al., 1991). Soluble β -glucans were found to be one of the responsible components for this effect (Newman and Newman, 1991; Klopfenstein and Hosenev, 1987). Barley β -glucans altered intestinal viscosity and reduced plasma cholesterol concentration in chicks (Wang et al., 1992, Klopfenstein et al., 1987). In this study, Montana barley flours (Merlin, Glacier, high amylose Glacier and high amylose hull-less Glacier) were incorporated into Nuwest, a Montana Hard White Winter Wheat, and Australian Standard White wheat to make noodle dough sheets. The chemical composition of wheat and barley flours were analyzed and the color changes of dough sheets were recorded over 96 hours. The objective of this study was to test the color changes of noodle dough sheets when the barley flours were incorporated into noodle products.

Materials and Methods

Materials

Nuwest, Merlin, Glacier, high amylose Glacier, and high amylose hull-less Glacier were kindly provided by Western Plant Breeders Inc., Bozeman, MT. Australian Standard White (ASW) was kindly provided by M. Kruk, Wheat Marketing Center Inc., Portland, OR.

Noodle Preparation

During all procedures, laboratory conditions were maintained at 25 °C and 50% relative humidity. Flour(300g) was pre-mixed at a low speed in a Hobart mixer for 1 min, or 15 min when the 5% of barley flours was added into wheat flours. The mixing speed was then increased to medium and a solution containing 3 g sodium chloride, 3 g sodium carbonate and 114 ml distilled water was poured into the flour within 20 to 30 seconds, mixing continued for a total mixing time of 5 min. The dough was rested in a plastic bag for 10 min. After resting, the dough was folded length wise and passed through a noodle machine (Otake Mfg. Co. Ltd., Tokyo, Japan) 6 times at a gap size of 8 mm (compression series). The temperature of the noodle machine rolls was maintained at 30°C. The dough was rested in a plastic bag for 10 min, and then passed through a gradual reduction series until a final dough thickness of 1.6 mm was achieved. Noodle dough sheets were stored in sealed plastic bags at 85% relative humidity and 30°C throughout the duration of the color

analyses.

Dough Color Analysis

The doughs were cut into circular pieces (6 cm in diameter) and color values were measured with a Minolta CR-310 Chroma Meter using the L*a*b* color system.

Analytical Method

Moisture and ash were determined by AACC approved methods 44-15A and 08-1, respectively (AACC, 1983). Total starch and resistant starch content were determined by the Megazyme method (McCleary et al., 1994, Megazyme, 1995). Protein (Kjeldahl N x 5.7), ether extract (AOAC 1990), dietary fiber (Prosky et al., 1988) and insoluble and soluble β -glucan (McCleary and Codd, 1991) were also determined.

Statistical Analyses

All the doughs were repeated three times and each dough was measured twice at different point. Color measurements of noodle doughs were determined from the average of six individual analyses. Data were analyzed by analysis of variance using the General Linear Model Procedure (SAS, 1986). The error bars in the graphs show the standard deviation.

Results

Chemical Composition of Flours

The chemical composition of wheat and barley flours are shown in Table 3. The insoluble fiber, soluble fiber, insoluble β -glucan and soluble β -glucan were much higher in barley flours than those in wheat flours. The ether extract levels were also higher in barley flours than those in wheat flours. Wheat flours had higher starch content than barley flours.

Color Changes in Noodle Dough Sheets

L* value decreased about 4 to 10 when barley flours replaced 5% of the wheat flour in noodle dough. In both Nuwest and ASW, Merlin decreased the color most while Glacier decreased the color least (Figs. 16 and 17). The decreases in b* values were also dramatic when barley flours were blended into Nuwest or ASW (Figs. 18 and 19). The decreases were least when Merlin flour was added and highest when high amylose hull-less Glacier flour was added. Increases in a* values were also observed when barley flours were added into Nuwest and ASW (Figs. 20 and 21).

Conclusion

Addition of barley flour into noodles dough increased the insoluble fiber, soluble fiber, insoluble β -glucan and soluble β -glucan of the product. Although the increase was

Table 3. Chemical Composition of Flours^a

Ingredients	Nuwest	ASW	Merlin	Glacier	HAG ^c	HANG ^d
Moisture	11.09±0.03 ^b	10.67±0.03	8.30±0.01	7.68±0.01	8.00±0.01	7.35±0.01
Protein	13.19±0.01	11.61±0.01	10.82±0.01	12.67±0.01	13.47±0.01	14.40±0.00
Ether Extract	1.24±0.01	1.16±0.01	3.27±0.01	2.34±0.01	3.37±0.01	2.71±0.00
Total Starch	75.68±1.00	79.25±0.27	64.32±0.35	65.97±0.80	59.02±0.72	58.36±0.80
Resistant Starch	0.26±0.04	0.18±0.02	0.12±0.02	0.27±0.05	0.33±0.03	0.32±0.05
Insoluble Fiber	0.65±0.22	0.77±0.11	5.10±0.33	5.80±0.60	8.07±0.55	7.50±0.17
soluble Fiber	0.65±0.01	0.94±0.02	2.03±0.06	2.84±0.01	3.03±0.55	3.17±0.06
Insoluble β-Glucan	0.17±0.02	0.20±0.02	2.26±0.05	2.99±0.22	4.84±0.17	4.71±0.14
Soluble β-Glucan	0.04±0.01	0.03±0.01	1.31±0.08	1.77±0.26	1.03±0.08	1.52±0.11

^aAll results reported on a % dry basis, except moisture.

^bValues were means±SD. Protein and fiber contents are average of duplicated measurements, others are average of four measurements.

^cHigh amylose Glacier.

^dHigh amylose hull-less Glacier.

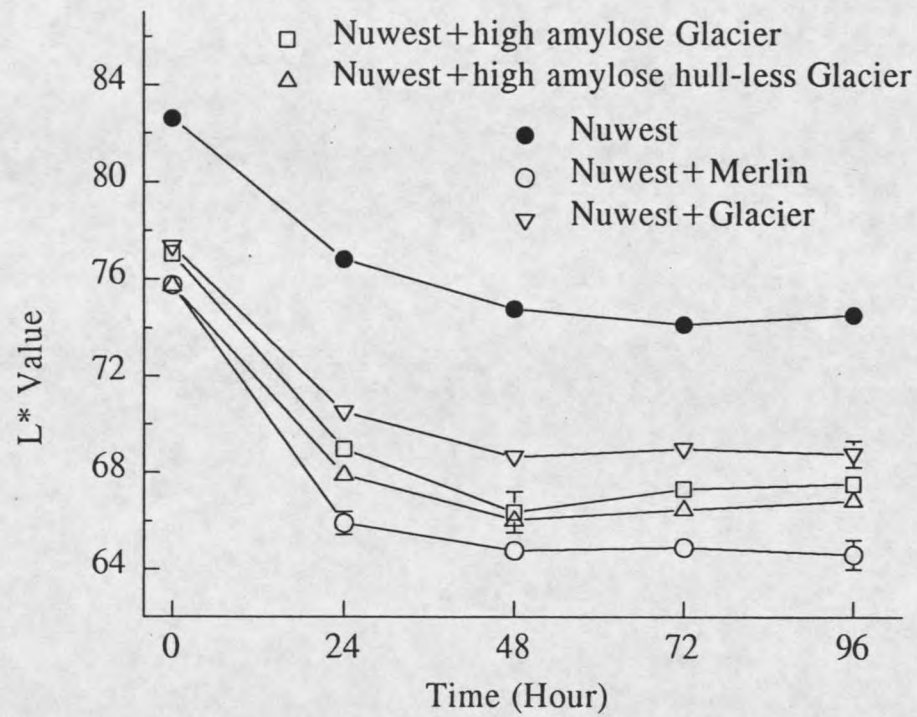


Fig. 16. Changes in L* values of raw doughs during 96 hr storage at 30°C and 85% relative humidity in sealed plastic bags.

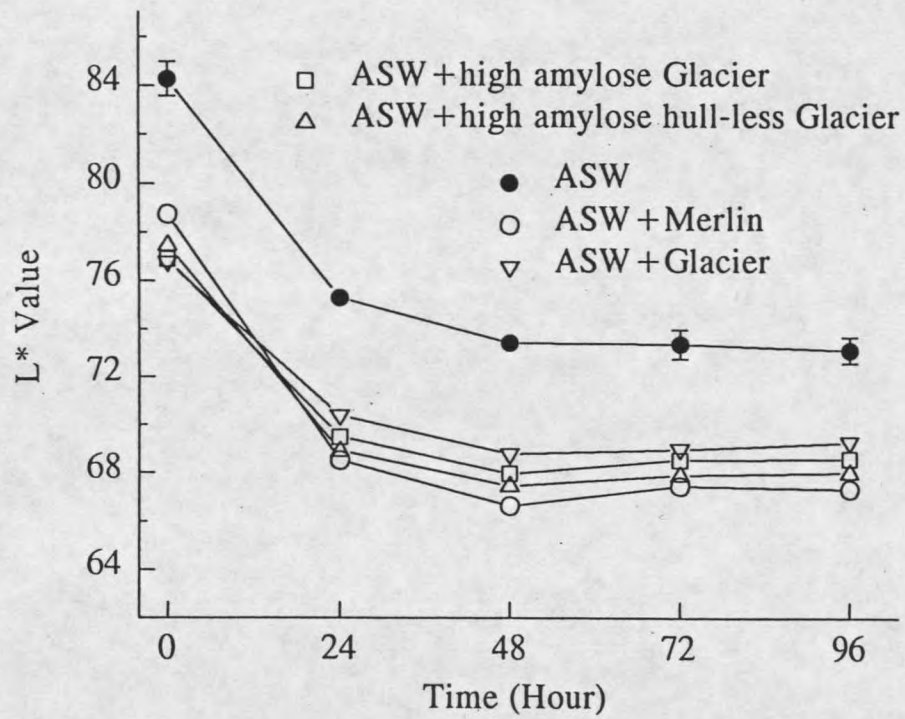


Fig. 17. Changes in L* values of raw doughs during 96 hr storage at 30°C and 85% relative humidity in sealed plastic bags.

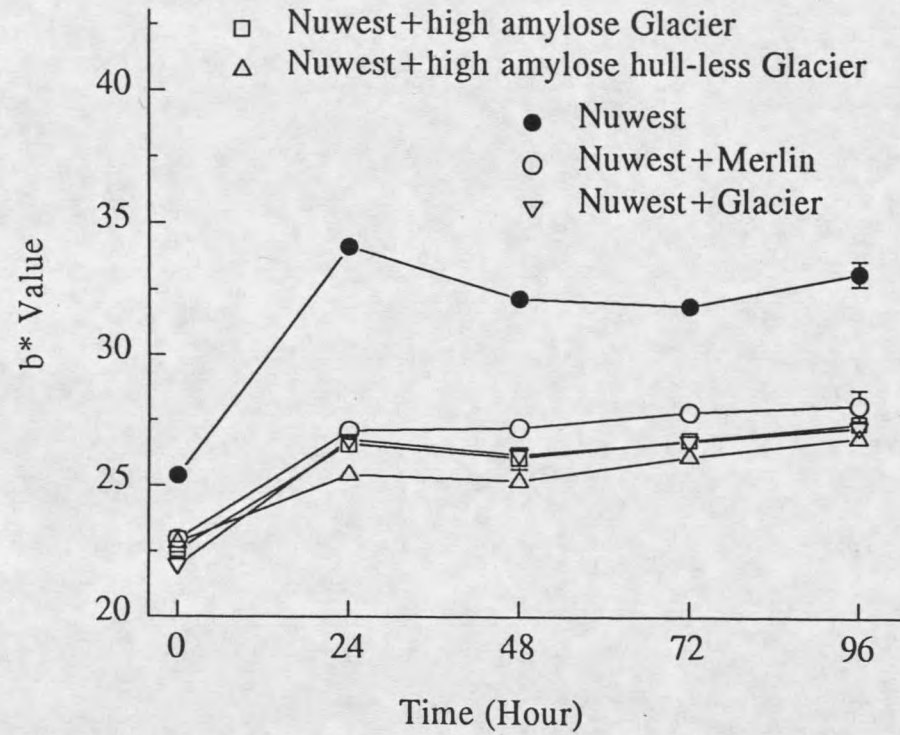


Fig. 18. Changes in b* values of raw doughs during 96 hr storage at 30°C and 85% relative humidity in sealed plastic bags.

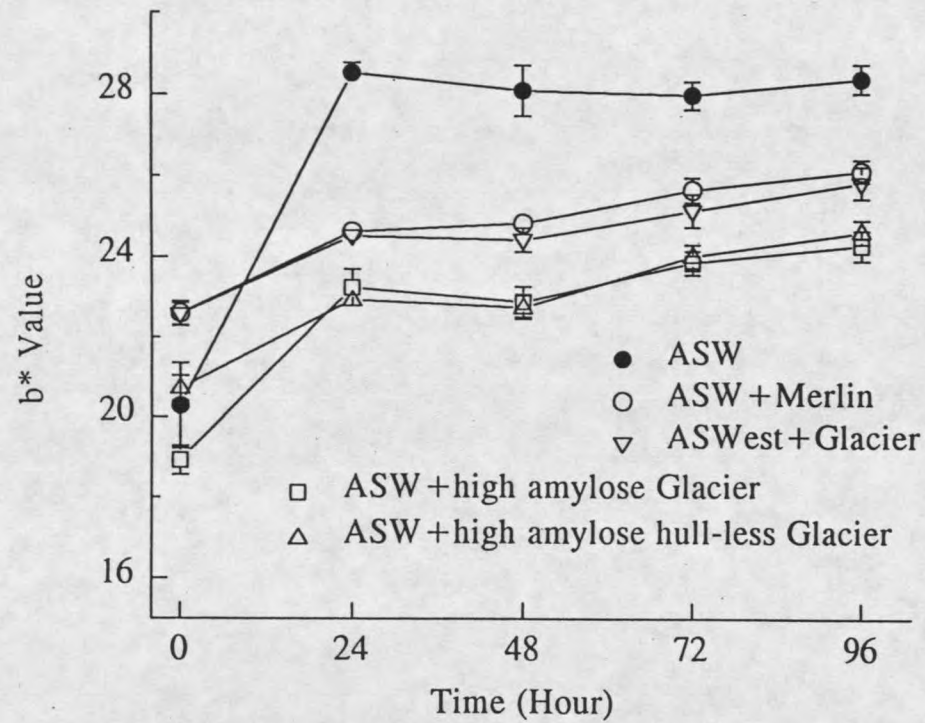


Fig. 19. Changes in b* values of raw doughs during 96 hr storage at 30°C and 85% relative humidity in sealed plastic bags.

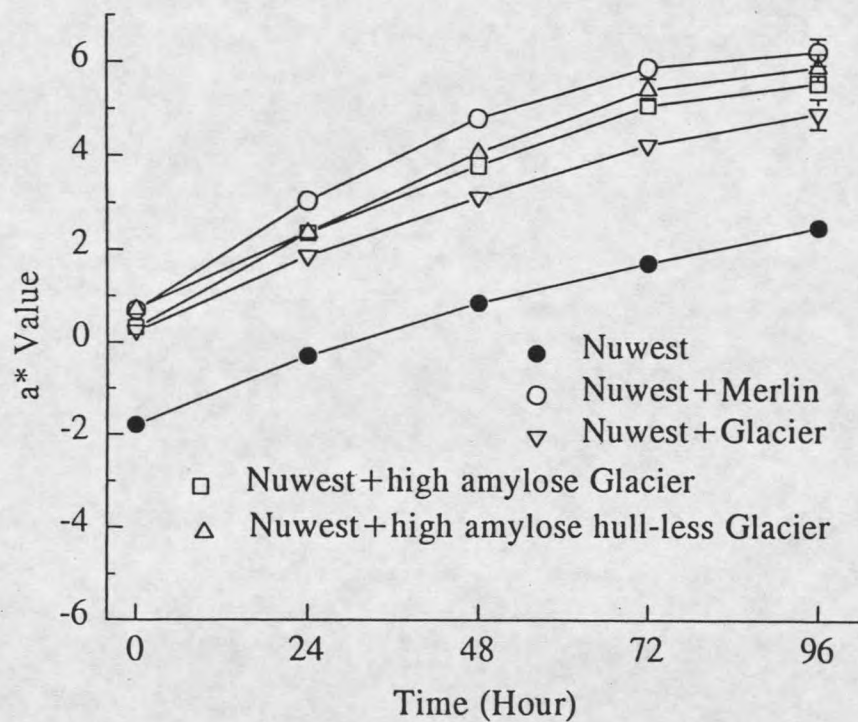


Fig. 20. Changes in a* values of raw doughs during 96 hr storage at 30°C and 85% relative humidity in sealed plastic bags.

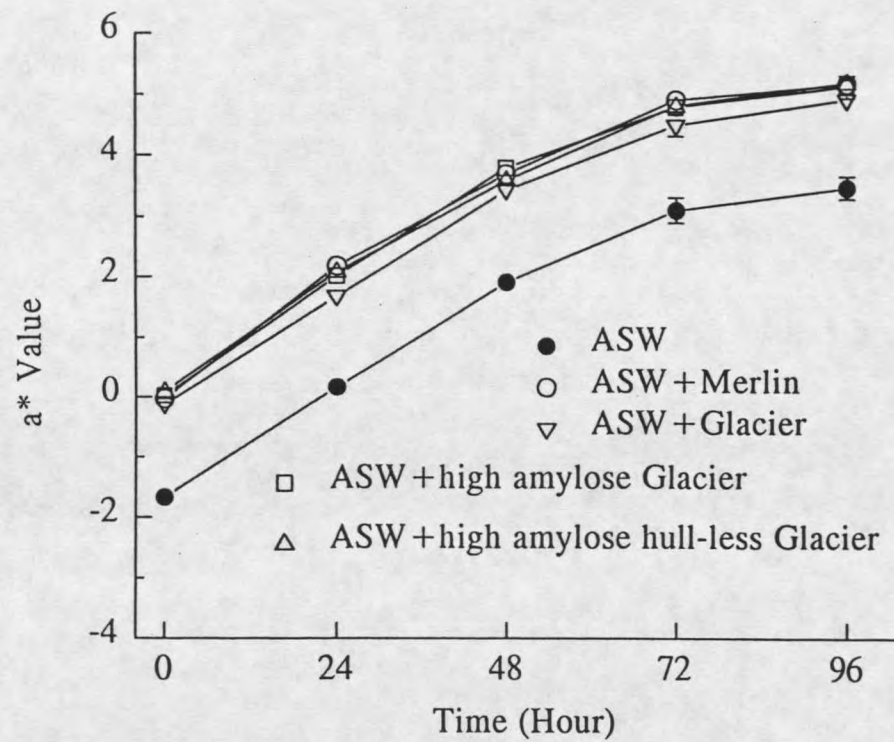


Fig. 21. Changes in a* values of raw doughs during 96 hr storage at 30°C and 85% relative humidity in sealed plastic bags.

not great considering only 5% of the wheat was replaced with barleys, daily consumption of the product is expected to have healthy benefits. Barley flours had higher ether extract and lower starch content than wheat flours.

Incorporation of barley flours into noodle dough decreased L^* (brightness) and b^* (yellowness) values. Among the four barley flours tested, Merlin decreased the L^* value most and b^* value least. Addition of barley flours increased a^* value. This study showed that barley addition into noodles dough would increase the insoluble fiber, soluble fiber, insoluble β -glucan and soluble β -glucan content but would cause undesirable color changes for Chinese noodles. The color change may not be a problem in a dark Japanese noodle such as Soba.

CHAPTER 5

SUMMARY

The effects of machining on color changes in Chinese noodle dough were examined in the study. Three interesting phenomena were observed. First, Chinese noodle doughs produced on the Otake noodle machine had different L^* and b^* values for the tops and bottoms of the dough sheets during the first hr after they were made. The differences appear to be due to the uneven distribution of water at the surfaces of the doughs. The difference in water distribution may be due to the temperature difference between the top and bottom of the dough sheet or differences in forces exerted on either side of the dough sheet during machining. Secondly, L^* values decreased and b^* values increased during the time the dough rested. Passing the dough through the rolls of the machine a second and third time caused a subsequent increase in the L^* values and decrease in the b^* values of the doughs. Thirdly, the changes in the L^* and b^* values which occurred during the first hour after the dough had been passed through the reduction series appeared to be directly related to distribution of water in the dough. After 7 hr, the L^* and b^* values for all dough sheets produced from the same original dough were similar regardless of machining differences. This is significant in that researchers examining various flours for noodlemaking quality should bear in mind that the dramatic differences in L^* and b^* values seen between the initial time the dough is prepared and 1 hr after the dough has

rested is dependent upon distribution of water to the surface of the dough and not upon enzymatic activity occurring throughout the dough. The present study suggests that the surfaces of the doughs appear to become evenly hydrated after 1 hr. of resting and then the effects of other phenomena which may affect the color of the dough can be accurately measured. However, it appears to take approximately 7 hr for all doughs to become fully hydrated and completely accurate color analyses can be performed. However, this time period will vary depending upon the absorption of the flours being studied.

Re-machining doughs which are not completely hydrated appeared to affect the L^* and b^* values due to mechanical reorientation of incompletely hydrated particles of flour at the surface of the doughs. All doughs which exhibited this phenomenon eventually produced identical L^* and b^* values after complete hydration of the dough occurred. Therefore, the first color data should be taken at the point of complete dough hydration and not immediately after the dough is produced for the first accurate representation of the intrinsic color attributes contributed to noodle doughs by a particular flour.

The second part of the study showed Nuwest, a Montana hard white wheat produced Asian noodles which were comparable in quality to those produced from Australian Standard White Wheat (ASW). Most notably, the color and color stability of the noodles produced from Nuwest were closely correlated to the color and color stability of noodles produced from ASW even under conditions which mimicked the environment of South East Asia. Because of its higher flour protein content, Nuwest produced noodles

which had a harder "bite" than the noodles produced from ASW. Additionally, the noodles produced from Nuwest were shown to be less adhesive than the noodles produced from ASW. Nuwest also has comparable breadmaking quality to ASW. Nuwest produces a high quality flour suitable for producing excellent Asian noodles as well as performing well in the breadmaking process.

In the third part of the study, Four Montana barley, Merlin, Glacier, high amylose Glacier, and high amylose hull-less Glacier were added into two wheat flours, Nuwest and ASW. Addition of 5% barley flour into noodle increased the insoluble fiber, soluble fiber, insoluble β -glucan and soluble β -glucan of the product. Although the increase was not great considering 5% of barley being added, daily consumption of the product was expected to have healthy benefits. Barley flours had higher ether extract and lower starch content than wheat flours.

Incorporation of barley flours into noodle dough decreased L^* (brightness) and b^* (yellowness) values, which was undesirable changes in color. Among the four barley flours tested, Merlin decreased the L^* value most and b^* value least. Addition of barley flours increased a^* value; the change from red side to green side. This study showed that barley addition into noodles would have increases in insoluble fiber, soluble fiber, insoluble β -glucan and soluble β -glucan but would have undesirable color change.

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