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Note

Quality Evaluation of Yellow Alkaline Noodles Made from the Kitanokaori Wheat Cultivar

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We examined the relationship between flour/starch properties and the yellow alkaline noodle (YAN) color or physical properties of Kitanokaori, a Hokkaido hard wheat cultivar, and four other samples. Regarding flour properties, Kitanokaori had low polyphenol oxidase (PPO) activity and low amylose content. A time-course experiment showed that a raw noodle sheet made from Kitanokaori had less reduction in color brightness than sheets made from other flour samples that had high PPO activity. This finding suggests that the brightness stability of the Kitanokaori noodle is caused by its low PPO activity. Regarding physical properties and texture, Kitanokaori had high breakdown and low setback viscosity, as measured with a Rapid Visco Analyzer (RVA), and high elastic indices of the starch gel and YAN as a result of the low amylose content. In assessment of the eating quality, the total score of YAN made from Kitanokaori was higher than that obtained from other samples. This was because Kitanokaori had high elasticity and smoothness, which was related to its low amylose content, and the reduction in hardness related to low amylose was suppressed, since the protein properties of Kitanokaori are relatively strong. The results of comparison demonstrated that the superior qualities of YAN made from Kitanokaori could be attributed to the low PPO activity and low amylose content of the flour.

Keywords: Kitanokaori, yellow alkaline noodle, color, texture, polyphenol oxidase, amylose content

Introduction

Yellow alkaline noodles (YAN), including raw, boiled, and steamed noodles, represent almost 50% of all noodles manufactured in Japan. The flavor and texture of YAN are influenced by the addition of 1% alkali, usually a mixture of sodium and potassium carbonates. The key criteria for quality in YAN are color and texture.

Color stability is especially important for YAN because they may be stored for a day or even longer before being purchased. Discoloration, or a reduction in color brightness, is assumed to be caused by the enzymatic reaction of polyphenol oxidase (PPO), peroxidase (POD), phenolic compounds, and subsequent autooxidation products (Pierpoint, 1969; Singleton, 1987; Taylor and Clydesdale, 1987; Hatcher and Kruger, 1993, 1996). Cultivars of wheat and their flours have variable levels of PPO that tend to be related to the rate of discoloration (Baik *et al.,* 1995; Kruger *et al.,* 1992, 1994a, b).

Noodle discoloration is also associated with grain protein content (Baik *et al.,* 1994a, 1995; Lang *et al.,* 1998; Miskelly, 1984; Oh *et al.,* 1985). Baik *et al.* (1995) reported that, within a cultivar, noodle discoloration is affected by protein content more than by PPO. However, the genetic differences between cultivars regarding noodle discoloration are primarily due to PPO (Baik *et al.,* 1995).

The texture of YAN is an important factor influencing consumer acceptance. Ideally, boiled YAN should be firm, springy, and smooth (Miskelly and Moss, 1985; Shelke *et al.,* 1990). In studies of factors affecting the texture of YAN, the protein contents of wheat or flour have been positively associated with noodle firmness (Shirao and Moss, 1978; Shelke *et al.,* 1990; Ross *et al.,* 1997) and negatively linked with smoothness (Konik *et al.,* 1994; Ross *et al.,* 1997). Noodle texture was also affected by protein quality. Flours with stronger dough properties were reported to produce noodles that were firmer (Moss, 1984; Miskelly and Moss, 1985; Ross *et al.,* 1997) and more elastic (Miskelly and Moss, 1985; Ross *et al.,* 1997), but less smooth (Ross *et al.,* 1997).

The improvement of noodle texture has been associated with a lower flour gelatinization temperature (Nagao, 1977), low starch paste stability, or high starch paste peak viscosity (Shirao and Moss, 1978; Moss, 1980; Oda *et al.,*

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1980; Crosbie, 1991; Konik and Moss, 1992; Yun *et al.*, 1996), as well as with high starch and flour swelling power or swelling volume (Endo *et al.*, 1988; Crosbie, 1989, 1991; Toyokawa *et al.*, 1989; Crosbie and Lambe, 1990, 1993; McCormick *et al.*, 1991; Crosbie *et al.*, 1992; Konik *et al.*, 1993; Wang and Seib, 1996; Yun *et al.*, 1996). On the other hand, Baik *et al.* (1994) reported that, in contrast to white salted noodles (WSN), starch characteristics may be less important in other noodle types, including YAN. More recent studies have confirmed the importance of the starch component and reported significant correlations between the textual characteristics of YAN and selected flour pasting characteristics (peak viscosity and breakdown) determined with a Rapid Visco Analyzer (RVA) or swelling parameters measured in flour or wholemeal (Konik *et al.*, 1994; Batey *et al.*, 1997; Ross *et al.*, 1997).

The amylose content has been reported to affect the starch gelatinization, pasting, and gelation properties (Zeng *et al.*, 1997; Araki *et al.*, 2000; Noda *et al.*, 2001). A generally lower amylose content corresponds to higher peak viscosity and breakdown. Hexaploid wheat carries three homologous *Wx* loci, i.e., *Wx-A1, Wx-B1* and *Wx-D1,* on chromosomes 7AS, 4AL, and 7DS, respectively (Chao *et al.*, 1989). Mutation at all three loci results in fully waxy or amylose-free wheat (Nakamura *et al.*, 1995). The lack of the *Wx-B1* protein due to the null *Wx-B1b* allele is the most significant factor for reduction of the amylose content (Miura *et al.*, 1996). Zhao *et al.* (1998) provided evidence for the genetic combination of the null *Wx-B1b* allele with high peak viscosity. Ishida *et al.* (2003) reported that the mechanical properties of WSN are determined primarily by the amylose content of the flour and the properties of the starch gel. They also reported that WSN made from the flours of single-null types, which lack either the *Wx-B1* or the *Wx-D1* protein, and double-null types, which lack both the *Wx-A1* and *Wx-D1* proteins, had desirable textures- especially double-null types.

"Kitanokaori", hard winter wheat cultivar grown in the Hokkaido region in Japan, has unique characteristics; namely, its low amylose content and the high degree of yellow color in its flour. Flour from this cultivar is mainly used for bread; however, it is expected to be suitable for YAN as well. In the present study, we examined the relationship between the above-mentioned characteristics and the noodle color or physical properties of YAN, and evaluated the quality of "Kitanokaori" for YAN.

Materials and Methods

Wheat, flour, and starch samples Kitanokaori, Haruyokoi, Hard Red Winter (HRW), Australian Prime Hard (PH), and commercial strong wheat flour were used in this study. Haruyokoi is the most important hard spring wheat cultivar in the Hokkaido region of Japan. The seeds of Kitanokaori and Haruyokoi were sown in late September 2003 and late April 2004, respectively, in the research field at the National Agricultural Research Center for Hokkaido Region, Memuro, Hokkaido. Kitanokaori was grown in an experimental plot consisting of eight 5-m rows with 15-cm row width, and Haruyokoi was grown in an experimental plot consisting of four 8-m rows with 72-cm row width under standard field management. HRW and PH were provided by the General Food Policy Bureau. The commercial flour, Tenanmon, was purchased from the Nisshin Flour Milling Co., Ltd., Tokyo, Japan.

In order to produce wholemeal flour, wheat samples were milled using the Cutting Mill (ZM 1, Retsch Co., Ltd., Haan, Germany). Wheat samples were also tempered to 16% moisture and milled with a Bühler test mill (Buühler Inc. Uzwil, Switzreland) to produce wheat flour (60% yield). Starch from each flour sample was isolated by the method of Oda *et al.* (1980).

Wholemeal flour, flour, and starch properties The ash content was measured using the rapid (magnesium acetate) method developed by the American Association of Cereal Chemists (AACC) (2000). The protein content of the flour was measured using a near-infrared reflectance instrument (Inframatic 8120, Percon Co., Hamberg, Germany). The amylose content (amylose content/starch content) was determined colorimetrically, as described by Juliano (1971) with modification by National Food Research Institute (1992). Potato amylose was used for calibration. The PPO activity was measured by the oxygen consumption method according to Marsh and Galliard (1986). Oxygen consumption was determined using a YSI model 5300A Biological Oxygen Monitor (Yellow Spring Instrument Co., Yellow Spring, Ohio, U.S.A.). The polyphenol content was measured using the Prussian blue method (Price and Batler, 1977). The pasting properties of the flour were measured using a Rapid Visco Analyzer 3D (RVA) (Newport Scientific Ptd., Ltd., Warriewood, Australia). In 25 ml of a distilled water and *kansui* solution (K_2CO_3, 0.0216 g; Na_2CO_3, 0.0144 g; NaCl, 0.036 g/25 ml distilled water), 3.6 g of flour was dispersed, kept for1 min at 50°, heated to 95℃ at 15℃/min, kept at 95℃ for 4 min, and then cooled to 50℃ at 15℃/min. The peak viscosity, breakdown, and setback viscosity were recorded from the RVA-flour curves. Each assay was carried out in duplicate.

Preparation and color measurement of a YAN dough sheet YAN dough sheets were prepared according to the Japanese standard method with slight modifications. Flour sample weight was calculated as 13.5% moisture base and water was added to produce 34.5% moisture dough (flour sample weight (g)=50*(100−13.5)*100/(100-sample moisture(%)), water volume (ml)=16+(50-sample weight)). Flour and an alkaline *kansui* solution (K_2CO_3, 0.3 g; Na_2CO_3, 0.2 g; NaCl, 0.5 g; distilled water) were mixed for 10 min to obtain a crumbly dough using a domestic-type dough maker (MK SEIKO Co., Ltd., Chikuma, Japan). The dough was folded and passed through a laboratory noodle-making machine (Sanwa-syokai Co., Ltd., Sapporo, Japan) three times at a gap size of 3 mm and then successively passed through three progressively narrower roller settings to achieve a final noodle sheet thickness of 1.4 mm. The dough sheet was then cut into two circles for color analysis.

The noodle sheet color was evaluated using a Minolta CM-3500d chromameter (Minolta Camera Co, Ltd., Tokyo, Japan) using the Commission International De l'Eclairage (CIE) L*(brightness) a* (red-green) b* (yellow-blue) color system. Noodle color was measured immediately after sheeting (0 h), and after storage for 4, 24, 72 h at 25℃.

Preparation and mechanical measurements of YAN, flour, and starch gels YAN noodle sheets were prepared according to the methods noted above, and a noodle sheet was cut into strips of approximately 20 cm in length using cutter (No. 2). Cross sections of 1.5 mm in width were prepared to evaluate the physical properties of YAN. Raw noodle strips were cooked in 3 L of boiling water for 3 min or 7 min (3 min in boiling water and 4 min in boiled water) and then rinsed in a water bath at 20℃ for 1 min. Water on the surface of the noodles was removed by wiping with tissue paper.

Instrumental texture measurements were performed using a RHEONER (model RE-33005, YAMADEN Co., Ltd., Tokyo, Japan) fitted with a 2,000-g-load cell. A cutting test using raw and boiled noodles was performed with a cutting plunger (Type No. 21, YAMADEN Co., Ltd., Tokyo, Japan) at a speed of 5 mm/s. The noodles, cut into 5-cm-long pieces, were placed in the center at right angles to a slot on the sample table (Type No.102, YAMADEN, Co., Ltd., Tokyo, Japan) and cut crosswise with the stainless steel cutter of a cutting plunger. From the force-deformation curves, the maximum force (breaking force) was determined, and the breaking force/breaking deformation value (BF/BD) was calculated. A compression test of boiled noodles was also performed with a wedge plunger (P-31, YAMADEN, Co., Ltd., Tokyo, Japan), as described by Tanifuji *et al.* (2003). From the compression curve, the maximum compressing stress (hardness) was determined, and the elastic index (hardness/stress at compressing to 50% of the maximum deformation) was calculated. These assays were replicated four times.

The flour and starch gels were prepared as follows. The gelatinization of flour and starch was achieved in an RVA. The RVA conditions were equivalent to those described above except that cooling was stopped at 70℃. The obtained 6 g paste was placed in a 50-ml plastic tube with a flat bottom. The paste was centrifuged at 3,000 rpm for 5 min, in order to remove bubbles from the paste and to make the gel to a cylindrical shape with 2.5 cm diameter and 1 cm height. The tube was kept in a water bath at 20℃ for 2 h to completely change the paste into a gel. A compression test of the flour and starch gels was also done with a RHEONER. The flour and starch gels were taken out from the tubes and placed in the center of the RHEONER table, and the gels were compressed to 90% of the first thickness with the use of a circular plunger (Type No. 3, YAMADEN Co., Ltd., Tokyo Japan) at a speed of 1 mm/s. From the compression curve, the maximum compressing stress (hardness) was determined and the elastic index (hardness/stress at compressing to 50% of the maximum deformation) was calculated. The assay was carried out in triplicate.

Sensory evaluation of YAN The sensory evaluation of the YAN was carried out according to procedures based on the Japanese standard. Sixty-seven grams of raw noodles were cooked in 3 L of boiling water for 3 min. Six panelists performed a sensory evaluation of the texture of the YAN. This assessment included three parameters: hardness, elasticity, and smoothness, because in general, these are considered in many reports to be the most important textures that are used as assessment parameters for YAN. Panelists compared the eating quality of YAN on a scale of 5.0 points (0 = minimum, 5.0 = maximum). The most popular commercial strong flour, Cameriya, in Japan was scored 2.5 as control.

Statistical Analysis Statistical analysis was performed using the data analysis tools of Microsoft Excel, according to the LSD Multiple Range test.

Results and Discussion

Protein, ash, polyphenol, amylose content, and PPO activity The characteristics of the flour quality of the five wheat samples are summarized in Table 1. PH had the highest flour protein content (13.0%), and commercial flour had the lowest flour protein content (11.2%). The other three samples ranged from 11.5% to 12%.

The wholemeal flour ash content of PH was lower than the other samples, and there was no significant difference among the other samples, in which the flour ash contents were highest for Kitanokaori and Haruyokoi and lowest for commercial flour.

The wholemeal flour PPO activity and polyphenol content were lowest in Kitanokaori; those of the other three samples were higher. On the other hand, Kitanokaori, PH, and commercial flour had low flour PPO activity and low flour polyphenol content. PPO and polyphenol localize in the aleuron and bran layers. Kitanokaori and PH had low flour PPO activity and polyphenol content, but PH had higher wholemeal flour PPO activity and polyphenol content than Kitanokaori, and these values were similar to those of Haruyokoi and HRW. These findings indicated that the lower flour PPO activity and the lower polyphenol content of PH were caused by decreased contamination by the aleuron and bran layers, and those of Kitanokaori were caused by lower grain PPO activity and polyphenol content.

Kitanokaori and Haruyokoi had the lowest amylose contents, and HRW had the highest amylose content. Using the method of Nakamura *et al.* (2002), it was identified that Kitanokaori and Haruyokoi are cultivars of the null *Wx-B1b* allele type, and HRW is composed of the wheat cultivar of the wild type. PH and commercial flour had an intermediate content. Therefore, it was suggested that PH and commercial flour are composed of mixed cultivars of the null *Wx* allele type and the wild type.

Color of flour paste and raw noodle sheet of YAN The color of the flour paste and raw YAN of the five wheat samples is shown in Table 2.

Regarding the flour paste, the brightness (L* value) of commercial flour was rated highest; followed by PH; and Kitanokaori had the lowest L* value. The degree of red (a* value) was lowest for PH and commercial flour, and highest for that of Kitanokaori and HRW. Kitanokaori

Table 1. Analytical properties of wholemeal flours and flours.

Cultivars	Protein (%)	Ash (%)		PPO activity (nmol O_2/min/g)		Polyphenol (mg/g)		Amylose (%)
	flour	Wholemeal flour	flour	Wholemeal flour	flour	Wholemeal flour	flour	flour
Kitanokaori	11.5 cd	1.71 a	0.55 a	187 b	22.4 c	0.490 c	0.131 c	22.5 c
Haruyokoi	11.9 b	1.73 a	0.54 a	282 a	24.0 b	0.532 a	0.148 a	22.7 c
HRW	11.8 bc	1.57 a	0.46 b	271 a	25.4 a	0.537 a	0.143 b	26.4 a
PH	13.0 a	1.38 b	0.45 b	272 a	22.6 c	0.510 b	0.132 c	24.7 b
Commercial flour	11.2 d	-	0.38 c	-	19.7 d	-	0.102 d	25.1 b

Values followed by the same letter in the same column are not significantly different according to the LSD Multiple Range test at $p<0.05$ ($n=2$).

Table 2. Color of Flour Paste and Raw Yellow Alkaline Noodles.

Cultivars	Flour Paste			Noodle								
				L*			a*			b*		
	L*	a*	b*	0h	72h	Δ0-72h	0h	72h	Δ0-72h	0h	72h	Δ0-72h
Kitanokaori	87.0 d	1.35 a	20.9 a	80.1 b	66.6 b	-13.5 a	0.19 a	2.10 d	1.91 c	31.5 a	33.2 a	1.71 a
Haruyokoi	87.5 c	1.07 ab	14.2 cd	78.5 b	60.8 c	-17.7 c	-0.11 b	2.77 b	2.88 b	26.7 b	24.5 b	-2.18 c
HRW	87.8 c	1.28 a	16.3 b	79.6 b	61.9 c	-17.6 c	-0.28 c	3.07 a	3.35 a	27.1 b	24.2 b	-2.88 d
PH	88.7 b	0.61 bc	13.7 d	79.6 b	66.4 b	-13.2 a	-1.04 d	2.24 c	3.27 a	26.7 b	21.4 c	-5.22 e
Commercial flour	89.2 a	0.54 c	15.1 c	84.7 a	70.1 a	-14.6 b	-0.92 d	0.69 e	1.62 d	22.5 c	22.1 c	-0.41 b

Values followed by the same letter in the same column are not significantly different according to the LSD Multiple Range test at $p<0.05$ ($n=2$). ⊿0-72 h=L*, a*, b* (0 h) L*, a*, b* (72 h).

had the highest degree of yellow (b* value), and PH had the lowest.

Noodle sheet brightness was the highest for commercial flour, as measured immediately after sheeting (L* (0 h)), and the other samples had similar values. The degree of red (a* (0 h)) was lowest for commercial flour and PH, and highest for Kitanokaori. The degree of yellow (b* (0 h)) was highest for Kitanokaori, and lowest for commercial flour. Kitanokaori had inferior flour paste brightness, but its noodle sheet brightness was similar to that of the other samples, with the exception of commercial flour.

The noodle sheet brightness measured after storage for 72 h at room temperature (L* (72 h)) was highest for commercial flour, followed by Kitanokaori and PH. The degree of red (a* (72 h)) was lowest for commercial flour, followed by Kitanokaori. The degree of yellow (b* (72 h)) was highest for Kitanokaori.

The change in noodle sheet color during storage is summarized in Fig. 1. The L* of all samples decreased and the a* of all samples increased over time. On the other hand, the b* of all samples increased until 4 hours after sheeting, followed by a gradual decrease. The decrease in the L* value of Kitanokaori, PH, and commercial flour from 0 until 72 h(⊿L*=L*(0 h)-L*(72 h)) was smaller than that of the other flours (Table 2). Baik *et al.* (1994a, 1995) and Kruger *et al.* (1994b) reported that PPO in flour causes a reduction in noodle brightness and a decrease in color stability over time. In this study, Kitanokaori, PH, and commercial flour had the lowest PPO activity (Table 1). Therefore, it was suggested that the brightness stability of these three samples was caused by their low PPO activity. On the other hand, the increase or decrease for ⊿a* (a*(0 h)-a* (72 h)) and ⊿b* (b*(0 h)-b* (72 h)) was smallest for Kitanokaori and commercial flour, and largest for PH. It has also been reported that high grain protein content was associated with discoloration (Baik *et al.,* 1994

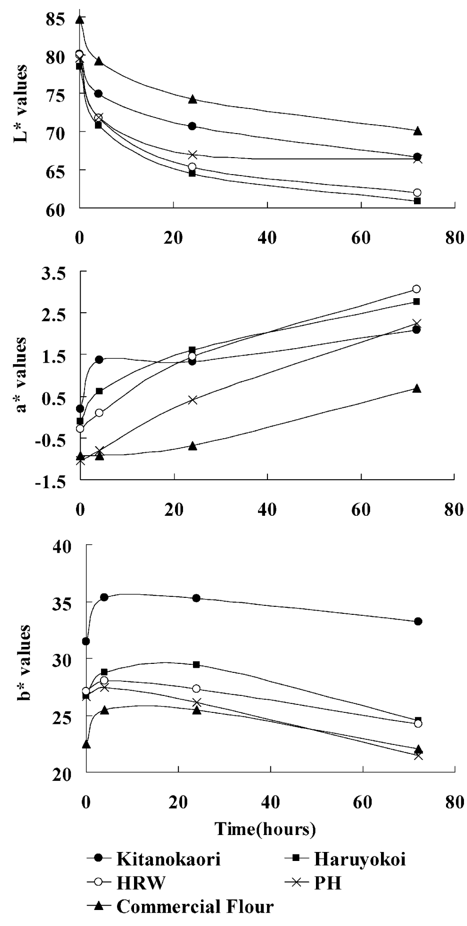

Fig. 1. Changes in brightness (L*), redness (a*) and yellowness (b*) in yellow alkaline noodles across time.
●: Kitanokaori, ■: Haruyokoi, ○: HRW, ×: PH, ▲: commercial flour.

Table 3. Pasting Properties of Hours Using Water and a Solution Containing NaCl and Kansui (w/w).

Cultivars	Water			NaCl+Kansui		
	Peak Viscosity (RVU)	Breakdown (RVU)	Setbak (RVU)	Peak Viscosity (RVU)	Breakdown (RVU)	Setbak (RVU)
Kitanokaori	232 b	119 a	44.9 b	302 a	163 a	41.9 c
Haruyokoi	234 b	117 a	39.0 c	265 b	103 d	43.6 c
HRW	232 b	76 c	55.2 a	242 c	90 e	58.6 b
PH	237 ab	103 b	53.7 a	237 c	113 c	72.3 a
Commercial flour	242 a	105 b	55.2 a	264 b	122 b	64.6 ab

Values followed by the same letter in the same column are not significantly different according to the LSD Multiple Range test at $p < 0.05$ ($n = 2$).

Table 4. Physical Properties of Flour and Srarch Gels Made by Using a Solution Containing NaCl and Kansui (w/w).

Cultivars	Flour gel		Starch gel	
	Hardness ($N/m^2 \times 10^3$)	Elastic Index(-)	Hardness ($N/m^2 \times 10^3$)	Elastic Index(-)
Kitanokaori	5.80 c	2.99 b	18.0 c	4.03 b
Haruyokoi	7.33 b	3.30 a	19.6 bc	4.51 a
HRW	10.63 a	2.95 b	25.6 a	3.60 c
PH	7.33 b	2.78 c	20.6 b	3.73 bc
Commercial flour	7.20 b	2.80 c	18.5 c	3.49 c

Values followed by the same letter in the same column are not significantly different according to the LSD Multiple Range test at $p < 0.05$ ($n = 3$).

a, 1995; Lang *et al.,* 1998; Miskelly, 1984; Oh *et al.,* 1985), and it is suggested that the large Δa^* and Δb^* for PH was caused by its high grain protein content.

Pasting properties of flour The pasting properties of flours using water and the solution containing NaCl and *kansui* are shown in Table 3. A small variation was found in the RVA peak viscosity using water. Regarding breakdown, Kitanokaori and Haruyokoi had the highest values, and HRW had the lowest. PH and commercial flour had intermediate values. Haruyokoi had the lowest setback, followed by Kitanokaori, and the other samples had similar values. Ishida *et al.* (2003) reported that the null *Wx-B1b* allele type had higher breakdown and lower setback than the wild type, which can explain our results. These pasting properties, high breakdown and low setback, generally indicate that the paste has high viscosity and a smaller increase in hardness over time.

Using a solution containing NaCl and *kansui,* a large variation was found in the peak viscosity, and Kitanokaori had the highest value. Kitanokaori had the highest breakdown, and HRW had the lowest breakdown. Kitanokaori and Haruyokoi had the lowest setback, followed by HRW, while PH had the highest value. The peak viscosity of Kitanokaori and Haruyokoi was higher using NaCl and *kansui* than using water. It is generally accepted that *kansui* increases springiness and the expansion of protein and promotes starch gelatinization. Therefore, *kansui* promoted the gelatinization of low amylose flours more than high amylose flours. In addition, the breakdown of Kitanokaori using *kansui* was also higher than using water. Thus, regarding Kitanokaori flour, the change in the pasting properties resulting from *kansui* was larger than that in other samples, but the reason could not be clarified in this study.

Physical properties of flour and starch gels The physical properties of flour and starch gels made using a solution containing 0.13% each of salt and *kansui* (w/w) are shown in Table 4. Regarding the flour gels, hardness was highest for HRW and lowest for Kitanokaori, PH, Haruyokoi and commercial flour had intermediate values. The elastic index was highest for Haruyokoi, followed by Kitanokaori and HRW, and lowest for PH and commercial flour.

Regarding the starch gels, hardness was highest for HRW, and lowest for Kitanokaori and commercial flour. The elastic indices of Haruyokoi and Kitanokaori, which are low amylose flours, were higher than that of high amylose flours, indicating a relationship between the elastic index of starch gel and the amylose content.

Mechanical properties of raw and boiled YAN The force-deformation curve showing the mechanical properties of noodles from Kitanokaori flour is shown in Fig. 2. The measured properties of the noodles were breaking force (BF), breaking deformation (BD), and BF/BD. The mechanical properties of raw and boiled YAN are shown in Table 5.

Raw noodles were harder than boiled noodles. In raw noodles, a large variation was found in BF. PH had the highest value, and Haruyokoi, the lowest. BD was highest for HRW and PH, and lowest for Haruyokoi. BF/BD was lowest for Haruyokoi, and highest for Kitanokaori and PH. However, no relationship was observed among BF, BD and BF/BD in regards to protein or amylose content.

In boiled noodles (3 min), BF was highest for PH, followed by Haruyokoi. BD was highest for Kitanokaori,

Table 5. Physical Properties of Raw and Boiled Yellow Alkaline Noodles.

Cultivars	Raw BF ($N \times 10^{-1}$)	Raw BD (mm)	Raw BF/BD ($N/mm \times 10^{-1}$)	Boiled(3min) BF ($N \times 10^{-1}$)	Boiled(3min) BD (mm)	Boiled(3min) BF/BD ($N/mm \times 10^{-1}$)	Boiled(7min) BF ($N \times 10^{-1}$)	Boiled(7min) BD (mm)	Boiled(7min) BF/BD ($N/mm \times 10^{-1}$)	Boiled(3min) Elastic Index(-)	Boiled(7min) Elastic Index(-)
Kitanokaori	10.50 b	3.98 bc	2.64 a	4.41 c	5.18 ab	0.86 d	2.55 b	3.83 a	0.67 b	4.76 ab	3.78 a
Haruyokoi	4.61 d	3.75 c	1.23 c	4.81 b	4.90 bc	0.98 cd	2.60 b	3.80 a	0.69 b	5.00 a	3.58 ab
HRW	9.81 bc	4.63 ab	2.12 b	4.46 c	3.85 d	1.16 b	3.29 a	3.40 a	0.97 a	3.88 c	3.06 c
PH	14.32 a	5.18 ab	2.78 a	5.49 a	3.98 d	1.38 a	3.29 a	3.40 a	0.97 a	4.65 ab	3.13 bc
Commercial flour	9.27 c	4.45 bc	2.10 b	4.51 c	4.45 cd	1.02 bc	2.55 b	3.30 a	0.78 b	4.49 b	3.21 bc

Values followed by the same letter in the same column are not significantly different according to the LSD Multiple Range test at $p < 0.05$ ($n = 4$).
BF: breaking force, BD: breaking deformation.

Table 6. Eating Quality Assessment of Boiled Yellow Alkaline Noodles.

Cultivars	Hardness	Elasticity	Smoothness	Total Score
Kitanokaori	3.00 a	3.83 a	3.83 a	10.67 a
Haruyokoi	2.33 a	3.50 ab	3.33 ab	9.17 b
HRW	2.83 a	2.50 c	2.67 b	8.00 b
PH	3.17 a	3.17 bc	3.33 ab	9.67 ab
Commercial flour	2.50 a	2.83 bc	3.17 ab	8.50 b

Values followed by the same letter in the same column are not significantly different according to the LSD Multiple Range test at $p < 0.05$ ($n = 6$).

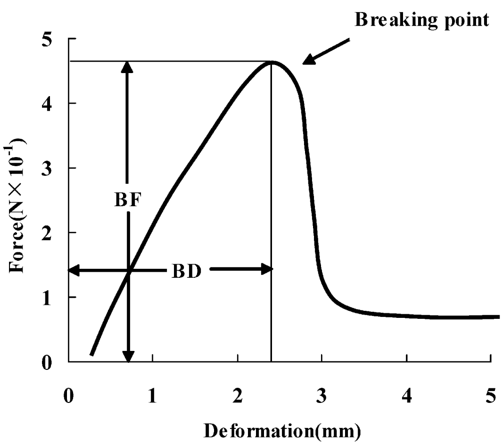

Fig. 2. Force deformation curve showing the mechanical properties of noodles from Kitanokaori flour.
BF: breaking force, BD: breaking deformation.

followed by Haruyokoi. BF/BD was lowest for Kitanokaori, followed by Haruyokoi. BD and BF/BD of boiled noodles are suggested to be related to amylose content. Ishida *et al.* (2003) reported that BD tended to increase and BF/BD tended to decrease in boiled WSN when the amylose content was lower, and that lower amylose content produced more elastic, softer noodles. Our results for YAN are in agreement with those of Ishida *et al.* for WSN.

On the other hand, in case of boiled noodles (7 min), BF was highest for HRW and PH, while values for Kitanokaori, Haruyokoi and commercial flour decreased over time. BD of all samples had similar values, and BF/BD was lowest for Kitanokaori and Haruyokoi.

The results of the elastic index in a compression test are also shown in Table 5. In boiled noodles at 3 and 7 min, the elastic index was highest for Kitanokaori and Haruyokoi, and lowest for HRW. These results indicate that low amylose flour has high elastic index over time.

Eating quality assessment of boiled YAN The results of the eating quality assessment of YAN are shown in Table 6. No significant difference was observed among the samples for hardness. The elasticity was highest for Kitanokaori and Haruyokoi, and lowest for HRW. This assessment provided further evidence that YAN made from low amylose flours had more elasticity than those made from high amylose flours. The relationship between eating quality-assessed elasticity and amylose content agrees with the relationship between elastic indices of starch gel and boiled YAN and amylose content. The smoothness was rated highest for Kitanokaori, followed by Haruyokoi and PH. HRW was the lowest. The findings suggest that smoothness is also related to amylose content. The total score was highest for Kitanokaori, which suggests that low amylose flour has a suitable texture, especially in regards to elasticity and smoothness, for YAN.

Quality assessment of Kitanokaori for YAN Kitanokaori contains two characteristics that are very important for the color and texture of YAN, namely, low PPO activity and low amylose content.

YAN made from Kitanokaori had a brightness stability caused by low PPO activity. In addition, changes in the degree of red and yellow were smaller than those observed in other samples. Kitanokaori results in flour and YAN with a high degree of yellow coloring. These color properties of Kitanokaori are superior for YAN.

Regarding physical properties and texture, Kitanokaori had high breakdown and low setback viscosity, as measured with an RVA, high elastic indices of both starch gel and YAN, and high elasticity and smoothness in the eating quality of the boiled YAN, as a result of low amylose content. In assessment of the eating quality, the total score of YAN made from Kitanokaori was also significantly higher than that obtained from YAN using other samples, with the exception of PH. In previous reports, it was demonstrated that YAN made from low amylose flour had good elasticity and smoothness, but was less hard (Ross *et al.,* 1997; Tanaka *et al.,* 2006). It was also reported that hardness is a very important aspect of the eating texture of YAN, as are elasticity and smoothness, which were different from those of the WSN (Miskelly *et al.,* 1985; Akashi *et al.,* 1999). In fact, the results regarding the physical properties of boiled noodles (Table 5) show that the BF of Kitanokaori was smaller than high amylose flour, HRW, and flour with relatively low amylose, PH; furthermore, the elastic index of Kitanokaori was also higher than HRW and PH, in agreement with the reports above. Conversely, although the results of the elasticity and smoothness from the eating quality assessment (Table 6) agreed with previous reports, the hardness of YAN made from the low amylose flour, Kitanokaori, was not inferior to HRW and PH. The large dispersion of hardness score and strong protein properties of Kitanokaori seem to be related to the above result of hardness on the eating quality. The strong protein properties of Kitanokaori are indirectly demonstrated by the BF of raw Kitanokaori noodles, shown in Table 5, which had a higher value that those obtained from the other samples, with the exception of PH. This value is related to the physical properties of the flour protein. The reasons that the Kitanokaori noodles had the highest score for the eating quality assessment are as follows. YAN made from Kitanokaori had high elasticity and smoothness, which were related to its low amylose content, and the reduction in hardness that is also related to low amylose was suppressed, since the protein properties of Kitanokaori are relatively strong. Therefore, it was concluded that the texture of YAN made from Kitanokaori was superior to that of noodles obtained from other wheat cultivars.

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