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Quantitative assessment of protein fractions of Chinese wheat flours and their contribution to white salted noodle quality

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Abstract

Protein quantity and quality play a significant contribution to white salted noodle processing. The objective of this study was to determine the contribution of different protein fractions to 25 Chinese varieties on wheat based noodle quality. The results showed: the average ratio of monomeric protein, soluble glutenin and insoluble glutenin in Chinese Huanghuai winter wheat was 3.7:1.0:1.8. Compared with Canadian wheat varieties, the ratio was 4.4:1.0:2.0. The monomeric protein and insoluble glutenin were lower in the Chinese varieties, the soluble glutenin content was higher; while the dough character was lower than Canadian hard wheat, but most Chinese wheat can make good quality noodles. This may be the defining difference between noodle wheat and bread wheat. The monomeric protein content was significant positive correlated with fresh noodle maximum resistance, and high significant positive with extension distance and area. The soluble and insoluble glutenin were mainly responsible in fresh noodle maximum resistance, extension distance and using a texture analyzer, but were high negative correlated with fresh noodle sheet length (Table 2). For cooked noodles, the soluble glutenin content demonstrated a high significant positive relationship to cutting firmness, and a significant negative correlation to cooking loss. The insoluble glutenin content was high significant positive correlated with cooked noodle thickness, hardness and cutting firmness (Table 3). The results suggested that the monomeric protein is less important than that of the glutenin for fresh noodle resistance. The soluble glutenin content is the most important property for noodle wheat, and soluble glutenin content can be used in the early generations to identity Chinese noodle wheat.

Keywords: Wheat; Noodle quality; Monomeric protein; Soluble glutenin; Insoluble glutenin

1. Introduction

About 40% of wheat products in Asian countries are consumed in the form of noodles (Crosbie, Miskelly, & Dewen, 1990). The most extensively studied white salted noodle type is Japanese Udon, but Chinese white salted noodles have also received some consideration (Hou, 2001). There are many reports on the contribution of the protein fractions to bread-making quality, but few researches have been carried out on the functionality of protein fractions on noodle quality. Therefore, it is necessary to evaluate the protein characteristics related to noodle making quality to determine the suitability of wheat flour for making noodles and to develop objective methods for screening wheat in breeding programs (Park, Hong, & Baik, 2003).

Quantity characteristic that contribute to the production of improved white salted noodles include high starch pasting peak viscosity, low protein content, soft grain texture, and high protein quality as measured by SDS sedimentation value (Wang, Kovacs, Fowler, & Holley, 2004). Many researchers agree that protein content of wheat has a

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negative relationship with noodle color and a positive relationship with texture properties, especially the hardness of cooked noodle (Baik, Zuzanna, & Yeshajahu, 1994; Hatcher, Kruger, & Anderson, 1999; Miskelly, 1984; Morris, Jeffers, & Engle, 2000; Park et al., 2003). Protein content of wheat flours determines the uses of wheat for specific food products and has served as an index for the predication and evaluation of flour quality for end products. Flours with ≈10% protein content are acceptable for making white salted noodles (Nagao et al., 1997; Park et al., 2003).

Few investigations have been done in determining the contribution of protein fraction composition for noodle quality. Insoluble glutenin content plays an important role in fresh noodle quality, and is directly related to optimum cooking time, fresh noodle cutting force and cooked noodle resilience (Baik et al., 1994; Huang & Morrison, 1998; Wang & Kovacs, 2002b). SDS sedimentation volume based on constant protein weight, proportion of salt-soluble protein, and score of HMW-GS compositions correlated with optimum water absorption of noodle dough and hardness of cooked white salted noodles (Park et al., 2003).

Therefore, establishing a protein quality standard of wheat for making Asian noodles and developing an efficient methodology for measuring protein quality is critical for identifying cultivars possessing the required protein characteristics for making noodles and for screening breeding lines for noodle quality. Currently, there are intensive breeding efforts to develop wheat cultivars suitable for making noodles. However, little information is available for selecting wheat based products on protein quality.

The objectives of this study were to determine the influences of protein fractions and their content on processing characteristics of flour and texture properties of noodles. A secondary objective was to compare the protein quality and noodle processing between Chinese white salted noodle commercial flour, Chinese and Canadian wheat varieties. The information between protein fractions and noodle quality was found to be helpful for breeding commercial wheat for noodle purpose.

2. Materials and methods

2.1. Wheat samples

In 2001, a set of 25 typical widely cultivated wheat varieties from Shaanxi and Henan provinces, were used in this experiment. Wheat was tempered according to its hardness, milled with a Brabender Junior pilot mill, yielding ≈60% flour. Two commercial wheat flours suitable for making Chinese white salted noodle and Japanese Udon noodle were obtained from the Xinjiang Tianshan flour company (Xinjiang, China) and the Nippon flour company (Tokyo, Japan). The flour was stored in a cool room at −5 °C before experiment.

The 25 Canadian wheat flours that was chosen to compare the protein quality between Chinese and Canadian wheat varieties came from Cereal Research Centre of Winnipeg (Wang & Kovacs, 2002a, 2002b, 2002c).

2.2. Protein extraction and determination

Protein was fractionated according to the procedure of Wang and Kovacs (2002a). This procedure classified the proteins into three fractions: monomeric protein, soluble glutenin and insoluble glutenin. The procedure used to compare the protein fractions in the two sources of wheat was the same as employed by Wang and Kovacs (2002c).

2.3. Noodle making and texture of cooked noodles

Fresh white salted noodles (Chinese style noodles) were made according to the procedures described by Wang and Kovacs (2002b).

Sheets were cut into 6.2 mm × 1.0 mm cross-section noodle strands. The fresh noodles were put into plastic bags for 2 h (23 °C, RH80%).

A set of three fresh noodles was placed parallel on the flat panel of a texture analysis machine (Micro Stable System, Texture analyzer TA.XT/2i, Hasteners, England) and a Kieffer extensibility rig was used to measure the fresh noodle extensibility. The parameters were as follows: pretest speed 5.0 mm/s, test speed 3.3 mm/s, test distance 50 mm, and trigger force 5 g. The fresh noodle quality indexes were maximum extensibility, area, and length of fresh noodle extension.

Eighteen strands of raw noodles were cooked in a beaker with 2000 mL distilled water. The optimum cooking time for noodles was from the time the noodles were placed in boiling water until the noodle's white core disappeared. The cooking time was evaluated by squeezing the strand between two transparent plates (Oh, Seib, Deyoe, & Ward, 1983). The cooked noodles were taken out, and cooled in another beaker containing 300 mL of distilled water at room temperature. Texture profile analysis (TPA), surface firmness, compression, and cutting firmness were then determined.

A set of three strands of cooked noodles was placed parallel on a flat metal plate and compressed crosswise twice to 70% of their original height, using the 3.175 mm metal blade. The testing parameters of the TPA test were carried out according to Baik et al. (1994). From force–time curves of the TPA, the hardness (height of the peak) and adhesiveness (negative area between the first and second peak) were determined. Springiness was indicated by the ratio between the recovered height after second compression and the height of the first compression. Cohesiveness was indicated by the ratio between the area under the second peak and the area under the first peak. Cutting and surface firmness were determined by the method of Oh, Seib, Deyoe, and Ward (1985). The test speed and test distance of cutting firmness and surface firmness were 0.8 mm/sec, 5.0 mm and 0.2 mm/sec, 20%.

2.4. Analytical tests

Flour protein ($N \times 5.7$) was determined by American Association of Cereal Chemist (AACC) approved method 46-13 (American Association of Cereal chemists, 2000). Cooking loss was measured according to American Association of Cereal chemists (2000) method 66-50. Cooking loss is the dry matter divided by the noodle weight.

2.5. Statistical analysis

All measurements were conducted at least in duplicate and all values were averaged. Correlations between protein fractions and noodle qualities were calculated using data analysis tools in Microsoft Excel 97. Twenty-five Chinese wheat variety's noodle processing quality was averaged to compare with Canadian wheat varieties, Japanese Udon commercial flour, and Chinese noodle commercial flour.

3. Results and discussion

3.1. Protein quality

The monomeric protein is composed of albumin, globulin and gliadin. Salt-soluble protein includes albumin and globulin, while 50% 1-propanol-soluble protein includes albumin, globulin and gliadin, and soluble glutenin (Sapirstein & Fu, 1998). Though Chinese wheat varieties had higher monomeric protein than Japanese Udon and Chinese noodle flour, but for the monomeric protein content in the total protein content, there were no significant differences (Table 1). For 25 Chinese wheat flours, the higher monomeric protein contributed to higher protein content.

The absolute and relatively soluble glutenin content of 25 Chinese wheat varieties were all higher than Japanese Udon flour and Chinese noodle special flour (Table 1). The soluble glutenin is made up of low molecular weight glutenin subunits, and makes an important contribution to wheat products processing property.

Japanese Udon's proportion of insoluble glutenin to total protein was higher than the Chinese wheat varieties. Ratios of glutenin content to total protein, Chinese wheat varieties (26.57%), and Chinese noodle commercial flour (27.10%) had lower ratios of glutenin content to total protein than Japanese Udon flour (31.18%) (Table 1).

The same methods have been used by Wang and Kovacs (2002c) to study Canadian wheat protein characteristics. They found that the proportion of the average monomeric protein content, soluble glutenin content and insoluble glutenin content of Canadian wheat was 4.4:1.0:2.0, the proportion of durum wheat was 2.5:1.0:1.5 (Wang & Kovacs, 2002c). In this research, the proportion of Chinese wheat was 3.7:1.0:1.8. Generally speaking for Chinese varieties, the soluble glutenin content was higher, the monomeric content and the insoluble glutenin content were lower, while the dough character was better than durum but worse than Canadian hard wheat.

Table 1
Protein characteristics of wheat flours and commercial flours

	Average of Chinese ($n = 25$)	Japanese Udon	Noodle flour
MP (%)	5.71 ± 1.09ab	4.39b	5.24b
SG (%)	1.66 ± 0.54b	1.19b	1.47b
IG (%)	3.11 ± 0.65ab	2.73b	2.90b
PRO (%)	11.63 ± 1.58ab	8.83b	10.70b
MP/P (ratio)	49.17 ± 7.02a	49.66a	48.97a
SG/P (ratio)	14.34 ± 4.38ab	13.50b	13.74b
IG/P (ratio)	26.57 ± 3.53a	31.18a	27.10a
FNL (mm)	62.17 ± 2.90a	60.50ab	60.00ab
FNT (mm)	1.17 ± 0.08a	1.21a	1.20a
MEXT (g)	110.78 ± 25.75b	92.79b	113.27b
Area (g × mm)	309.91 ± 193.07b	238.20b	160.72b
Length (mm)	14.14 ± 5.02ab	13.83ab	8.78b
CTH (mm)	1.81 ± 0.14a	1.85a	1.84a
CFM (g)	522.80 ± 83.66ab	456.90b	551.13ab
CHD (g)	2300.6 ± 242.76a	1838.0b	2247.2ab
ADH (g × mm)	−120.96 ± 43.36a	−152.62a	−131.93a
SPR (ratio)	0.96 ± 0.03b	0.98ab	1.03a
COHE (ratio)	0.65 ± 0.05b	0.74a	0.66b
OPT (s)	375.3 ± 91.41a	390.0a	470.0a

Values within a row labelled with same letter are not significantly different ($\alpha = 0.05$); ±standard deviation

MP – monomeric protein content; SG – soluble glutenin content; IG – insoluble glutenin content; PRO – protein content, MP/P – monomeric protein content divided by the flour protein content; SG/P – soluble glutenin content divided by the flour protein content; IG/P – insoluble glutenin content divided by the flour protein content; FNL – fresh noodle length; FNT – fresh noodle thickness; MEXT – maximum extensibility of fresh noodle, Area – area of fresh noodle extension; Length – length of fresh noodle extension; CTH – cooked noodle thickness; CFM – cutting firmness; CHD – cooked noodle hardness; ADH – cooked noodle adhesiveness; SPR – cooked noodle springiness; COHE – cooked noodle cohesiveness; OPT – dry noodle optimum cooking time.

3.2. Fresh and cooked noodle characteristic and texture properties

Using a small specialist machine to give noodles of repeatable sheet length and thickness, the results provide two good indexes; fresh noodle sheet length and noodle thickness, for measuring fresh noodle quality. The more stable the dough remains, the greater the noodle sheet contraction, the more the noodle sheet shortens, and the thicker the noodle sheet becomes. Noodle made of Chinese wheat had highest fresh noodle sheet length (62.17 mm) but lowest noodle thickness (1.17 mm) (Table 1). Chinese wheat flours had higher fresh noodle extension length, energy and maximum extensibility. When noodles were cooked, Japanese Udon has significant difference in cutting hardness and cohesiveness. Chinese wheat flour noodles had higher surface firmness, texture profile analysis hardness, gumminess, and lower adhesiveness than Japanese Udon flour. Of course, these results could have been related to the strong possibility that the Udon flour was lower in amylase compared to the Chinese flour. As the Japanese preference for Udon is based on the softer, slightly more elastic and adhesive texture.

There was no consistence in adhesiveness and cohesiveness of cooked noodles between different 25 wheat flours. Commercial flour had higher springiness, optimum cooking time and fresh noodle sheet length. Still, adhesiveness of cooked noodles was much lower in Chinese wheat varieties and noodle commercial flour than Japanese Udon flour and waxy wheat flours. Cohesiveness of cooked noodles was similar with the tendency of adhesiveness; this found was similar with Park et al. (2003).

During the noodle processing procedure, most Chinese wheat flour can make good noodles and the noodle sheet is smooth, but for Canadian wheat varieties, only varieties with desirable protein content can make good noodles. The higher or lower protein content varieties do not make quality noodles, because the noodle sheet is not smooth, and it sticks to the roller. We found that most Chinese wheat varieties have higher soluble glutenin content and may be the defining difference between noodle wheat and bread wheat.

3.3. Relationships between protein fractions and fresh noodle properties

The soluble and insoluble glutenin content had a high significant negative relationship to fresh noodle sheet length, and a high significant positive relationship to fresh noodle sheet thickness (Table 2). In all cases, the higher the soluble glutenin content, the more contraction during noodle sheeting, and the thicker and shorter the noodle sheet was following the same noodle processing procedure. From the fresh noodle extensibility test, it can be concluded that soluble glutenin and insoluble glutenin content had a high significant positive correlation with fresh noodle maximum resistance, extension length and extension energy. The monomeric protein content also had a significant relationship of all the 0.05 or the 0.01 level with the fresh noodle extension ability. As a result, noodle processing is not only related to glutenin content, but also with the soluble glutenin content. The soluble glutenin content was negatively related to maximum extension resistance and energy (Sapirstein & Fu, 1998). The low molecular glutenin subunits were significantly correlated with dough extensibility (Andrews & Skerwitt, 1996). Insoluble glutenin content was significantly related to maximum extension resistance (Gupta, Batey, & MacRitchie, 1992). In this research, for Chinese wheat varieties, the monomeric protein content showed no relationship with other protein quality indexes, which corresponded with the results from Sapirstein and Fu (1998). Thickness of the noodle dough sheet generally increased as flour protein content increased. Proportion of salt-soluble protein correlated positively with optimum water absorption of noodle dough and negatively with thickness of noodle dough sheets. Protein quality determined by SDS sedimentation volume with constant protein basis, mixograph mixing time, proportion of salt-soluble protein, and HMW-GS composition influence water absorption of noodle dough and thickness of the noodle dough sheet in white salted noodles Kruger, Anderson, and Dexter (1994).

3.4. Relationships between protein fractions and cooked noodle properties

The soluble glutenin content demonstrated a high significant positive relationship to cooked noodle cutting firmness, and significant negative relationship to cooking loss (Table 3). The insoluble glutenin content was high positive significantly correlated with cooked noodle thickness, hardness and cutting firmness. Protein content had the same tendency with the insoluble glutenin content. Monomeric protein was not related to other TPA parameters for cooked noodle. Protein content was high significant or significant positive related to cooked noodle thickness, hardness, and cutting firmness. Hu, Wei, Kovacs, and Wang (2004) and Hu et al. (2003) reported that soluble glutenin content negatively correlates with noodle cooking water gain; insoluble glutenin content has a significant positive relationship with noodle optimum time, but a significant negative correlation with noodle cooking loss and water gain. Monomeric protein made no contribution to noodle cooking quality. The insoluble glutenin content is an important quality index of noodle processing and cooking. A higher cutting stress of noodles prepared from higher protein content flours than those from low protein content flours was also reported by Oh et al. (1985). No significant differences in adhesiveness, springiness, and cohesiveness were found between flours of different protein content within the wheat varieties.

Table 4 shows stepwise multiple linear regression results between fresh noodle quality and cooked noodle characters (including protein content and protein fraction). The regression ($R^2 \geqq 0.70$) indicated a good fit of the data in a prediction test for noodle quality and suggested that fresh

Table 2
Relationships between protein fractions and fresh noodle properties

	FNL	DNT	FRE	FAR	FLE
MP	−0.030	−0.027	0.445*	0.503**	0.441*
SG	−0.540**	0.468**	0.590**	0.683**	0.584**
IG	−0.661**	0.477**	0.659**	0.716**	0.621**
PRO	−0.482**	0.353	0.611**	0.780**	0.755**

*, ** Significantly at $p < 0.05$, 0.01 level.
FNL – fresh noodle sheet length; DNT – dry noodle thickness; FRE – maximum extensibility of fresh noodle; FAR – area of fresh noodle extension; FLE – length of fresh noodle extension.

Table 3
Relationships between protein fractions and cooked noodle texture profile analysis character indices

	CTH	CHD	CFM	CL
MP	0.085	0.132	0.266	−0.229
SG	0.044	0.128	0.661**	−0.436*
IG	0.626**	0.476**	0.733**	0.044
PRO	0.435*	0.489**	0.663**	−0.200

*, ** Significantly at $p < 0.05$, 0.01 level.
CTH – cooked noodle thickness; CHD – cooked noodle hardness measured with texture profile analysis; CL – cooking loss.

Table 4
Predicting noodle quality using stepwise multiple linear regressions of protein content and composition

	Selected parameters	R^2
Fresh noodle length	SG, IG, PRO	0.76**
Fresh noodle thickness	SG, IG	0.42*
Maximum extensibility of fresh noodle	IG, PRO, IG/P	0.92**
Area of fresh noodle extension	IG	0.92**
Length of fresh noodle extension	PRO, IG/P	0.74**
Cutting firmness	IG	0.74**
Cooked noodle hardness	IG, PRO	0.44*
Cooked noodle springiness	SG, MP/P, SG/P, IG/P	0.61**
Cooked noodle cohesiveness	MP/P, SG/P, IG/P	0.98**
Dry noodle optimum cooking time	MP, SG, MP/P, SG/P	0.77**

*, ** Indicates $p < 0.05$ and 0.01 ($n = 27$). Abbreviations as defined in Table 1.

noodle length, maximum extensibility of fresh noodle, area of fresh noodle extension, length of fresh noodle extension, cutting firmness, cooked noodle springiness, cohesiveness and dry noodle optimum cooking time. The insoluble glutenin contributed more to fresh noodle quality, but soluble glutenin had more effect on cooked noodle character.

Noodles prepared from wheat flours with low protein content are more fragile than those with high protein content because the protein network in the low protein noodles is weaker than in the high protein noodles (Park et al., 2003). The optimum water absorption of noodle dough decreased as protein content increased because flours with low protein content require more water for forming a uniform protein matrix and making a continuous noodle sheet with good handling properties. The effects of protein content on the cooked noodle texture can be explained by the competition between starch and protein for water absorption, and the inhibition of starch granular hydration due to the protection provided by the gluten network. The extent of starch swelling and granular disintegration depends on the amount of gluten and continuity of the gluten matrix. The connecting outer bond between starch and protein become weaker during cooking, but the connecting inner bond between protein fractions stays strong. Surface starch (especially damaged starch) is dissolved and separated from the protein network, which then reduces the noodle surface firmness, but the inner firmness is still high (Oh et al., 1985). During noodle cooking, gluten protein reabsorbs water and strengthening the network, and gives elasticity and springiness to the noodle. This gluten network can block water from coming into the noodle, and prevent the starch dissolving from the noodle.

Park et al. (2003) found the proportion of salt soluble protein showed a negative relationship with hardness of cooked noodles. A higher cutting stress of noodles prepared from high protein content flours than those from low protein content flours was also reported by Oh et al. (1985). Therefore, in addition to protein content, protein quality of flour protein should be considered in the evaluation and selection of wheat flour for making white salted noodles.

4. Conclusion

Monomeric protein is of lesser important than glutenin for fresh noodle resistance to extension. The soluble and insoluble glutenin are closely related to sedimentation volume, swelling index of glutenin, dough rehology properties, ease of fresh noodle making of good texture. Protein quality of wheat protein, in addition to protein content, should be considered in the evaluation and selection of varieties for making white salted noodle. Soluble glutenin content is the most important property for noodle special wheat, and soluble glutenin content can be used in the early stages to screen Chinese noodle wheat.

Noodle sheet color and extensibility is very important for Asian noodle making. Canadian wheat had higher insoluble glutenin content, and it is suitable for bread-making and Chinese high quality dry noodle and instant noodle processing. To satisfy Asian market demands, Canadian soft white spring, soft white winter and hard white wheat have good potential for making Asian noodles. Especially, hard white wheat has enjoyed growing attention from both domestic and international wheat industries for its uses in making bread and noodles.

Challenges are that: (1) quantity and quality together control the protein characteristics of wheat flour and influence processing and end product quality; (2) the quantity of protein depends mainly on growing conditions, while the quality of protein is controlled by the genetic background of the wheat; (3) generally, soft and hard wheat have quite different protein qualities and are used for different purposes (Park et al., 2003). Chinese had imported several millions of tons Canadian wheat to satisfy its requirements because it is a huge market. The USA and Australia have exported much wheat to China. The Canadian wheat breeders now pay more attention to Chinese wheat flour specification, such as white salted noodle market. Therefore, establishing a protein quality standard of wheat for making Asian noodles and developing an efficient methodology for measuring protein quality of wheat is critical for identifying wheat cultivars possessing the required protein characteristics for making noodles and for screening breeding lines for noodle wheat.

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