In: Advances in Cereal and Pseudocereal ... ISBN: 978-1-62618-347-6
Editors: N. Morita, P.V. Hung et al.

Chapter 1

POLISHED-GRADING TECHNIQUE

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ABSTRACT

The appearance of all the graded flours was distinctly more brownish than that of a conventionally milled soft-type flour, 'N61', hard-type flour, 'Hermes' and No. 1 Canada Western Red Spring (1CW) flour, 'CW'. The graded flours contained larger amounts of dietary fiber, ash and minerals (K, Ca and Fe) than N61, Hermes or CW. In addition, they showed a higher diastatic activity and contained a larger amount of damaged starch as compared with the common flours. Any kinds of graded flours alone could not make a good gluten structure and the dough was clearly hard and not extensible. The loaves baked with the graded flours alone were smaller and the bread crumbs were harder than those of common flours. The 10 % substitution of soft-type graded flours for N61 improved the dough and baking properties. Moreover, the addition of hemicellulase (HEM), cellulase (CEL) and pentosanase (PEN) to the substituted N61 flours increased the loaf volume and softness of the

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bread. The combined addition of hard-type graded flours and sucrose fatty acid ester (SE) to CW increased the amount of gas generation and maturity of the dough with the high hydrophilic property. All the graded flours contained larger amounts of water-soluble pentosan (WSP) and water-insoluble pentosan (WISP) than those of common flours. The substitution of the graded flours for N61 increased the amounts of WSP, while the ratio of Ara/Xyl (arabinose to xylose) of WSP decreased. The improvement of graded flours for breadmaking was caused by large amounts of ferulic acid and low Ara/Xyl, which are related to the gel-forming ability of WSP and to the presence of heat stable foam. This stable foam accelerated the extensibility and maturity of the dough, resulting in the production of end products of good quality. In addition, the combination of graded flours and PEN, the presence of enough amount of WSP, and degradation of WSP and WISP having low Ara/Xyl make the dough extensible and viscous, resulting in favorable end products.

1. Structure of Wheat Grain and Preparation of Graded Flours

1.1. Structure and Composition of Wheat Grain

The wheat kernel or grain, known botanically as a caryopsis, is the fruit of the plant. The kernel consists mainly of 3 parts: bran, endosperm and germ [Pomeranz, 1988a]. It is normally about 4-8 mm (in average 6.2 mm) long, 1.4-4.7 mm (2.7 mm) wide, 1.25-1.40 (1.35) specific gravity and approximately 0.03 g weight, depending on the variety and conditions of growth [Nagao, 1996]. The relationship between the botanical constituents and major milling fractions, the color of the kernel is primarily affected by the components present in the pericarp or seed coat [Pomeranz, 1988a]. The pericarp consists of an outer epidermis and hypodermis, next to the layer of thin-walled cells and several other types of cells. Altogether, the pericarp is about 50 μm thick. Then, we find another thin seed coat, covering nucellar epidermis, and then an aleurone layer before coming to the starch-rich endosperm. Bran of the milling fractions is chiefly the outer material down to and including the aleurone layer [Pomeranz, 1988a]. The starch endosperm is the material from which white flour is made. Aleurone layer is also a part of endosperm, but it is separated from bran layers in the milling process. It comprises starch granules (64-74 %) embedded in a matrix of proteins (8.3-

13.0 %) [Pomeranz, 1988a]. The proteins consist of albumins, globulins, gliadins and glutenins. The combination of the gliadins and glutenins is referred to as the gluten complex and is regarded as storage protein [Pomeranz, 1988a]. On the other hand, the wheat germ consists of several parts. The plumule is one part of embryonic axis and forms a shoot when the seed germinates. There is also the scutellum, which is the storage, digestive and absorbing organ, and attached to the plumule. It contains food for the plant, which is supplied at the time of germination, and also transfers further food from the endosperm. The germ is also readily separated from endosperm together with bran by roll milling. But it is an important dietary supplement, providing a rich source of vitamin E [Cornell and Hoveling, 1998]. With regard to various compositions of each milling fraction, bran and germ contain larger amounts of nutrients and vitamins, compared with endosperm [Pomeranz, 1988a].

1.2. Milling Process of Wheat Grain

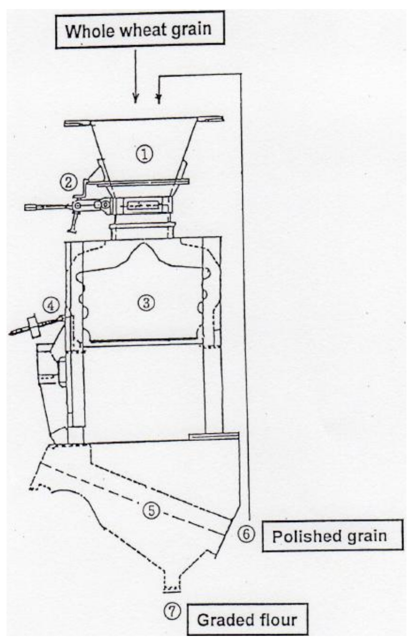
Concerning a milling method, a normal milling contains processes of grinding and separating steps. Grinding is done on break, sizing and reduction rolls. Separation is carried out using machines called sifters or purifiers. In principle, the milling process may be divided into the seven distinct operating systems, which are break, grading, purification, sizings (scratch), reduction, flour dressing and millfeed systems [Pomeranz, 1988a]. Wheat delivered to a mill usually requires much more extensive cleaning to remove foreign or harmfull materials such as stones, mud, ergot, metals and other seeds, which might adversely affect the appearance or functionality of milled product, and might even damage the mill itself. Hence, before milling, wheat is transferred from the elevator to the wheat cleaning section, often referred to as the “screen room”. The cleaned wheat is then prepared for milling by being conditioned (tempered) with an appropriate addition of water [Pomeranz, 1988b]. Conditioning (or tempering) is a controlled addition of moisture to wheat to achieve the following objectives:

1) To harden the pericarp to prevent it from powdering during the milling process (powdered bran cannot be separated from flour at any stage in the milling process);
2) To facilitate the physical separation of endosperm from bran;
3) To mellow the endosperm so that it may be easily to reduce flour;

4) To ensure that all materials leaving the grinding rolls are in optimum condition for sifting; and
5) To ensure that grinding produces the optimum level of damaged starch consistent with the hardness of the wheat and the end use of flour [Pomeranz, 1988b].

The milling process of wheat flour by a conventional method is illustrated simply. At first, about 15% water is added to the wheat grain, and conditioning is done to remove the hard bran from the soft endosperm more easily. Then, breaking, sieving and purification are carried out. In this stage, the prepared flour is very hard with a large particle size and contains some bran.

Therefore, the flour is called 'semolina'. Moreover, this semolina is gradually ground through smooth rolls in the reduction system to produce the finished flour. Finally, these finished flours are divided depending on the quality of flours, dressed and the commercial wheat flour is prepared. As shown in this procedure, the conventional method can remove the bran and germ from the wheat grain. Therefore, the recovery is approximately 70%.



1, Receiver; 2, Lever; 3, Roller; 4, Controller; 5, Sieve; 6, Outlet for polished grain; 7, Outlet for graded flour.

Figure 1-1-1. Milling process of the graded flour by the polished-grading method.

Table 1-1-1. Graded flours prepared from various cultivars

Cultivar					
Norin 61		Norin 61		1CW	
Sample	Fraction (%)	Sample	Fraction (%)	Sample	Fraction (%)
NA-1	100-90	NB-1	100-90	C-1	100-90
NA-2	90-80	NB-2	90-80	C-2	90-80
NA-3	80-70	NB-3	80-70	C-3	80-70
NA-4	70-60	NB-4	70-60	C-4	70-60
NA-5	60-50	NB-5	60-50	C-5	60-50
NA-6	50-40	NB-6	50-40	C-6	50-40
NA-7	40-30	NB-7	40-30	C-7	40-30
NA-8	30-0	NB-8	30-0	C-8	30-0

Hermes, conventionally milled hard-type wheat flour; N61, conventionally milled soft-type wheat flour of Norin 61, CW, conventionally milled hard-type wheat flour of 1CW.

NA and NB are sieved through a pore size of 125 and 600 mm, respectively.

NA and NB are soft-type graded flours obtained from Norin 61and C is hard-type graded flours obtained from 1CW.

NA-1 (100-90%), 10% layer graded from outer part of whole grains; NA-2 (90-80%), 10 % layer graded from outer part of NA-1; NA-3~NA-7, same 10 % grading as above; NA-8 (30-0%), 30%-core of the whole grains. NB-1~NB-8 and C-1~C-8 are prepared by the same grading method as in NA-1~NA-8.

Figure 1-1-1 shows the procedure for a polishing process by the polished-grading method, which we used in this study. This apparatus is a modified Japanese rice-polisher. At first, a whole wheat grain is put into position 1, and the grain is gradually polished from the outer layer in a stepwise manner by the vertical roller located at position 3. Then the polished-graded flours are sieved through the sifter in position 5, and only the passed flour is recovered from position 7 as a graded flour. For example, 100 Kg of wheat grain is put into the receiver (position 1). If 10% of the original weight, namely 10 Kg of flour is recovered from position 7, the flour corresponds to 100 to 90 % of the whole grain. Likewise, the next 10 Kg flour recovered from position 7 corresponds to 90 to 80 % of the whole grain. In this way, the polished-grading process is quite simple and this method can produce the wheat flours from the whole wheat grain with theoretically 100 % of recovery.

Therefore, if we prepare the wheat flour using the polished-grading method, it is no need to discard the bran and germ, which have been removed or used for animal foods until now. Moreover, we can obtain the special wheat flour “ the graded flour” derived from the whole wheat grain, containing large amounts of dietary fiber, vitamins and minerals. Accordingly, the graded flours are sure to produce end products with high safety, deliciousness and nutrition, which are essential factors to be needed for foods. These end products must sufficiently satisfy the appetite of our consumers. Therefore, the graded flours seem to be expected as a new foodstuff.

1.3. Preparation of Various Graded Flours by the Polished-Grading Method

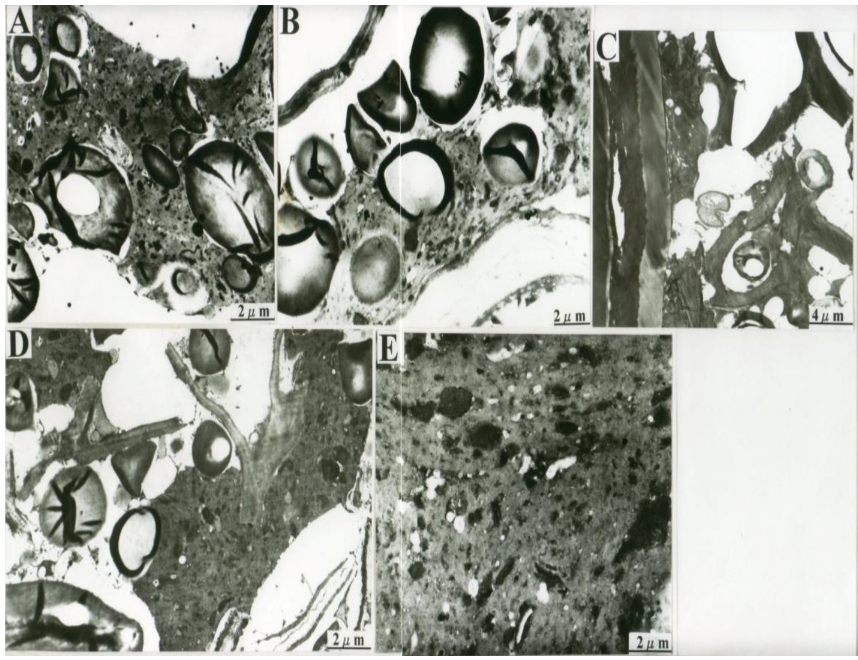
Table 1-1-1 shows the various graded flours used for this experiment. For the case of graded flours obtained from Norin 61, the graded flour samples were sieved through a pore size of 125 μm (named as 'NA') or 600 μm (named as 'NB'). For the case of hard-type graded flours, capital letter of 'C' was attached to the name. NA-1, NB-1 and C-1 correspond to the graded flour from 100-90% of the whole grain; NA-2, NB-2 and C-2, 90-80%; NA-3, NB-3 and C-3, 80-70%; NA-4, NB-4 and C-4, 70-60%; NA-5, NB-5 and C-5, 60-50%; NA-6, NB-6 and C-6, 50-40%; NA-7, NB-7 and C-7, 40-30%; NA-8, NB-8 and C-8, 30% to the core. These graded flours were used for the following experiments.

2. Characterization of Soft-Type Polished-Graded Wheat Flours

Characteristics of wheat flour graded by polishing and the effect of the graded flour substitution for conventionally milled flour on the physical properties of wheat dough and bread were studied. When wheat grains are milled by the conventional method, most of the fibers and minerals are removed. For this reason, a polished-grading method which keeps whole part of grains was introduced. Wheat grains were gradually polished in a stepwise manner from the outer layer by 10% of the total weight to the core of the original soft-type wheat grain Norin 61 (N61). The loaf volumes of all graded flours were distinctly smaller than that of conventionally milled N61 and the bread crumbs were quite hard. All graded flours clearly increased viscoelastic properties such as compression stress, modulus of elasticity and viscosity coefficient. The graded flours had a higher SH content, whereas there was a lower SS content in dough than conventionally milled hard-type flour. Any fraction of the polished-graded flours alone did not have good dough and baking properties (Figures 1-1-2, 1-1-3). When 10% of N61 was substituted with a fraction of the graded flour, A-4 (70-60 % of original grains) or A-7 (40-30 %), the specific volume increased slightly as compared with that of N61 alone. Moreover, the addition of hemicellulase (HEM) to the combined flour improved the loaf volume distinctly, and the bread crumbs became quite soft. Microscopic observation of the dough showed that the gluten matrix became thicker and most of the starch granules were sufficiently covered with the matrix, as compared with N61 alone. From these results, a 10% substitution of graded flours A-4 and A-7 to N61 with or without hemicellulase was found to improve some of the viscoelastic and baking properties of wheat dough.

3. Effect of Polished-Graded Soft-Type Wheat Flour Substitution for Commonly Milled Wheat Flour on the Breadmaking

The optimum conditions for breadmaking composed of various amounts of polished-graded flour and N61 were studied. The viscoelastic properties of the doughs were also tested. When 30 or 50% of N61 was substituted with the 70~40 % graded flour (fraction B) of the whole wheat grain, the loaf volume and softness of bread crumbs increased with optimum amounts of water of 75 and 85%, respectively. Moreover, the addition of pentosanase (PEN) or cellulase (CEL) to the substituted N61 distinctly improved the loaf volume and retarded the retrogradation of bread crumbs as compared with those of N61 alone. Especially, the addition of PEN or CEL to the 50%-substituted N61 having 85% water clearly increased viscoelastic parameters, such as the modulus of elasticity (γ) and viscosity coefficient (η), as compared with those of N61 alone. In Farinograph data, 50%-substituted N61 also decreased the arrival and development times but increased the stability time. For the DSC result, 50% substitution tended to decrease gelatinization enthalpy with the addition of PEN or CEL. Microscopic observation of the 50% graded- flour-substituted N61 containing PEN showed that most of the starch granules were covered with extensible gluten and expanded still more during fermentation. In the case of the dough with the optimum water content, the gluten matrix was more fibrous and continuous, followed by sufficient gelatinization of starch granules as compared with N61 alone. Therefore, for the case of substituted N61 flour with graded flour, the optimum amount of water and hydrolysis of pentosan or cellulose in the endosperm and bran by PEN or CEL were needed to make good dough and baking properties.



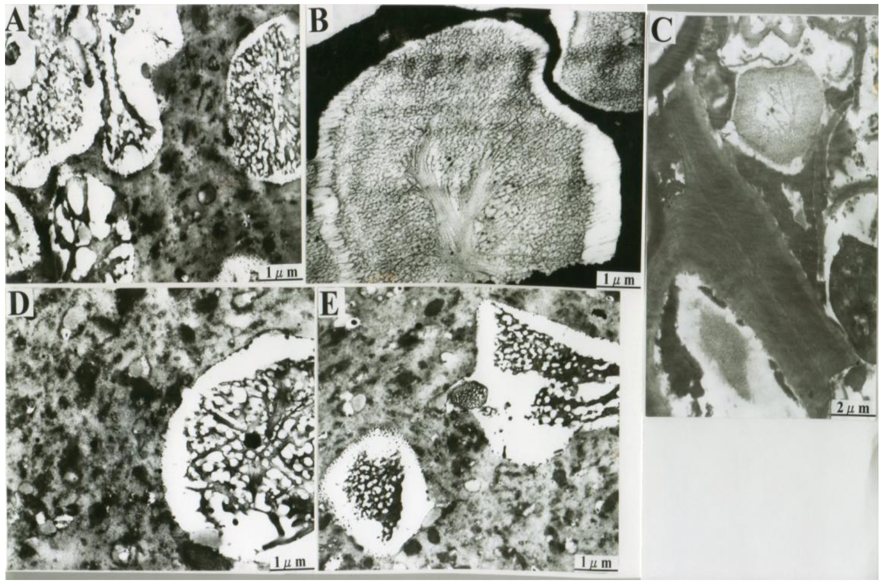
A, Hermes; B, N61; C, NA-1; D, NA-5; E, NA-8. Abbreviations are the same as in Table 1-1-1.

Figure 1-1-2. TEM of wheat dough mixed in a home baker.

Table 1-1-2. Characteristics of various graded flours

Sample	General analysis				Amounts of various components							
	Moisture (%)	Ash (%)	Protein (%)	Dietary fiber (%)	S (%)	Cl (%)	K (%)	Ca (ppm)	Fe (ppm)	Ni (ppm)	WSP (%)	DS (%)
Hermes	11.8	0.4	11.8	1.9	0.17	0.08	0.15	300	29.9	1.6	0.73	15.29
CW	12.3	0.2	12.3	2.1	0.17	0.05	0.10	250	19.3	1.3	0.74	15.47
C-1	11.1	4.3	16.1	32.8	0.27	0.10	1.04	1030	270.2	2.1	0.59	16.54
C-5	9.1	1.0	13.9	5.7	0.20	0.08	0.30	410	48.3	1.7	1.09	39.06
C-8	6.9	0.5	8.1	3.8	0.14	0.07	0.15	270	31.8	1.6	0.80	27.95

C-1, C-5 and C-8 were 100-90 %, 60-50 % and 30-0 % layers of the 1CW whole grains, respectively. WSP, water-soluble pentosan; DS, damaged starch.



A, Hermes; B, NB-1; C, NA-1; D, NA-5; E, NA-8**.** Abbreviations are the same as in Table 1-1-1**.**

Figure 1-1-3**.** TEM of dough after baking in a home baker**.**

4. CHARACTERIZATION OF HARD-TYPE POLISHED-GRADED FLOURS

Graded flour was prepared from the hard-type wheat grain 1CW by the polished-grading method and the effect of the flour quality on the dough and baking properties was studied. The graded flours contained large amounts of ash or dietary fiber as compared with a conventionally milled hard-type 1CW flour (CW) (Table 1-1-2). These graded flours also had larger amounts of K, Ca and Fe than CW. All the graded flours, except for the outermost layer, distinctly increased in water-soluble pentosan as compared with CW (Table 1-1-2). Moreover, they contained higher β-amylase or diastatic activities and also higher amounts of damaged starch than CW. The specific volumes of the bread made from the graded flours were distinctly smaller than that of CW. None of the graded flours alone had a favorable effect on the bread firmness. For the viscoelastic properties, all parameters of the graded flours tested distinctly higher than those of CW. Microscopic observations of the graded flour dough alone indicated that the co-existence of bran could not produce a favorable gluten matrix, resulting in poor quality bread.

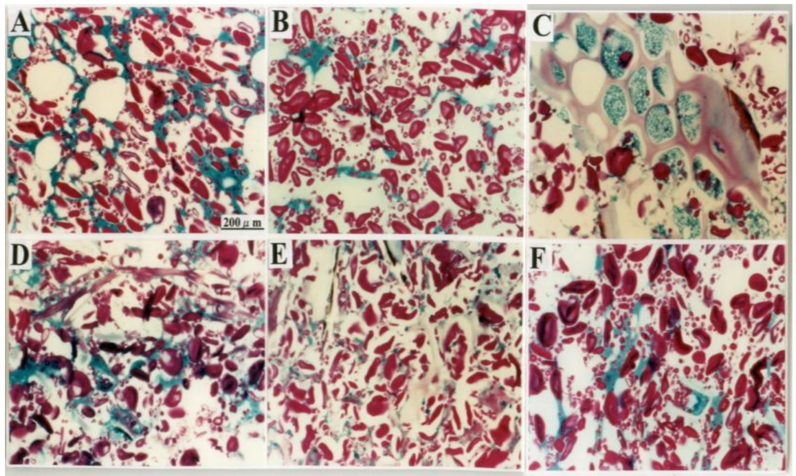
These results suggested that graded flour alone could not make dough with the desired baking properties, because of the presence of high amounts of diastatic activity, damaged starch, dietary fiber or wheat bran.

5. Effect of Polished-Graded Hard-Type Wheat Flour Substitution for Commonly Milled Wheat Flour on the Breadmaking

The effect of substituting polished-graded hard-type wheat flour for commonly milled hard-type wheat flour on the properties of dough and bread was studied. The CW was also prepared and breadmaking was carried out by the AACC method. Thirty (30 CW) or 50% (50 CW) graded-flour substitution for CW was tested for baking using the 70~40 % layer fractions of the whole grain.

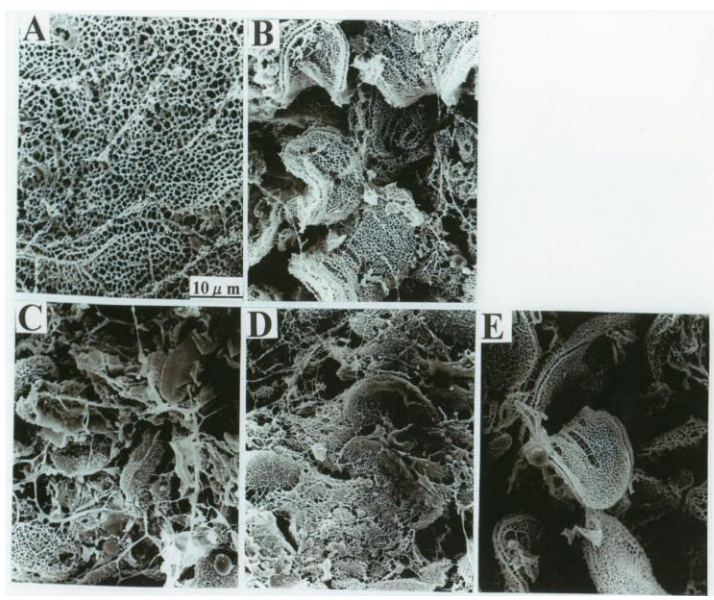
The addition of pentosanase (PEN) or sucrose fatty ester (SE) to 30 CW distinctly increased the loaf volume or softness of the bread crumbs due to the small size of the gas cells and retarded retrogradation. Moreover, 30 CW with PEN or SE increased the enthalpy value of the starch. On Farinogram, the addition of SE to 30 CW decreased water absorption, arrival and development times, while it increased the stability time as compared with that of CW alone. The viscoelasticity of 30 CW with SE showed larger values for all parameters than those of CW. The ratio between resistance and extensibility of the 30 CW and SE dough increased significantly (after 90 and 135 min) as compared with CW on the extensogram. The substitution with graded flour alone or its combination with PEN or SE increased the rate of gas generation. Microscopic observation of the 30 CW dough with PEN or SE distinctly accelerated formation of the gluten network. The extensible gluten material could entirely cover the starch granules.

From these results, the addition of graded flours and SE to CW might increase maturity of the dough. Furthermore, these additions were considered to control dispersion of the water in the dough and improve the dough and baking properties when compared with those of CW alone.



A, Hermes; B, N61; C, NB-1; D, NA-1; E, NA-5; F, NA-8.
Abbreviations are the same as in Table 1-1-1.

Figure 1-1-4. Light microscopic observation of dough stained with PAS and light green.



A, Hermes; B, N61; C, NA-1; D, NA-5; E, NA-8**.**
Abbreviations are the same as in Table 1-1-1**.**

Figure 1-1-5**.** Scanning electron microscopic observation of bread baked in an automatic baker**.**

Table 1-1-3. Effects of pentosan obtained from graded flours on baking properties

Sample	Amount of pentosan added (%)	Specific volume (cm^3/g)	Storage days			
			0	1	2	3
Hermes	0	4.25	16.7	28.7	41.3	43.3
N61	0	2.73	70.3	134.3	193.7	220.0
WSP 0.2	0.2	3.79	21.3	52.7	78.0	104.3
WSP 0.5	0.5	3.84	19.3	49.0	69.0	89.0
WSP 1.0	1.0	4.38	18.0	40.0	60.0	80.0
WISP 0.5	0.5	2.77	83.3	148.0	202.3	225.7
WISP 1.0	1.0	3.84	20.7	39.7	60.3	83.3
WISP 5.0	5.0	4.07	31.7	90.7	128.7	174.0
WISP 10.0	10.0	3.96	15.7	45.0	67.3	85.7

* Firmness ($10^2 Nm^{-2}$); WSP, water-soluble pentosan; WISP, water-insoluble pentosan**.**

6. Flour Quality and Pentosan Prepared by Polishing Wheat Grain on Breadmaking

Whole grains of soft-type wheat were polished from the surface layer to the center by 10% of the total weight using a modified rice-polisher. Qualities of classified-graded flours and effect of pentosan in the graded flours on breadmaking were determined. All the graded flours contained larger amounts of dietary fiber and damaged starch, and showed higher diastatic activity than a conventionally milled wheat flours of Hermes or N61. All kinds of graded flours made harder or less moist dough from microscopic observations than Hermes or N61 did (Figure 1-1-4). The gluten matrix of graded flour dough was distinctly not continuous in the presence of large dietary fiber, and the gluten sheet was clearly more discontinuous than those of Hermes and N61. Also, the gelatinization of starch in graded flours during baking appeared to be more incomplete than that observed with Hermes or N61 (Figure 1-1-5). However, additions of water-soluble and -insoluble pentosans obtained from the innermost fraction of graded flours to N61 significantly improved the bread qualities (Table 1-1-3). The improvements of bread quality and maturity of dough might be caused by the large amounts of pentosans and damaged starch in graded flours.

7. Characterization of Pentosan of Various Graded Flours

All the soft-type graded flours contained larger amounts of water-soluble pentosan (WSP) and water-insoluble pentosan (WISP) than those of Hermes and N61. The substitution of the graded flours for N61 increased the amounts of WSP, while the ratio of Ara/Xyl (arabinose to xylose) of WSP decreased. The additions of PEN and CEL could decrease the Ara/Xyl of WSP. Hydrolysis with PEN or CEL increased the solubility of WISP in 50 NA (50% soft-type graded flours substitution for N61) at 50 % or 10 %, respectively, as compared with 50 NA alone. And all the hard-type graded flours had the larger amounts of WSP and WISP similar to the soft-type graded flours. The additions of PEN and SE to 30 CW (30% hard-type graded flours substitution for CW) could increase the solubility of WISP by about 18 % and 5 %, respectively, compared to 30 CW alone. And, the addition of PEN showed the lower ratio of Ara/Xyl of WSP than those of 30 CW and 50 CW alone, whereas the addition of SE slightly increased Ara/Xyl of and viscosity of WSP. The PEN hydrolysis of water-insoluble arabinoxylan (WISAX) decreased molecular weight of its polysaccharide, contributing to make a good dough property. In contrast, the addition of SE to 30 CW affected the WISP entangled in the doughs with the high hydrophilic property, resulting in the looseness of structure of WISAX.

Ara/Xyl of WSP and WISP isolated from NA-8 (the soft-type graded flour from 30-0 layers of whole grain) was lower than that of Hermes. And, in NA-8 the WSP has lowly branched WSAX, while the WISP, highly branched WISAX than those in N61. The WSP and WISP of NA-8 included the larger amount of ferulic acid, and also the WSP made protein foam more stable against heating than those of Hermes and N61.

When WSP and WISP from NA-8 were hydrolyzed by PEN, the degrees of chain length in final products were distinctly decreased. The PEN hydrolysis of WISPs from N61 and NA-8 made them soluble in water by around 65 %. The WSP formed from enzyme hydrolysis of WISP had favorable effects on the breadmaking. Therefore, the substitution of graded flours and PEN for N61 improved breadmaking by the presence of WSP rather than WISP. For the case of corn arabinoxylan, the addition of AX of a high-molecular weight and low ratio of Ara/Xyl improved the dough and baking properties, as compared with that of AX of a low-molecular weight and high ratio of Ara/Xyl. These results indicated that the improvement of graded flours for breadmaking was caused by large amounts of ferulic acid and low Ara/Xyl, which are related to the gel-forming ability of WSP and to the presence of heat stable foam. This stable foam accelerated the extensibility and maturity of the dough, resulting in the production of end products of a good quality. In addition, the combination of graded flours and PEN, the presence of enough amount of WSP, and degradation of WSP and WISP having low Ara/Xyl make the dough extensible and viscous, resulting in favorable end products.

8. General Discussion and Conclusion

Many non-starch polysaccharides, such as β-glucan, hemicellulose, pentosan and gluco-, as well as galacto-mannan are well known to exist in wheat grain. In most cases, pentosans in cereals are linked to protein as a kind of glycoproteins, which are composed of large amount of pentose, small amount of hexsose, and only a little of protein. The nomenclature of these substances in the field of cereal chemistry is somewhat ambiguous, so no district definition has been made between pentosans, hemicelluloses and glycoproteins. The nomenclature in this study was based on the suggestion by Meuser and Suckow [1988]. Wheat flour has about 2-3 % of pentosan, and about 25 % of the pentosan is soluble in water (WSP). WISP means alkali-soluble pentosan or hemicellulose and its structure is essentially similar to that of WSP, except for the differences in the degree of branching and molecular weight. WSP prepared from wheat flour is usually reported to contain some hexoses, protein and phenol as impurities. It could be classified into two fractions, judged from solubility in saturated ammonium sulfate solution or in 80 % ethanol. The precipitated fraction was AX complexed with protein. The soluble fraction was arabinogalactan (AG) covalently linked to a protein. AX has been proposed to take up an extended left-handed three-fold helix which has a long main chain of β-(1-4)-linked D-xylopyranose units having side chains of L-arabinofuranose linked at the position 2 or 3 of xylose residue. The side chains are responsible for the water solubility of AX; the backbone xylan of which precipitates easily when the arabinose residue is hydrolytically liberated from the molecule [Neuko et al., 1967]. These AX and AG fractions are water-soluble glycoproteins named arabinoxylan-protein complexes (AXPC) and arbinogalactan-protein complexes (AGPC), respectively. These substances are also referred to as WSP [Pomeranz, 1988a].

AXPC contains a small amount of a phenolic component (2.0 and 0.01 mg/g for AXPC and flour, respectively) that is labile to oxidation and has been identified as ferulic acid. Ferulic acid or diferulic acid are covalently linked to WSP and WISP. The diferulic acid has been reported to serve as coupling unit to an insoluble gel network during oxidative gelation of WSP [Meuser and Suckow, 1988]. Especially, a wheat flour of a good quality contains higher amounts of AXPC and polyphenols than that of a poor quality. The higher content and degree of oxidative gelation of AXPC in a good quality flour resulted in a higher viscosity than that from a poor quality flour.

The addition of AXPC of a good quality flour to gluten-starch mixture shows more favorable effects on the improvement of dough and baking properties, than that of a poor quality flour. Furthermore, the addition of oxidants increased the effects. The oxidative cross-linkage of WSP containing glycoproteins has an evident effect on dough properties because of a high water-holding capacity and gel formation. WSP might play a regulatory role with respect to water dispersion in the dough during breadmaking. Because WSP neither coagulates through heat treatment (as is the case with protein), nor retrogrades through cooling and storage (the case with starch), it has positive effects on keeping bread fresh. WSP can hold water even during baking processes, and then water is continuously supplied to the starch granules, thereby, the rate of retrogradation is retarded. In addition, WSP has an ability to retain gas in the dough with a formation of 'membrane' [Meuser and Suckow, 1988]. From these facts, WSP has been considered to have positive effects on the baking properties, such as loaf volume, crumb structure and staling of bread.

For the case of WISP, it might be swollen and the water-holding capacity is 3.5-6.3 and 6.7-9.9 times of its weight for WSP and WISP, respectively. The high water absorption in the dough would depend on the conformation of these pentosan molecules. This change would be derived from the association between carbohydrates and proteins [Meuser and Suckow, 1988]. WISP of wheat is primarily composed of AX, but contained a small amount of hexoses, such as mannose and glucose, which can form mannan or glucomannan as polysaccharides [Meuser and Suckow, 1988]. The insolubility of WISP is explained from the strong physical entanglement of WISP caused by the higher degree of branching than WSP, together with the presence of phenolic acid in the tailings [Pomeranz, 1988a]. But, reasons for the insolubility have not been fully understood. Total content of phenolic acid which was calculated as ferulic acid was found to be 1.2 and 0.4 mg/g of tailings and flour, respectively.

WISP has also been reported to improve the loaf volume, freshness, or staling, crumb structure of the bread and elasticity of the dough [Meuser and Suckow, 1988; Pomeranz, 1988a]. In addition, WISP was found to be a binding agent suitable for making bread from non-gluten flour. Regarding the retrogradation of starch in the dough, the effects of pentosans have been reported as follows: WSP appeared to affect the solubility of amylopectin in starch, and WISP retarded the retrogradation of both amylose and amylopectin. The rate of starch setback was slowdown more obviously by WISP than by WSP [Pomeranz, 1988a].

These results lead to a conclusion that WSP and WISP in wheat flour influence the rheological behavior of doughs and texture of bakery products. This effect was possibly due to the high water-holding capacity of WISP as well as their swelling ability, to the ability of WSP to form highly viscous aqueous solutions, and to the capacity of glycoproteins to increase the viscosity under the influence of oxidants. In this study, authors examined dough and baking properties of polished-graded flour. The graded flour alone could not show good dough and baking properties regardless of the soft- or hard-type wheat grain, and these graded flours had almost the same flour quality. All the graded flours contained larger amounts of dietary fiber, ash and minerals than conventionally milled flours. In addition, the formers showed a higher diastatic activity and contained a larger amount of damaged starch. Since the dietary fiber (WSP and WISP), diastatic activity and damaged starch might absorb an excess amount of water and promote the degradation of starch in the dough, they might give rise to the poor baking qualities. However, these factors are nutritionally effective, and they might be also expected to bring about the enough fermentation on the breadmaking. Even though these unfavorable materials for breadmaking contained in the flour, the graded flours have been used because of the presence of large amount of dietary fiber. The poor dough and bread properties might be caused by the high water-holding capacity of WSP and WISP, resulting in the deficiency of water to make a good gluten structure. Moreover, large amounts of damaged starch and high diastatic activity in the graded flours made the gluten structure unstable, which leads to retard the extensibility of gluten and gelatinization of starch during subsequent baking processes. However, when the graded flours were partially substituted for the conventionally milled flours, the dough properties could be improved by the increase in amounts of damaged starch and diastatic activity in substituted flours. As a result, the maturity and gas generation in doughs were increased during fermentation.

Additives such as HEM, PEN, CEL and SE improved dough and baking properties. PEN could hydrolyze WISP and then produced the WSP. Thus formed WSP might change the gluten structure to be quite extensible, providing the expansion of the dough during fermentation and baking processes. WISP has been considered to retard the formation of good gluten structure by the high water-holding capacity. However, when PEN was added to the substituted flours, the part of WISP might be decomposed and solubilized, resulting in construction of good gluten structure. In contrast, SE with a high ability of emulsification increased the viscosity of water-extracts containing WSP. Moreover, SE might control the distribution of water to protein and starch by the high surface activity, even if WISP prepared from the graded flours were added. Consequently, the substituted flours with SE were inferred to increase the suitable hardness of dough, caused by the entanglement of WISP, and also to prevent the dough from escaping the generated gas during fermentation.

Although effects of PEN and SE on breadmaking were apparently different, the quality of end products was quite similar. This fact suggests that the mechanisms of baking process are quite complicated, because many kinds of constituents in the flour and ingredients added change individually during the baking processes, and also interact each other. Nevertheless, the properties of WSP or WISP on the breadmaking as reported previously were sure to associate strongly with the qualities of graded flours.

Therefore, the combination of graded flours with enzyme and emulsifier improved not only the dough and baking properties but also the nutrition in the end product. In addition, these improvements might be due to characteristics of WSP and WISP as described above. However, further extensive studies are needed for polished-graded wheat flours to make clear not only flour characteristics but also the dough and baking properties, together with the application of this flour for other food ingredients. Consequently, the practical use of graded flours for our daily diet as a new foodstuff will be desired.

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