

Study on Wheat Flour Factors Contributing to Wheat Product Quality

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Summary

Although wheat is widely used in Japan for making bread, noodles, and various processed foods, Japan's wheat self-sufficiency is very low and its quality is lower than that of imported wheat. To improve quality, clarifying factors contributing to wheat product quality is required.

Starch is the main component of wheat flour and its properties are important to the quality of the final product. Most starch consists of the polysaccharide molecules, amylose and amylopectin. The ratio of amylose and amylopectin affects the physicochemical properties of starch. Starch heated with excess water swells and gelatinizes, leading to a loss of crystallinity and the molecular order and hydration of the starch. During cooling and storage, starch products undergo retrogradation involving changes such as starch molecule reassociation, crystallization, precipitation, and gelation. These changes are responsible for the unique properties of wheat flour products. Non-starch polysaccharide (NSP), although a minor component of wheat grains, is thought to influence dough characteristics and baking performance due to its water binding capacity and high viscosity. NSP is classified into water-soluble (WSP) and insoluble fraction (WIP) by solubility. WSP and WIP appear to have different functions and chemical structures.

In this study, the roles of two important components in wheat flour, starch and NSP, were investigated as factors affecting wheat product quality. The effects of NSP and starch characteristics on wheat starch gelatinization and retrogradation were studied. The relationship between starch properties and noodle quality was also studied.

- 1) Influence of NSP isolated from wheat flour on wheat starch gelatinization and gelation

Seven wheat cultivars with different WIP and WSP composition were selected and their NSP rich fraction was extracted from wheat flour. Isolated NSP was added to 2

types of isolated wheat starch having different amylose content. The effects of isolated NSP on wheat starch gelatinization and gelation were analyzed using a Rapid Visco Analyser (RVA) and dynamic viscoelastic measurement. Adding NSP increased the peak viscosity at higher concentrations in RVA measurement. The effect of NSP on the storage shear modulus (G') differed for low and normal amylose starch. In Kanto 107 starch, which has lower amylose, adding NSP showed increased rigidity, and G' and loss shear modulus (G'') of starch mixed with NSP rich fraction correlated with the ratio of WIP to WSP. In Norin 61 starch, adding NSP reduced the amount of solubilized starch and amylose, suppressing G' of starch and NSP mixtures.

Two wheat cultivars were selected to isolate WIP and WSP separately from wheat flour. The isolated WIP and WSP were added to 2 types of isolated wheat starch having different amylose content. The influence of WIP and WSP on wheat starch gel properties was analyzed using dynamic viscoelastic measurement. WIP and WSP clearly affected these properties differently. Adding WIP increased G' of starch gel, suggesting that WIP increased the rigidity of starch gel due to increased concentration in the continuous phase. Adding WSP, however, decreased G' of starch gel, yielding a softer gel, suggesting that WSP may prevent the reassociation of starch molecules and weaken the gel network.

2) Effect of wheat starch properties on swelling power

Starches were isolated from 6 wheat cultivars with a wide swelling power range. The amylose and lipid contents, distribution of amylopectin chain length, and granule size were analyzed. The relationship between swelling power and gelatinization and retrogradation behaviors of starch granules measured using Differential Scanning Calorimetry (DSC) was also evaluated. Starch amylose content correlated negatively with swelling power but lipid content showed no such correlation. Higher proportions of long chains ($DP \geq 35$) in amylopectin increased starch swelling. Swelling power correlated positively with native starch gelatinization temperatures and enthalpy measured by DSC and significantly with the regelatinization enthalpy of retrograded starches at 5 °C for 2 and 4 weeks. This suggests that factors contributing to granule crystallinity influence differences in starch swelling power. Multiple regression analysis showed that amylose content had the greatest influence on swelling power, which is an

important property to the quality of wheat flour products such as white salted noodles.

3) Production of wheat starch with different amylose content and analysis of gelatinization and retrogradation properties

The effects of amylose content on gelatinization and retrogradation properties of starch were studied using wheat starches with different amylose content. Starches were isolated from waxy and non-waxy wheat and reciprocal F_1 seeds by crossing waxy and non-waxy wheat. Two types of F_1 starch had amylose content not found in existing cultivars. The amylose content differed between waxy/non-waxy and non-waxy/waxy starch in F_1 seeds, suggesting that gene dosage affects amylose content by double fertilization. Mixed starches with the same amylose content as F_1 seeds were produced by mixing waxy and non-waxy wheat starches. Endothermic enthalpy and final gelatinization temperature measured by DSC correlated negatively with amylose content. Gelatinization onset and peak temperature clearly differed between F_1 and mixed starch with the same amylose content as F_1 starch. The enthalpy of melting recrystallized starch correlated negatively with amylose content. RVA measurement showed that the peak viscosity of F_1 starch was higher than that of parent cultivars, non-waxy and waxy wheat. The difference in pasting properties reflected amylose content. Mixed starch showed characteristic pasting profiles with 2 low peaks. In mixed starch, non-waxy starch and waxy starch developed viscosity at different temperatures. These results suggest that some gelatinization properties reflect the homogeneity of starch granules in addition to amylose content.

4) Comparison of physical properties of wheat starch gel with different amylose content contributing to the quality of wheat flour products

The effect of amylose content on concentrated starch gel properties was evaluated using 10 wheat cultivars with different amylose content and mixed starches with an amylose content of 5, 10, 18, 20, 23, and 25%. Mixed starch was prepared by blending starches isolated from waxy and non-waxy wheat at different ratios. The dynamic viscoelasticity of 30% and 40% starch gels was measured using a rheometer with parallel plate geometry. The difference in amylose content between cultivars

greatly influenced starch gel properties. Low-amylose starch had significantly lower G' than starch with higher amylose content during storage. Waxy starch gel had a higher frequency dependence of G' and properties clearly different from non-waxy starches. In 40% starch gel, starch with lower amylose showed a faster increase in G' during 48 hr of storage, and waxy starch showed an extremely steep increase in G' . In mixed starch, a small difference in the proportion of waxy starch markedly affected G' and starch retrogradation. Since the amylopectin of waxy starch granules was solubilized more easily in hot water than that of non-waxy starch granules, mixed starch containing more waxy starch was more highly solubilized and formed weaker gel. For 40% starch gel, mixed starch containing more waxy starch showed rapidly developed G' and had a higher rate constant of starch retrogradation. These results suggest that amylopectin reassociation plays a major role in the retrogradation of the concentrated starch system. The amylose content and concentration of starch suspension markedly affected starch gel properties.

5) Effect of wheat starch properties on rheological properties of white salted noodles

The rheological properties of white salted noodles were analyzed using 10 wheat cultivars with different amylose content. Their dynamic viscoelasticity was measured using a rheometer with parallel plate geometry. Compressive stress and creep-recovery were measured using various probes. Noodles with lower amylose content showed lower G' and G' correlated highly with G' of 30% and 40% starch gels, suggesting that the viscoelasticity of starch gel greatly influenced noodle viscoelasticity. Noodles made from lower amylose wheat flour showed lower compressive force and softer texture. Noodles of waxy wheat had higher compressive force than non-waxy wheat, when the deformation was over about 80%, suggesting that waxy wheat noodles are soft but difficult to cut. Creep compliance of noodles with lower amylose content was higher. The difference in amylose content in wheat flour strongly reflected noodle creep-recovery measurement.

6) Conclusion

NSP, a minor wheat grain component, greatly influences starch gelatinization

and retrogradation. WIP and WSP affected these properties differently and the ratio of WIP to WSP correlated with starch gel viscoelasticity. Our results indicate that rheological properties of wheat flour products could be controlled by changing NSP content and composition in wheat flour.

Certain starch properties were clarified to be factors contributing to rheological properties of wheat flour. Amylose content, amylopectin structure, and starch crystallinity affected starch gelatinization and retrogradation properties related to food quality. A small difference in amylose content markedly influenced rheological properties of starch gel. The concentration of starch suspension also played an important role in retrogradation. The proportion of waxy wheat starch in the mixture played a major role in starch gel properties. Starch gelatinization and gel properties also reflected the homogeneity of starch granules. Noodle viscoelasticity correlated highly with that of starch gel, which indicates that starch properties are responsible for noodle quality.