AN ABSTRACT OF THE THESIS OF

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in Crop Science presented on April 22, 1994

Title: Kernel Hardness, Protein, and Viscosity as Predictors of Udon-Noodle Quality.

Abstract approved: Redacted for privacy

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The Asian noodle market is responsible for the increased volume of wheat imported to that region in recent years. Soft white wheat produced in the Pacific Northwest is mainly used for baked products, whereas an Australian wheat, Australian Standard White, is preferred for noodles. To enter this market soft white-wheat cultivars with properties similar to or better than Australian Standard Whitemust be developed. This process is difficult as little is known of the factors that influence noodle quality.

The use of grain-protein percentage, kernel hardness, and six viscosity parameters measured by the Rapid Visco Analyzer for predicting Japanese udon-noodle quality was evaluated. The Rapid Visco Analyzer was developed to indicate quickly and reliably the starch properties of a small wheat sample. Experimental material included advanced winter-wheat selections from the Oregon State University wheat-breeding program and Stephens, a widely grown winter-

wheat cultivar. Two commercial spring cultivars, Owens and Klasic, thought to have good noodle quality were used as checks as was straight grade flour milled from Australian Standard White wheat. The material was grown at two locations (Rugg and Chambers) which represent diverse environments and management systems. Protein content, kernel hardness, and six viscosity parameters (Peak1, Low, Peak2, Peak1-Low, Peak2-Low, Peak1-Peak2) were measured. A sensory-evaluation panel evaluated the end product for surface appeal, texture, and taste.

Within each location differences were found for all traits except protein content at the Rugg site and surface appeal at the Chamber location. Between the two experimental sites the only traits for which no differences were detected were kernel hardness and surface appeal. Significant entry by location interactions were observed for kernel hardness, Peak1-Peak2, and the three sensory-evaluation traits.

Kernel hardness and grain-protein percentage were not associated, however both were negatively associated with the viscosity parameters. Associations of grain-protein, kernel hardness, and the viscosity parameters with the sensory evaluation traits were not statistically determined. A softer kernel texture appeared most useful for predicting Japanese udon-noodle quality as determined by sensory evaluation. Grain-protein percentage was not a good indicator by itself, but each cultivar may have a protein-content range within which noodle quality is optimized. This range may be influenced by the kernel texture. The viscosity parameters did not appear useful for predicting noodle quality as determined by the sensory evaluation panel. A more sensitive sensory evaluation method may be required to detect small however important differences and different viscosity parameters should be investigated.

Based on the sensory-evaluation data several experimental entries appeared promising in having the desired quality profile for Japanese udon-noodles.

Kernel Hardness, Protein, and Viscosity as Predictors of Udon-Noodle Quality.

by

Helle G. Ruddenklau

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed April 22, 1994

Commencement June 1994

APPROVED:

Redacted for privacy

Professor of Crop and Soil Science in charge of major

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Dean of Graduate School

Date thesis is presented April 22, 1994

Typed by Helle G. Ruddenklau

DEDICATED TO:

my family

for their love and support

ACKNOWLEDGEMENTS

I owe my deepest gratitude to Dr. Warren E. Kronstad for the opportunity to work under his guidance. His vision and enthusiasm has inspired me throughout my studies at Oregon State University.

Thank you to the members of my graduate committee, Drs. Patrick Hayes, Christopher Mundt, and A.J. Verts. The staff at the Western Wheat Quality Laboratory, Portland Trade Center Laboratory, and the Sensory Laboratory in the Food Science Department at Oregon State University provided valuable guidance for which I am grateful.

Thank you to the Oregon Wheat Commision for providing me with financial support.

I will never forget the fun times shared with my fellow graduate students. I will always value their friendships. Also, I appreciate the friendship and support of the wheat breeding group.

Thanks to my parents for instilling in me the desire to learn and the determination to succed. They teach by their actions. Finally, I am grateful to my husband, Bruce. His patience and understanding helped me immensely.

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INTRODUCTION

Approximately 85% of the wheat (Triticum aestivum L. em Thell) produced in the Pacific Northwest is exported. The Japanese market is a major recipient of this wheat; however, Japan and other countries require high milling and baking quality for desired end-product uses. For the udon-noodle, a mixture of domestic Japanese wheat and Australian Standard White wheat (ASW) is currently preferred, whereas soft white wheat from the Pacific Northwest is used primarily for other end products such as cookies and cakes.

To take advantage of the large potential noodle market, it is desirable to develop new white-wheat cultivars with characteristics suitable for this end-product use. To accomplish this breeding goal, factors that determine noodle quality must be defined and reliable methods identified to evaluate early generation progeny.

In this investigation grain-protein percentage, kernel hardness, and six viscosity parameters, measured by the Rapid Visco Analyzer (RVA), were evaluated for their ability to predict Japanese udon-noodle quality. Grain-protein and kernel hardness are already used by the Oregon State University wheat-breeding program as part of the milling and baking quality evaluations of advanced selections. The RVA was developed in Australia to detect sprout damage (Ross et al., 1987). It was quickly determined that the RVA could also provide starch-gelatinization curves similar to those obtained with the amylograph, but at a fraction of the time (Walker et al., 1988; Deffenbaugh and Walker, 1989). The RVA possesses the characteristics required for early-generation quality-evaluations as described by Gras and O'Brien (1990). It is simple, rapid, reliable and uses only a small sample of flour. The RVA was chosen for this investigation as it appeared promising as a potential early generation test for predicting Japanese udon-noodle quality.

The objectives of this investigation were:

1) To determine if kernel hardness and protein can predict udon-noodle quality.
2) To evaluate the use of the RVA to predict udon-noodle quality.
3) To determine associations among kernel hardness, protein, and the viscosity parameters obtained with the RVA.
4) To determine possible genotype by environment interactions for kernel hardness, protein, viscosity, and noodle quality.

To accomplish these objectives, sensory-evaluation tests were conducted on the experimental entries, two check cultivars, and ASW flour to provide a reference for the quality tests. Also, the study was conducted at two sites which differ for both environmental conditions and management practices.

LITERATURE REVIEW

Cereals provide a major source of carbohydrates for much of the world's population. In many areas, this takes the form of bread, pasta, pastry or other products. In Asia, a large part of cereals (especially wheat) are consumed in the form of noodles.

In their simplest form, noodles are prepared from a dough containing flour, water, and salt. Many variations exist, however, which depend greatly on the type of noodle and the specific region of Asia (Oh et al., 1983). In Japan, a soft noodle texture usually is preferred and is unique to udon-noodles (made from soft wheat flour) and soba noodles (made from buckwheat flour). In China, Korea, and Southeast Asia, noodles with a chewy, more elastic texture are preferred. Consequently, the steaming of noodles and the use of noodle formulations including high-protein flour, eggs, or kan-sui (alkaline salts) to increase chewiness are common in these countries. Noodles made from 100% rice flour or a blend of rice and wheat flour are popular in Taiwan. Noodles made of starch from mung beans, rice, or cassava are also popular throughout Asia, but to a much lesser extent than flour noodles (Dick and Matsuo, 1988).

Not only do noodles differ in their ingredients, but also in their manufacturing process. For example, so-men and udon-noodles differ only in thickness. To add to the confusion, hand-made so-men is called tenobe, whereas hand-made udon is called teuchii (Nagao, 1981). Mixing, sheeting, and cutting are common steps in making all noodles. Some noodles are sold at that point as raw noodles. Others are boiled for wet noodles, still some are dried while others are fried. Another group is further shaped, steamed, and divided into single servings after which they are either dried or fried for instant noodles.

Consequently, in discussing noodle quality it is necessary to distinguish which type of noodle is being researched. In this study, Japanese udon-noodle was the type of interest. It consists of flour, water, and salt which are mixed, sheeted, cut, and then sold fresh (or raw). The udon-noodle is a staple food in Japan, and is often eaten daily in soups. It is difficult to express the preferred characteristics for udon-noodles. Noodle texture is probably most significant followed by color, surface appearance, taste, and weight and volume upon cooking. Udon-noodles should be a bright white, have a smooth surface, and be soft but with a springy resistance when chewed. Furthermore, they should cook quickly without loosing solids to the cooking water (Toyokawa et al., 1989a).

Wheat usage in Japan

Japan used to produce most of its own wheat, however, due to drastic reductions in production Japan now imports over 60% of its wheat. Of this one-third comes from the United States (John Oades, US Wheat Associates, pers. com.). Soft-wheat flour is used for noodles, confectionery products, and all purpose flour (Nagao et al., 1976).

In the past, Japan imported soft red winter wheat from the United States, Victoria soft from Australia, as well as French wheat for the production of soft-wheat flours. Now Western White wheat (soft white plus at least 10% club) from the Pacific Northwest and ASW, which is a nonclassified mixture of soft white wheat grown in western Australia, are used in conjunction with domestic Japanese wheats for soft-wheat flours (Nagao et al., 1977a).

Western White wheat is important for cakes, biscuits, cookies, crackers, and Japanese buns (Nagao et al., 1977a). When it comes to noodles, however, ASW wheat is preferred. The Japanese people's taste preference for noodle quality originates from use of domestic Japanese wheat. Therefore, those wheat cultivars similar to Japanese wheats are desired. Nagao et al. (1977a) found ASW, soft white, and white club wheats different in some respects from Japanese wheats, yet they possessed unique characteristics favorable for making noodle flour. Among the three, however, the ASW was preferable.

Wheat is judged on the basis of test weight, vitreous kernels, shrunken and broken kernels, dockage, foreign material, moisture, and protein content (Nagao et al., 1976). In Japan, the flour is milled for a dual confectionery/noodle purpose, however if the grain only possesses quality suitable for one or the other it can still be used.

Environmental effects on grain quality

Little is known as to how the environment may affect noodle quality. Potentially, many factors known to influence other end products could influence noodles as well.

In general, Nagao et al. (1977b) found a difference in noodle quality with respect to crop year, growing region, cultivar, and the percentage of club in Western White.

The sensitivity of udon-noodles to wheat quality was underscored in 1968 when flour milled in Japan from apparently sound Pacific Northwest wheat caused problems in noodle making. It was reported that some wheat had suffered undetected sprout damage. Bean et al. (1974ab) concluded that greater alpha-amylase activity was associated with the sprouted wheat. However, they attributed the problems with the noodle-making process to the presence of protease, solubilized carbohydrates, or other modified constituents formed in damaged grain.

Nitrogen fertilizer applied during grain filling will increase the protein content of the grain, decreasing noodle quality.

Grain quality

Research on milling and baking quality of wheat flour is extensive, however the focus has been on usages other than noodles. It is only recently that factors influencing noodle quality have come under scrutiny, thus the information is limited.

When noodles made from hard and soft kernel wheats with similar protein contents were compared, the hard-wheat noodles were generally darker and stronger but less firm at the surface (Oh et al., 1985c). Furthermore, the noodles made from hard wheat required longer boiling time, often not acceptable to the consumer. Thus cultivars with soft-kernel characteristics are preferred for noodles.

According to Nagao et al. (1977b) grain-protein about 10% is preferable. It has long been established (Bayfield, 1934) that grain-protein in wheat is highly correlated with flour protein, thus a protein determination on the wheat itself gives a fair indication of its future response when converted into flour.

Flour color:

According to Miskelly (1984), the color of the flour is one of the most important assessments of quality, particularly in regard to end product uses.

Flour should be milled in such a way as to cause as little damage to the starch as possible. In hard-texture wheat there is a loss in reflectance power due to entire starch granules being shattered or broken in milling. Miskelly (1984) found that granularity influences the color of dry flour with a flour of a finer-particle size being brighter and whiter. According to Nagao et al. (1976) the grain should be milled to yield a 60% extraction patent flour. Increasing the extraction percentage or including the third break and middling caused pieces of bran to be included in the flour which in turn caused discoloration of the finished product (Nagao et al., 1976; Oh et al., 1985c). The relationship between bran contamination and the decrease in color grade of flour and end product has been clearly established by several workers (Yasunaga and Uemura, 1962; Matsuo and Irvine, 1967; Moss, 1971; Oh et al., 1985c). Miskelly (1984) further found, that at 60% extraction the cultivars with softer kernels tended to have higher levels of bran contamination than hard-texture cultivars. She concluded that noodles should be produced from soft, patent flour rather than from flour with a predetermined extraction rate to ensure a clean, bright product.

For Japanese noodles, an increase in the level of either flour protein or brown pigment decreased flour brightness and produced dull noodles. However, neither the effect of brown pigment nor that of protein was found significant once the noodles had been boiled, presumably because the melanins and pigments dissolved in the cooking water. The color of boiled noodles was then limited by the yellowness of the flour. Noodle color was also related to cultivar (Miskelly, 1984).

Moss (1967) found that apart from those noodles made from one highly pigmented flour, the yellow color was not apparent in any noodles. Exploring this further, he found that noodle color is influenced by protein level, gluten, cultivar, salt, and drying temperature (in the case of dried noodles). Whiteness and brightness of the dried noodle decreased with increasing protein level. This agrees with the findings of Miskelly (1984). Cultivar differences were slight, compared with the effect of protein, but the stronger cultivars tended to give whiter noodles than weaker varieties at the same protein level. A strong cultivar shows high resistance and extensibility in the extensograph. According to Moss (1967), the color of the noodle appeared to be associated with the gluten. Also, an increase in salt produced whiter noodles, as did a higher drying temperature. Moss (1967) found no effect associated with yellow pigment, diastatic activity, water absorption, or any of the commonly measured quality characteristics of flour, apart from protein. After boiling, almost all of the noodles were equally white and lustrous; any factor contributing to discoloration apparently dissolved in the water.

Oh et al. (1985b) found that noodles became lighter in color as water absorption decreased. He explained this may be caused by a less compacted noodle structure at lower-water absorptions. According to Dexter and Matsuo (1979), a loose, flexible noodle structure allows for expansion without rupturing or pitting the surface. This would result in a smooth noodle surface which would probably reflect more light and appear lighter.

Yasunaga and Uemura (1962) found that yellow pigments could be effectively bleached by benzoyl peroxide. Moss (1971) reported success in partially suppressing development of a greyness by using acetone peroxide or chlorine dioxide at 20 ppm. He found benzoyl peroxide had no effect at the 20 ppm level. Harris et al. (1943) found that disease, sprout or immaturity could give rise to brownness by a non-enzymic Maillard or condensation reaction. Matsuo and Irvine (1967) found brownness in macaroni to be due to a Maillard-type reaction or to an enzymatic reaction. In studies on Canadian Durum and Hard Red

Spring wheats they found that brownness was related to a cultivar characteristic; a water soluble protein associated with copper. Moss (1971) suggested that the grey discoloration of noodles may be caused by the oxidation of tyrosine with consequent melanin formation. He observed that noodles made with flour to which 0.08% tyrosine was added darkened much more rapidly than noodles made from untreated flour. Some flours are still bleached, but one of the benefits of using ASW and Western White wheat for Japanese udon-noodles is that they instill a natural brightness to the flour and consequently give white and bright noodles throughout the manufacturing process.

Flour protein:

Bayfield (1934) postulated that protein content was an excellent measure of protein quantity and a measure accurate within a narrow range. According to Bayfield, its determination was free from biological influences, not the case with viscosity, fermentation, or baking tests. He suggested using protein determination in conjunction with a quality test such as acid viscosity to indicate the potential use of a new cultivar.

Yamazaki (1954) reported that water absorption was associated with the inherent kernel texture of a cultivar. It was not influenced by a range of protein levels within the same cultivar. This does not agree with the results of Oh et al. (1985c) who found that protein content of flour showed a significant negative association with noodle-dough water absorption. Yamazaki (1954) also found a positive association between flour-protein content and acid viscosity. Bresson and

Barmore (1955) confirmed this relationship using 17 commercial cultivars common to the Pacific Northwest. They suggested a method by which a graph of protein vs. acid viscosity could be used to draw lines representing various types of flour. By means of this chart the flour acid-viscosity data of promising new experimental cultivars could be compared with well-known commercial cultivars and with each other on a similar protein basis.

Other authors tried to eliminate the effects of flour protein on the acid viscosity test. Their approaches included using the amount of flour containing 2 g of protein (Bayfield, 1936), dividing viscosity readings by the amount of protein in the flour used (Blish and Sandstedt, 1925), or diluting the flour samples with starch to a common protein level (Bayfield, 1936).

Manufacturers face a dilemma in producing noodle flours or noodles for which the end product should have optimal eating quality and color. As protein content increases, the eating quality of the noodles becomes more acceptable, yet the color becomes less attractive (Miskelly and Moss, 1985). According to Oh et al. (1985c) noodles made from high protein wheats were darker, physically stronger, and firmer internally when cooked than noodles made from low-protein wheats. Protein content was the most influential factor determining internal firmness. They also found that surface firmness of hard-wheat noodles was not influenced significantly by protein content. Ten samples of soft-wheat noodles with protein contents ranging from 8.5 to 9.8% displayed considerable variability in surface firmness after cooking. In general, the authors concluded that differences in protein of flours could not always account for differences in noodles quality. Therefore, factors controlling surface firmness of noodles remain to be defined.

<u>Other factors:</u>

As with color development of flours and noodles, the milling process also influences the texture of noodles. Oh et al. (1985c) found a five-fold increase in starch damage when grain was ball-milled rather than pin-milled. High-starch damage and small-particle size resulted in higher-water absorption and softening in the cooked noodle. They also determined that increasing the extraction rate up to 80% did not affect noodle texture.

According to Toyokawa et al. (1989a), the range of flour ash from 0.35 for Japanese noodle flour to 0.41 for ASW flour was acceptable for making noodles. Bresson and Barmore (1955) observed that ash caused a reduction in acid viscosity in all cultivars except one; however, the reduction was not predictable.

Oh et al. (1985b) used a scanning electron microscope to examine the changes during boiling in the surface of noodles made from soft- and hard-kernel wheats. After 10 min of boiling, the surface of the noodles made from soft-textured wheats were smoother than the surface of noodles made from hard-kernel wheats. They attributed this to a loss in surface starch from the hard-wheat noodles with subsequent pitting of the surface. These rough surfaces became mushy and watery as the pits filled with water.

Components of flour, gluten and starch:

Of the various flour components, gluten and starch have the greatest influence on noodle quality and it is helpful to understand their role in the noodle making process.

When flour is kneaded in the hand under a steady, slow stream of water all components except the gluten are washed away. Storage proteins (gliadins and glutenins) are the main components of gluten, but lipids and carbohydrates are also present (Lorenzo, 1985). The lipids and carbohydrates are held strongly within the gluten-protein matrix and consequently do not contribute to the response of the gluten (Bloksma and Bushuk, 1988).

Gluten appears to be partly responsible for the viscoelastic property of dough and noodles through the combined effect of gliadins and glutenins (Kite et al., 1957; Oh et al., 1985c). Hoseney (1986) wrote that the unique ability of wheat flour to form a cohesive, elastic, and extensible dough is the result of gluten proteins in the wheat flour. However, according to Toyokawa et al. (1989a) gluten only influences the color of noodles, not their texture or viscoelasticity. Gliadins are single chained proteins that are sticky when isolated. They appear to be responsible for the viscous property of gluten, while glutenins are large multichained molecules and appear to be polymerized by disulfide bonds. Glutenins are physically resilient and resist extension. They appear to be responsible for the elastic property of gluten (Hoseney, 1986).

Based on the work of Bushuk (1966) uniform distribution of ingredients is the main purpose of dough mixing and gluten development which occurs to a limited extend is of secondary importance. When water is added to dry flour, the surfaces of the flour particles hydrate rapidly and gluten protein fibrils form spontaneously and extend from their surfaces into the surrounding water (Bernardin and Kasarda, 1973). Gluten, when dry, is a glassy polymer and when it takes up water it undergoes a transition rendering it mobile thus is able to interact with other gluten polymers to form a dough (Hoseney et al., 1986).

According to Fabion and Hoseney (1990) the absorbance of water can be visualized through a mixogram curve. As mixing begins, water rapidly moistens the outer surfaces of the flour particles. The large excess of water provides little resistance to extension and the mixogram curve is low. With continued stirring, the hydrated-protein fibrils on the flour-particle surfaces are wiped away by contact with other surfaces. The resulting new surface of the flour particle is then hydrated rapidly. This continuous process creates a system of hydrated-protein fibrils with starch granules dispersed throughout and little free water. Accordingly, the resistance to extension of the system increases causing the observed increase in mixogram-curve height. Fabion and Hoseney (1990) wrote that once all of the protein in the flour is hydrated, continued mixing does not increase the height of the mixing curve. Therefore dough mixing is essentially a hydration process, with the resulting dough being a random entanglement of hydrated-protein fibrils.

Noodle dough contains a limited amount of water (about 35%) compared to doughs for other end uses. Water must penetrate the flour particles before the protein becomes hydrated, interact, and form a dough (Fabion and Hoseney, 1990). In noodles, real dough formation does not occur, instead mixing produces a crumbly mass, which may be compressed by hand into the resemblance of a dough ball.

Bushuk (1966) working with bread dough estimated that 45.5% of the total water in dough might be associated with the starch, 31.2% with the protein and 23.4% with pentosans. It is not known how these percentages may differ in noodle dough. He also found that at the 2%-salt level in noodle flour the hydration capacity of gluten is reduced by about 8%. This suggests that the amount of water associated with gluten in a noodle dough is limited. To amend this situation, a period of resting is often allowed after mixing for uniform water distribution and "mellowing" of the gluten. Oh et al. (1985a) showed that an initial resting period of up to 1 hour increased surface firmness. The optimal water absorption can be determined by the handling characteristics of the dough. Too much water gives a sticky dough that stretches excessively during handling, whereas too little water gives a stiff dough that resists sheeting. Further gluten development occurs during sheeting. As the dough is always sheeted in the same direction, the gluten molecules change alignment from a random organization in the dough to an ordered parallel alignment in the noodle sheets. As a result the noodles are stronger length-wise than they are cross-wise (Oh et al., 1985a).

According to Dexter and Matsuo (1979) and favored by Oh et al. (1985a), the degree of gluten development influences the surface firmness of noodles. They reasoned that in noodlemaking water absorption is low and mixing and sheeting times are fixed. Therefore, the variation found in surface firmness is due to variations in gluten development of different flours. In noodles made from hard-kernel wheat with well-developed gluten the bond between surface starch and protein was weakened in boiling water but the bond between surface protein and the remaining developed protein remained strong. The surface starch (especially damaged starch) was etched away, leaving behind the denatured-protein matrix (Oh et al., 1985b). The pitting of cooked noodles, which they saw on the scanning electron microscope micrographs, could be due to erosion of surface starch. The voids between the surface proteins (previously occupied by the starch) fills with water reducing surface firmness. Consequently, the gluten-rich surface of hard wheat noodles feels less smooth to the palate and more watery and mushy than if the surface had retained the starch. In contrast, when gluten is not fully developed, as in the soft-wheat noodles, solids erode from the surface as chunks of protein and starch, because the gluten matrix is poorly developed. The remaining surface still contains swollen gelatinized starch, and consequently seems smoother.

Difference in surface firmness of noodles made from soft- vs. hard-textured wheats may also be attributable to a difference in gluten strength. Hard-kernel wheat with strong gluten could give a more rigid, less flexible structure which would be more susceptible to rupture under the stresses of swelling and protein denaturation during cooking (Dexter and Matsuo, 1979; Oh et al., 1985a). In a study of gluten and noodle making, Oh et al. (1985b) found that between dough pH 4 and pH 8 breaking stress of uncooked noodles increased steadily with greater water absorption, but between dough pH 8 and pH 10 the breaking stress leveled off as absorption increased. They argued that strong-noodle structure with high-water absorption would account for the greater breaking stress. Greater water absorption would cause further gluten development and the establishment of good adhesion between starch granules and gluten proteins.

Most of the endosperm and consequently wheat flour is starch. Starch occurs as discrete, partially crystalline (30%) granules in two sizes (Lineback and Rasper, 1988). The large, lenticular granules constitute only 3-4% of the total number of granules, but they contribute 50-75% of the total weight of the starch (Duffus and Murdoch, 1979). The other type of granule has a small, spherical shape. The chemical composition and properties of the two types of granules are essentially the same, except the surface-to-mass ratio is much greater for the small granules. Besides being partially crystalline, starch granules show "birefringence" brought about by the highly ordered structure of the granules. This birefringence takes the appearance of a "maltese cross," a result of the early growth of the granule (Hoseney, 1986).

Starch consists almost exclusively of the sucrose polymers, amylose and amylopectin, with a trace of lipids, phosphorus, nitrogen, and other minerals (Hoseney, 1986). Wheat starch contains about 25% amylose and 75% amylopectin (Kite et al., 1957). Amylose is generally assumed to be a long, linear molecule;

however, part of the amylose appears to be lightly branched. The long linear nature of amylose is responsible for its tendency to associate with itself and precipitate from solution. The amylose will readily crystallize from solution or "retrograde." Retrogradation is the term used to denote recrystallization in starch gels. Amylopectin is branched to a much greater extent than is amylose. It carries the distinction of being one of the largest molecules found in nature (Hoseney, 1986).

The structure of starch is not known for certain. It appears that most of the molecules in the starch granules are oriented at a right angle to the surface of the starch granule. The amylopectin portion is thought to be responsible for the partial crystalline structure. Some or all of the outer chains of amylopectin molecules appear to occur as a double helix (Hoseney, 1986).

When starch and water are heated, the resulting change in the starch is responsible for much of the textural characteristics of noodles. "When starch is placed in water, the granule is freely penetrated by water to a point equal to 30% of its dry weight. The granule swells slightly, about 5%. The volume change and water absorption are reversible, and heating the system to just below its gelatinization temperature will not bring about any other changes. However, heating to higher temperatures results in gelatinization, which is irreversible" (Hoseney, 1986). This process can be shown with an amylograph.

The amylograph measures the relative viscosity of a system as it is heated at a constant rate. Viscosity provides a quantification of the flow characteristics of a liquid by measuring its resistance to stirring. When wheat starch is heated in the presence of water, viscosity increases between 50 and 57°C. This coincides with the loss of birefringence. Starch gelatinization is defined as the loss of birefringence. Continued heating increases viscosity. This increase in viscosity is a result of the starch absorbing water and swelling substantially. Consequently, the starch granule is distorted and soluble starch is released into the solution. This soluble starch combined with the continued uptake of water by the remnants of the starch granules are responsible for the increase in viscosity. Those changes that occur after starch gelatinization (loss of birefringence) are termed "pasting." Solubilization of the starch is continuous and is not complete till the granular structure is completely soluble. To occur, the temperature must exceed 120°C. This is not practical and heating in the amylograph is discontinued at 95°C and the temperature is held there for 1 hour. The viscosity of the starch system decreases markedly during this hour due to the molecules of the soluble starch orienting themselves in the direction of the stirring. This phenomenon, called "shear thinning," is a critical property of starch pastes, as it renders them susceptible to overmixing. After 1 hour, the amylograph procedure has a controlled cooling to 50°C. This results in a rapid increase in viscosity referred to as "setback." This is caused by a decrease of energy in the system that allows more hydrogen bonding thus greater viscosity (Hoseney, 1986).

The Rapid Visco Analyzer (RVA) was developed in Australia to detect sprout damage (Ross et al., 1987). Deffenbaugh and Walker (1989) compared the pasting curves obtained from the RVA with those of the amylograph. The shape of the pasting curves were similar for the two instruments but absolute viscosity values differed. Walker et al. (1988) concluded that the advantages of the RVA over the amylopgrahp were due to the quick and easy test procedure and a small sample size required. The procedure involves dispensing a set amount of water into a disposable aluminum sample container and adding a small sample of whole grain meal, starch or other material of interest. A plastic stirring paddle attached to the lid is manually used to partly mix the suspension before the sample is inserted into the instrument. The suspension is momentarily prestirred to ensure proper mixing before being heated rapidly by a tightly clamped split copper block. Viscosity is measured as the force required to rotate the paddle at a constant speed during this process and recorded as Stirring Number (SN). The instrument can be adjusted to heat and cool the sample for certain time periods.

When water is limited as in a noodle dough, starch gelatinization occurs over a much wider temperature range (50-80°C). The amount of water does not affect the temperature at which the birefringence starts to be lost but increases the temperature at which the process is completed (Hoseney, 1986).

Recently, there has been some research done using the amylograph to assess the effect of starch on the noodle making process. Nagao et al. (1977a) studied ASW from Australia, and soft white and club wheat from the Pacific Northwest. They found that all showed favorable characteristics for udon-noodles, and that the starches in all of the flours were found to swell at a relatively low temperature compared to those of other flours. Oda et al. (1980) found that the difference between peak viscosity of starch as measured by the amylograph and the viscosity after holding at 94.5°C for 10 minutes is a factor in determining the eating quality of udon-noodles. They also reported that amylose content of flour showed a significant negative correlation with eating quality.

In 1989, Toyokawa et al. (1989a) undertook a fractionation and reconstitution study of gluten, primary starch, tailing starch, and water solubles to investigate the role of each in udon-noodle quality. They found the primary and tailing-starch fractions to be most responsible for noodle texture. Of the two, the primary starch fraction contributed the most to the desirable viscoelasticity. On an equal weight basis, the tailing starch had the greater effect, but because it was only present in one-fifth the amount of primary starch its effect was overshadowed by that of the primary starch. They also compared ASW from Australia and soft white from the Pacific Northwest and found the ASW noodles were better in hardness, viscoelasticity, and total score, whereas the soft-white noodles were better in color. They concluded the gluten fraction only affected the raw and cooked color, and the water-soluble fraction had no effect at all. They explored this further by determining the physical and chemical characteristics of primary and tailing-starch fractions and the effect on noodle quality (Toyokawa et al., 1989b). In this second study, they found a significantly positive correlation between the water-holding capacity of the primary starch at 75°C and the viscoelasticity score of the noodles. They stated this relationship holds promise to provide a simple and quick predictive test for noodle texture. Furthermore, they studied the effect of amylose/amylopectin ratio, and determined that the quality of noodles made from high-amylose starches was extremely poor. These noodles could not hold water or form a noodle structure. This finding agreed with that of Oda et al. (1980). This could be explained by the low water-holding capacity, i.e., the water was not absorbed into the starch molecules because high amylose made a rigid and tight structure. However, Oda et al. (1980) discovered that noodles made from approximately 100% amylopectin also had poor quality as they were viscous and sticky. Subsequently, they suggested there is an optimum amylose/amylopectin ratio for good noodle quality. As the amylose/amylopectin ratio decreased, the viscoelastic score increased.

MATERIALS AND METHODS

Experimental materials used for this study were grown in the 1990/1991 Hard White Winter Wheat yield trials of the wheat-breeding program at Oregon State University. These included seven promising experimental selections and Stephens, the most widely grown soft white winter-wheat cultivar in the Pacific Northwest. The material was grown in two locations, the Chambers site near Corvallis and at the Rugg farm located northeast of Pendleton. Two check cultivars, Owens and Klasic, previously identified as having good noodlemaking characteristics, were grown at the Rugg site for comparison. For taste testing, noodles made from ASW straight grade flour were also used as a standard. ASW flour is known to produce udon-noodles of acceptable quality. The pedigrees of the experimental material are presented in the Appendix, Table 1 with a description of the commercial cultivars.

A randomized complete block design with three replications was used at both experimental sites. Each plot consisted of six, 3-m-long rows planted 14 cm apart.

The soil type at the Chambers site is a fine-silty, mixed, mesic, Cumulic Ultic Haploxeroll. The previous crop had been squash (Cucurbita maxima). The seeding rate was 123 kg ha^{-1}. Fertilizer was broadcast in February when the first node was detectable (Feekes 6). A blend of 157.0 kg ha^{-1} of N, 8.4 kg ha^{-1} P_2O_5, 102.0 kg ha^{-1} K_2O, 54.9 kg ha^{-1} S, and 74.6 kg ha^{-1} of Cl was used. Weeds were controlled with a combined application of Chlorsulfuron (17.5 g ha^{-1}) and Diuron (1.3 kg a.i. ha^{-1}) in the fall.

Coarse-silty, mixed, mesic, Typic Haploxeroll is the soil classification at the Rugg site. In the previous year, peas (Pisum arvense) had been grown in the experimental area. Wheat was seeded at a rate of 101 kg ha^{-1}. One hundred kg N ha^{-1} and 20 kg S ha^{-1} were incorporated at the time of planting in the form of anhydrous ammonia. In the spring when the 4th node was detectable (Feekes 7) 31.4 kg of N ha^{-1}, 3.5 kg of P ha^{-1}, and 3.5 kg of S ha^{-1} were applied as liquid 18-2-0-2. Bromoxynil (1.4 l a.i. ha^{-1}) was applied in the spring to control weeds.

At harvest, grain yield and test weight were measured on a whole-plot basis. These data are presented in the Appendix, Tables 2, 3, and 4. Approximately 1 kg of grain as well as a small subsample collected in an envelope were obtained for further testing at the Western Wheat Quality Laboratory (WWQL) in Pullman, Washington.

Protein and Hardness:

In the WWQL, enough seed from the envelope was ground on a Tecator mill for moisture determination according to AACC method 44-15A (Approved Methods of the American Association of Cereal Chemists, 1976). The remaining seed was ground on a Udy sample mill (0.5 mm screen). The mill was cleaned frequently to avoid overheating the grinder. This produced a whole-grain meal, finely ground whole kernels. Protein and hardness values of the whole-grain meal were determined by near infrared reflectance (NIR) spectroscopy (Technicon IA 450). Protein values were adjusted to 14% moisture basis (mb).

Viscosity:

Moisture was determined on the whole-grain meal. Subsequently, the meal was tested for viscosity using the Rapid Visco Analyzer (RVA). Four g whole grain meal (14% mb) was weighed within ±0.005 g. Distilled water (25 ml) was measured and poured into an aluminum beaker to which the meal was added. The paddle connected to the beaker lid was gently used to partly mix the whole meal and water. The beaker was then inserted into the RVA and the cycle initiated by firmly pressing the beaker down into the machine. The settings were 94°C for 4.5 min followed by 8 min at 51°C. The RVA was connected to a graph printer that continuously recorded the viscosity readings as a solid line. A representative graph can be seen in the Appendix, Figure 1. The noodle dough underwent gelatinization and pasting as the curve moved to Peak 1, the point of maximum viscosity. Continued stirring at the high temperature caused shear thinning and a subsequent decrease in viscosity to the "Low" point of the curve. As the paste was rapidly cooled, setback occurred and the increased viscosity measured by Peak 2. The viscosity values were displayed digitally on the RVA as "stirring number" (SN) units. The SN values corresponding to the two peaks and the lowest point on the curve (Appendix, Figure 1) were read from the digital display on the RVA and manually recorded. The differences between these values were then calculated and recorded also. The cycle was interrupted when the last peak was reached and the line became horizontal. This always occurred before the RVA's cycle had been completed. After the cycle was terminated, the machine needed time to return to 94°C before inserting a new sample. Approximately 12 min were required per sample.

Preparation of flour:

Twenty-four hours before milling, 1 kg of each grain sample was tempered to the appropriate moisture content. Soft-kernel lines (NIR hardness values < 55) were tempered to 14% moisture content and hard-kernel lines (NIR hardness values > 55) to 16%. Samples were put in a rotating drum and water added. The grain and water was allowed to mix for 20 min before being stored overnight in a glass jar. Approximately 30 min before milling, an additional 0.5% of water was added while the sample was in the rotating drum.

The samples were milled on a Buhler laboratory mill (Buhler Bros. Inc., Switzerland). Mill rolls were kept warm overnight with electric heaters and a 2 kg warm-up sample was milled each morning. Mill settings normal to the WWQL were utilized (Appendix, Table 3). Approximately 8 to 10 min were required to feed each sample into the mill. The feeding rate was 125-130 g min^{-1} for hard-kernel samples and 120 g min^{-1} for the soft. A modified version of cleanout method AACC 26-21A (Approved Methods of the American Association of Cereal Chemists, 1976) was used. The weights of 1st + 2nd break, 3rd break, 1st + 2nd reduction, 3rd reduction, shorts, bran, and set-off were determined and recorded.

Extraction rates between entries ranged from 50 to 64%. For milling data see the Appendix, Tables 6a and 6b.

First and 2nd break plus 1st and 2nd reduction were combined to produce a patent flour. To prevent loss of moisture, the flour was packaged in double layers of plastic, sealed, and transported back to Corvallis.

At the Trade Center Laboratory located in Portland, the bags of flour were sifted through a fine mesh sieve to remove any impurities. Two hundred-fifty g of flour from each replication of a line at one location were combined and mechanically mixed in a bowl for 15 min. The 750 g of mixed flour was bagged in two layers of plastic until used, one bag for each line per location.

Noodle preparation:

Noodles were made according to the procedure followed at the WWQL with a few modifications. A Kitchen Aid mixer (model K5A) with a flat beater was used to mix the dough. Three hundred g of flour was measured into the 5 l mixing bowl. The mixer speed was set at the lowest setting (setting 1) to avoid spilling the flour out of the bowl. Within the first 5 sec of mixing, 96 ml of 2% saltwater was added. After 30 sec the speed was increased slightly (setting 2) for 4 min. This gave a stiff and crumbly dough. The dough was allowed to rest for 10 min before sheeting. An Ohtake laboratory type noodle making machine (Ohtake-Tokyo, Japan) was used. The roll gap was set at approximately 4 mm for the first pass. A pass is the process of forcing the dough between the two rollers to produce a noodle sheet. The dough was passed through and recombined (folded over on itself). This was repeated twice. The roll gap was then reduced in three passes (without recombination) to approximately 2 mm. The noodle sheet was put through the 2 mm roll gap three times. During the last pass, the noodle sheet was directed through the cutting rolls. This produced noodle strings with a cross section of approximately 2.5 by 3.0 mm. The noodle strings were visually inspected and any strings discolored or distorted by the noodle machine discarded. The ends of the noodles were trimmed and the strings cut in half to produce noodles of approximately 30 cm length. They were then immediately sealed in ziplock bags and transported to Corvallis for sensory evaluation.

Sensory evaluation:

The noodles were prepared and taste tested on two separate days. A taste-test panel cannot evaluate 19 samples in one day, so the experimental entries and the check cultivars were randomly assigned to one of the days with the noodle made from ASW flour being included both days. Thus, a total of 10 lines was evaluated per day. All noodles were boiled in tap water for 18 minutes before being rinsed thoroughly in cold, running water. The noodles were served in a soup and evaluated for surface appeal, texture, and taste by a panel of Japanese students. Twenty-three students participated the first day and 17 the second. Each line was coded with a random five-digit number. Appendix, Figure 2 shows an example of the ballot used by the panel. The scores were then converted to a numerical value. "Dislike very much" was assigned the value of 1 up to "like very much" which was given the value of 7.

Statistical Analysis:

The statistical computer package, SAS, was used for the analysis (SAS Institute Inc., North Carolina).

For the quality data for entries grown at the Chambers site the design was unbalanced as rep 3 from Entry 18 was accidentally lost. Consequently, a General Linear Model (GLM) procedure was followed. At the Rugg site, the design was balanced and Analysis Of Variance (ANOVA) was performed. At both locations observed mean squares, coefficients of variation, and standard deviations were calculated for grain-protein concentration, kernel hardness, and the six viscosity parameters (Peak1, Low, Peak2, Peak1-Low, Peak2-Low, Peak1-Peak2). These calculations were also performed on the combined data from the two locations. For the entries at each location and the two check cultivars grown at Ruggs, the means for the quality traits were determined. Differences between means at the same location were evaluated by use of the Tukey-Kramer method. Associations between kernel hardness, protein, and the viscosity parameters were calculated as coefficients of correlation (r) from data for the experimental entries only. Associations within the viscosity parameters were not reported. Grain-protein percentages were adjusted to 14% mb before statistical analysis was performed.

Plot yields and testweights were expressed as kg ha^{-1} and kg hl^{-1}, respectively (Appendix, Tables 2, 3, and 4). Milling-data measurements are presented in the Appendix, Tables 6a and 6b.

The sensory evaluation data was unbalanced, thus GLM was used for the analysis. The entries were evaluated on two separate days and when the raw data were analyzed differences were found between scores awarded on the two days. This was attributed to a change in sensory evaluation methodology over the two days. Furthermore, an interaction between date and location was observed for texture and taste. This, however, was dismissed as an artifact of the much larger interaction between location and entry. Sensory evaluation scores were then adjusted for date. The correction values are presented in the Appendix, Table 7.

Observed mean squares, coefficients of variation, and standard deviations were calculated for surface appeal, texture, and taste at the two locations. At each location, the mean values for the experimental entries of these traits were calculated. Mean sensory-evaluation values for Owens, Klasic, and ASW were also determined. Differences were detected by the Tukey-Kramer method. Associations with kernel hardness, protein, and the viscosity parameters were not determined.

RESULTS

Observed mean squares for grain-protein percentage, kernel hardness, and six viscosity parameters are presented in Tables 1 and 2 for the Chambers and Rugg sites, respectively. At both sites coefficients of variation were low. Entry differences were found for all traits, except protein at the Rugg location (Table 2). When locations were combined, differences were again observed for all traits, except kernel hardness (Table 3). Significant entry by location interactions existed for kernel hardness and the viscosity parameter Peak1-Peak2.

Differences among entries grown at the Chambers location were found for both grain-protein percentage and kernel hardness (Table 4). Stephens and Entries 7 and 18 had the lowest protein contents, with Entry 55 having the highest. Entry 36 had the softest kernel texture and Entry 8 the hardest. In general, protein levels were higher at the Rugg site (11.71) than at the Chambers site (10.88) (Table 5). Kernel hardness values were similar at the two sites, except for Entry 7 which had a higher kernel-hardness value at the Rugg location. Entry 36 had the softest kernels and Entries 7 and 8 had the hardest for entries grown at the Rugg farm. No difference among the entries was found for grain-protein percentage at this location. Klasic had a higher grain-protein percentage and harder kernel texture than Owens (Table 6). For the data in Tables 4 though 6 the coefficients of variation were low.

Table 1. Observed mean squares and coefficients of variation (C.V.) for grain-protein percentage, kernel hardness and the visocity parameters for experimental entries grown at the Chambers farm in the 1990-1991 growing season.

				Viscosity Parameters‡					
Source of Variation	df	Protein (14% mb)	Kernel Hardness	Peak1	Low	Peak2	Peak1-Low	Peak2-Low	Peak1-Peak2
Total	22								
Rep	2	0.29	38.48	55.21	31.46	46.80	7.84	2.72	1.54
Entry	7	0.77 **	730.30 **	1930.43 **	364.13 **	893.91 **	805.53 **	154.96 **	763.01 **
Error	13	0.15	27.02	111.56	35.26	81.40	34.44	12.49	14.21
C.V. (%)		3.51	7.97	3.83	5.09	4.02	3.69	3.29	7.32

‡ for an explanation of the viscosity parameters please see the Appendix, Figure 1
** significant at the 0.01 probability level

Table 2. Observed mean squares and coefficients of variation (C.V.) for grain-protein percentage, kernel hardness and the visocity parameters for experimental entries grown at the Rugg farm in the 1990-1991 growing season.

				Viscosity Parameters‡					
Source of Variation	df	Protein (14% mb)	Kernel Hardness	Peak1	Low	Peak2	Peak1-Low	Peak2-Low	Peak1-Peak2
Total	23								
Rep	2	0.13	28.58	58.17	22.17	113.38	32.00	38.29	36.29
Entry	7	1.72 NS	1116.65 **	2172.38 **	276.74 **	763.62 **	1019.98 **	137.12 **	689.81 **
Error	14	0.72	12.86	133.31	25.02	72.57	61.05	15.39	24.72
C.V. (%)		7.01	5.45	4.40	4.50	3.99	5.17	3.83	10.18

‡ for an explanation of the viscosity parameters please see the Appendix, Figure 1
** significant at the 0.01 probability level

Table 3. Observed mean squares and coefficients of variation (C.V.) for grain-protein percentage, kernel hardness and the visocity parameters to show effect of location on experimental entries grown at Chambers and Rugg farms in the 1990-1991 growing season.

				Viscosity Parameters‡					
Source of Variation	df	Protein (14% mb)	Kernel Hardness	Peak1	Low	Peak2	Peak1-Low	Peak2-Low	Peak1-Peak2
Total	46								
Location	1	10.21 **	13.19 NS	1866.99 **	295.78 **	1139.52 **	676.55 **	274.19 **	89.34 **
Entry	7	1.67 **	1755.92 **	3866.95 **	579.76 **	1495.23 **	1729.33 **	258.78 **	1398.80 **
Ent×Loc	7	0.81 NS	73.65 **	217.79 NS	58.36 NS	146.44 NS	90.09 NS	28.18 NS	54.07 *
Error	31	0.42	21.46	114.30	29.55	77.24	44.58	14.83	19.56
C.V.(%)		5.54	7.07	3.98	4.78	4.02	4.31	3.67	8.82

‡ for an explanation of the viscosity parameters please see the Appendix, Figure 1
*,** significant at the 0.05 and 0.01 probability levels, respectively

Table 4. Mean values for grain-protein content and kernel-hardness values as measured by Near Infrared Reflectance Spectroscopy of experimental material grown at Chambers farm in 1990-1991.

Experimental Material	Protein (14% mb)	Kernel Hardness Value
Stephens	10.09 b[†]	54 ef
Entry 6	10.93 ab	63 de
Entry 7	10.56 b	75 cd
Entry 8	10.69 ab	89 c
Entry 16	11.00 ab	77 cd
Entry 18	10.59 b	55 e
Entry 36	11.12 ab	39 f
Entry 55	11.82 a	67 de
S.D.	0.41	5
C.V.(%)	3.77	8

† means with the same letter within a column are not significantly different at the 0.05 probability level

Table 5. Mean values for grain-protein content and kernel-hardness values as measured by Near Infrared Reflectance Spectroscopy of experimental material grown at Rugg farm in 1990-1991.

Experimental Material	Protein (14% mb)	Kernel Hardness Value
Stephens	11.35 a†	52 ef
Entry 6	11.80 a	65 cd
Entry 7	11.20 a	92 b
Entry 8	11.67 a	90 b
Entry 16	12.57 a	76 c
Entry 18	12.12 a	50 f
Entry 36	10.41 a	38 g
Entry 55	12.59 a	63 de
S.D.	0.77	4
C.V.(%)	6.61	6

† means with the same letter within a column are not significantly different at the 0.05 probability level

Table 6. Mean values for grain-protein content and kernel-hardness values as measured by Near Infrared Reflectance Spectroscopy of check cultivars grown at Rugg farm in 1990-1991.

Cultivar	Protein (14% mb)	Kernel Hardness Value
Owens	11.46 b†	39 d
Klasic	13.58 a	58 c
S.D.	0.49	3
C.V.(%)	3.93	5

† means with the same letter within a column are not significantly different at the 0.05 probability level

Differences were found among entries grown at the Chambers farm for the six viscosity parameters (Table 7). For Peak1, Entry 6 had the highest value while the values for Entries 7, 8, 16, 18, and 55 were low. For the parameter Low, Entry 6 displayed a higher value than all other entries except Stephens. Entry 6 had the highest value for Peak2, whereas lower and similar values were obtained for the other entries. For the parameter Peak1-Low, Entry 6 again had the highest value with the value for Entry 7 being the lowest. Entries 6 and 7 showed high values for Peak2-Low, whereas the values for Entries 16 and 18 were lower. Entries 6,18, and 36 had high values for the parameter Peak1-Peak2, whereas Entry 7 had the lowest. The coefficients of variation were low across all parameters.

Table 8 contains the mean values for the viscosity parameters for entries grown at the Ruggs farm. Entries 6 and 36 had high values across all parameters. Furthermore, Entry 55 also had high values for the parameters Low and Peak2, while the value of Entry 16 was high for Peak1-Peak2. For the first peak (Peak1) Entries 7, 8, 16, and 18 had low values and together with Stephens these entries were also low for the parameters Low and Peak2-Low. Stephens and Entries 8, 16, and 18 had low values for the second peak (Peak2), whereas Entries 7, 8, 18, and 55 had low values for Peak1-Low. For the parameter Peak1-Peak2, Entry 7 had the lowest value. Consistently low coefficients of variation were observed across all parameters except Peak1-Peak2 for which the coefficient of variation was elevated, but still low.

Table 7. Whole-grain meal viscosity values (Stirring Number) as measured by the Rapid Visco Analyzer of experimental material grown at the Chambers site during 1990-1991.

Experimental Material	Peak1[‡]	Low	Peak2	Peak1-Low	Peak2-Low	Peak1-Peak2
Stephens	279 bc[†]	123 ef	229 i	156 kl	106 opq	50 tu
Entry 6	329 a	140 e	261 h	189 j	121 n	68 r
Entry 7	242 d	110 fg	223 i	132 m	113 no	19 v
Entry 8	270 bcd	114 fg	217 i	156 kl	104 opq	52 t
Entry 16	269 bcd	107 fg	204 i	163 kl	98 q	65 r
Entry 18	257 cd	103 g	204 i	154 kl	101 pq	54 st
Entry 36	287 b	117 fg	224 i	170 k	106 opq	64 rs
Entry 55	267 bcd	116 fg	226 i	151 l	110 op	41 u
S.D.	10	6	9	6	3	4
C.V.(%)	4	5	4	3	3	7

‡ for an explanation of the viscosity parameters please see the Appendix, Fig. 1.
† means with the same letter within a column are not significantly different at the 0.05 probability level

Table 8. Whole-grain meal viscosity values (Stirring Number) as measured by the Rapid Visco Analyzer of experimental material grown at the Ruggs site during 1990-1991.

Experimental Material	Peak1[‡]	Low	Peak2	Peak1-Low	Peak2-Low	Peak1-Peak2
Stephens	262 b[†]	110 efg	210 ijk	152 m	100 pqr	52 tuv
Entry 6	303 a	126 d	239 h	177 l	112 o	64 s
Entry 7	227 c	102 g	205 je	125 n	103 pqr	22 w
Entry 8	248 bc	107 fg	207 ijk	141 mn	100 pqr	41 uv
Entry 16	256 bc	104 fg	200 jk	151 m	96 qr	55 stu
Entry 18	241 bc	100 g	192 k	141 n	92 r	49 uv
Entry 36	301 a	122 de	232 hi	179 l	110 op	69 st
Entry 55	260 b	117 def	222 hij	143 mn	105 pq	38 v
S.D.	11	5	9	8	4	5
C.V.(%)	4	4	4	5	4	10

‡ for an explanation of the viscosity parameters please see the Appendix, Fig. 1.
† means with the same letter within a column are not significantly different at the 0.05 probability level

Owens had higher values than Klasic for the viscosity parameters Peak1, Peak2, and Peak1-Peak2 (Table 9). Difference were not found between the two checks for the other parameters. Low coefficients of variation were observed across all parameters. For the parameters Peak1 and Peak1-Low the values of the check cultivars were similar to the values observed for the experimental entries grown at the Chambers (Table 7) and Rugg (Table 8) locations. However, for the parameters Low, Peak2, and Peak2-Low the values of the checks were lower when compared to the values observed for the experimental entries whereas values for Peak1-Peak2 were somewhat higher.

Negative associations were noted for grain-protein across the six viscosity parameters (Table 10). These negative associations were consistently greater at the Ruggs site. Within each location, the correlation coefficients (r) were similar in magnitude for the different viscosity parameters. Associations between kernel hardness and the viscosity parameters were negative, with the association being consistently larger at the Rugg site. At Chambers farm, the r-values were similar across the different viscosity parameters, whereas at Rugg farm a greater range was observed. The correlations between kernel hardness and the viscosity parameters were larger than the correlations observed between grain-protein content and the viscosity parameters. This was true at both locations. Little or no correlation was found between grain-protein percentage and kernel hardness at either Chambers or Rugg farms (Table 12).

Table 9. Whole-grain meal viscosity values (Stirring Number) as measured by the Rapid Visco Analyzer of check cultivars grown at the Ruggs site during 1990-1991.

Cultivar	Peak1[‡]	Low	Peak2	Peak1-Low	Peak2-Low	Peak1-Peak2
Owens	268 a[†]	101 c	191 d	167 f	90 g	77 h
Klasic	247 b	94 c	181 e	152 f	87 g	65 i
S.D.	8	2	5	7	4	4
C.V.(%)	3	2	3	4	4	6

‡ for an explanation of the viscosity parameters please see the Appendix, Fig. 1.
† means with the same letter within a column are not significantly different at the 0.05 probability level

Table 10. Correlation values (r) of grain-protein content with the viscosity parameters for the experimental material grown at Chambers and Rugg farms during the 1990-1991 growing season.

	Grain-protein Content	
Viscosity Parameter[‡]	Chambers	Rugg
Peak1	-0.067	-0.367
Low	-0.122	-0.229
Peak2	-0.092	-0.311
Peak1-Low	-0.019	-0.413 *
Peak2-Low	-0.035	-0.401
Peak1-Peak2	-0.003	-0.316
	N = 23	N = 24

‡ for an explanation of the viscosity parameters please see the Appendix, Fig. 1.
* significant at the 0.05 probability level

Table 11. Correlation values (r) of kernel hardness with the viscosity parameters for the experimental material grown at Chambers and Rugg farms during the 1990-1991 growing season.

	Kernel Hardness	
Viscosity Parameter[‡]	Chambers	Rugg
Peak1	-0.027	-0.539 **
Low	-0.129	-0.385
Peak2	-0.093	-0.294
Peak1-Low	-0.260	-0.580 **
Peak2-Low	-0.024	-0.149
Peak1-Peak2	-0.267	-0.646 **
	N = 23	N = 24

‡ for an explanation of the viscosity parameters please see the Appendix, Fig. 1.
** significant at the 0.01 probability level.

Table 12. Correlation values (r) of kernel hardness with grain-protein for the experimental material grown at Chambers and Rugg farms during the 1990-1991 growing season.

Experimental Location	Kernel Hardness by Grain-protein Content
Chambers farm	-0.064
Rugg farm	0.196
	N = 23

Differences among entries were found for texture and taste at both locations, while differences for surface appeal were only found at Rugg farm. The coefficients of variation were extremely high at both locations (Tables 13 and 14).

When the locations were combined, differences were observed for noodle texture and taste (Table 15). Significant entry by location interactions were detected for all three traits. Extremely high coefficients of variations were also observed across these traits.

Sensory-evaluation values for entries grown at the Chambers site are shown in Table 16. No difference was found among entries for surface appeal. For texture, Stephens and Entries 7, 8, 16, and 36 had high and similar values. Entry 16 had higher values than Entries 6, 18, and 55 for this trait. Stephens and Entries 6, 7, 8, 16, and 36 were similar in taste, and again, only Entry 18 was judged better tasting than Entries 18 and 55. For all sensory evaluation traits coefficients of variation were extremely high.

For the experimental material grown at the Rugg site the ranking of entries for the attributes were often reversed (Table 17). All entries, except Stephens and Entries 7 and 16, received scores higher than observed for the Chambers site. No differences were found among Entries 6, 7, 8, 16, 18, and 36 for surface appeal, however, the value for Entry 18 was higher than the values for Stephens and Entry 55. For texture, Entries 18 and 36 received higher values, whereas the values for Entries 7,8, and 55 were the lowest. No differences were observed among Entries 6, 8, 16, 18, and 36 which received high taste scores, but the score for Entry 18 was higher than the scores awarded to Stephens and Entries 7 and 55. Across the three traits coefficients of variation were extremely high.

No differences were found among the three checks for any of the sensory evaluation traits (Table 18). Coefficients of variation were extremely high across the three traits.

Several experimental entries appeared to be similar based on their sensory scores compared to the checks. Especially, Entries 16 and 36 appeared promising at both locations as did Entry 18 when grown at the Ruggs farm.

Table 13. Observed mean squares and coefficients of variation (C.V.) for sensory-evaluation traits to compare experimental entries grown at the Chambers site during the 1990-1991 growing season.

Source of Variation	df	Surface Appeal	Texture	Taste
Total	162			
Entry	7	6.47 *	14.80 **	10.11 **
Error	155	2.47	2.18	2.01
C.V.(%)		34.22	37.01	33.04

*,** significant at the 0.05 and 0.01 probability levels, respectively

Table 14. Observed mean squares and coefficient of variation (C.V.) for sensory-evaluation traits to compare experimental entries grown at the Rugg site during the 1990-1991 growing season.

Source of Variation	df	Surface Appeal	Texture	Taste
Total	149			
Entry	7	3.24 NS	13.89 **	9.61 **
Error	142	2.12	1.97	2.34
C.V.(%)		30.04	31.30	32.75

** significant at the 0.01 probability level

Table 15. Observed mean squares and coefficient of variation (C.V.) for sensory-evaluation traits to show effect of location on entries grown at the Chambers and Rugg sites in 1990-1991.

Source of Variation	df	Surface Appeal	Texture	Taste
Total	312			
Location	1	3.36 NS	15.83 **	14.23 *
Entry	7	4.31 NS	9.27 **	5.50 *
Ent×Loc	7	4.89 *	18.66 **	11.26 **
Error	297	2.30	2.08	2.17
C.V.(%)		32.19	34.09	32.59

*,** significant at the 0.05 and 0.01 probability levels, respectively

Table 16. Sensory-evaluation scores awarded by a Japanese student taste panel for surface appeal, texture, and taste of Japanese udon-noodles made from experimental material grown during the 1990-1991 season at the Chambers site.

Experimental Material	Surface Appeal	Texture	Taste
Stephens	5.1 a†	4.6 bc	4.8 fg
Entry 6	4.2 a	3.5 cde	3.9 fgh
Entry 7	4.9 a	4.6 bc	4.8 fg
Entry 8	4.2 a	4.1 bcde	4.4 fgh
Entry 16	5.4 a	5.0 b	5.0 f
Entry 18	4.0 a	2.7 e	3.1 h
Entry 36	4.9 a	4.4 bcd	4.6 fg
Entry 55	4.0 a	3.2 de	3.5 gh
S.D.	1.6	1.5	1.4
C.V.(%)	34.2	37.0	33.0

† means with the same letter within a column are not significantly different at the 0.05 probability level

Table 17. Sensory-evaluation scores awarded by a Japanese student taste panel for surface appeal, texture, and taste of Japanese udon-noodles made from experimental material grown during the 1990-1991 season at the Rugg site.

Experimental Material	Surface Appeal	Texture	Taste
Stephens	4.4 b†	4.6 def	4.4 ijk
Entry 6	5.1 ab	4.6 def	4.7 hij
Entry 7	4.6 ab	3.2 g	3.5 k
Entry 8	4.7 ab	4.1 efg	5.2 hi
Entry 16	5.1 ab	4.8 de	4.9 hi
Entry 18	5.4 a	5.7 c	5.5 h
Entry 36	5.2 ab	5.0 cd	5.1 hi
Entry 55	4.3 b	3.7 fg	4.1 jk
S.D.	1.5	1.6	1.6
C.V.(%)	30.0	31.3	32.7

† means with the same letter within a column are not significantly different at the 0.05 probability level

Table 18. Sensory evaluation scores awarded by a Japanese student taste panel for surface appeal, texture, and taste of Japanese udon-noodles made from check cultivars grown during the 1990-1991 season at the Ruggs site and from Australian Standard White (ASW) flour.

Cultivar or Marketclass	Surface Appeal	Texture	Taste
Owens	4.6 a[†]	4.5 b	4.9 c
Klasic	5.2 a	4.2 b	4.7 c
ASW	4.8 a	4.2 b	4.5 c
S.D.	1.7	1.7	1.7
C.V.(%)	35.0	40.2	36.2

† means with the same letter within a column are not significantly different at the 0.05 probability level

DISCUSSION

Soft-white wheat from the Pacific Northwest is the preferred wheat for confectionery products in the Pacific Rim countries. In the rapidly expanding noodle market, however, ASW has been preferred. To remain competitive, it is necessary for wheat breeders in the Pacific Northwest to develop cultivars with milling and baking properties similar to or better than those of ASW. Unfortunately, little is known regarding what noodle quality properties are critical to find acceptance in the Asian market. One approach would be to compare current soft-white wheat cultivars grown in the Pacific Northwest to ASW wheat in terms of their milling and baking properties for noodles, thus it was the overall objective of this study to provide such information and perhaps provide the breeders with a better way to measure quality. Unfortunately, no direct comparison could be made in this study between ASW and the Pacific Northwest entries as only the flour of the ASW was available. Furthermore, the ASW wheat was milled several years ago to a straight grade flour (including 3rd break and 3rd reduction mill streams), whereas the experimental entries and the two check cultivars included in this study recently were milled to a patent flour. If these limitations are recognized it can still be observed from the sensory evaluation data that ASW was not noticeably superior to Stephens, the major Pacific Northwest cultivar now being grown. The spring varieties, Klasic and Owens, were also similar to ASW. Finally, some of the experimental cultivars appeared promising based on the sensory evaluation data.

Several factors must be considered when comparing Pacific Northwest grown cultivars with ASW flour. Was the particular ASW sample poor? The ASW flour was a straight grade rather than a patent flour; therefore, the quality might have been inferior? The ASW flour was several years old which may have reduced the quality. The sensory evaluation test may not have been powerful enough to detect real differences. In this study, the sensory-evaluation data were based on a consumer survey test, in which a large, random sample of consumers are asked to evaluate many samples of a product. Several problems were encountered. The consumer sample was not large and random, but rather, consisted of Japanese students at Oregon State University. The panel was not trained thus small, but real, differences may not have been detected and noticeable differences may have been exaggerated.

Being careful to consider the shortcomings of the sensory-evaluation test, it still appears that progress is being made in developing new cultivars with improved noodle quality. At this point, however, it is not the result of a conscious breeding effort, rather, it is the byproduct of a general emphasis on improving the quality of soft-white wheat.

End-product quality is one of the main objectives in most wheat breeding programs. Because of the many attributes involved and the nature of inheritance, including a large genotype by environment interaction, it is often difficult to evaluate this at an early stage in the breeding program. Also, most quality tests require large amounts of flour not available till later generations. As a result, experimental entries which have poor characteristics for end product quality are carried forward for many generations before they are discarded. Preferably, progeny could be selected in earlier generations (F_2, F_3, or F_4) based on a combination of agronomic and quality characteristics.

It would be beneficial to develop tests that require a minimal amount of grain to be highly efficient in predicting end-product quality. Gras and O'Brien (1990) wrote that early generation quality tests must be simple, rapid, reliable, and require only a small sample of seed. They described a derivation of the mixograph test that required only 2 g of flour (5 g of seed). A good range of variation in the mixograph parameters as well as low errors of determination were noted. High heritability estimates were obtained for mixing time, resistance breakdown, bandwidth breakdown, and time to maximum bandwidth. This indicated the suitability of the 2 g mixograph for early generation selection for some quality attributes. If an early generation test could also be found to simulate the amylograph test, it would be possible to obtain an estimate of both gluten and starch properties as well. Combined with a protein and hardness determination this would give a reliable indication of potential end-product quality of early generation experimental entries.

In this study the Rapid Visco Analyzer (RVA) was evaluated for its usefulness in comparing cultivars with ASW flour. The RVA fits the criteria for an early generation tests as outlined by Gras and O'Brien (1990). It is easy to operate, rapid and reliable, and it uses only a small amount of flour. Whole-grain meal was used as this would be the only realistic option for early generation testing. Three measurements, Peak1, Low, and Peak2 were determined by the RVA. It was hoped these parameters or the differences between them would estimate the starch properties of the selected cultivars.

Grain-protein and kernel-hardness determinations were made, as these also are realistic options for early generation evaluation of quality. Whole-grain meal samples were first used for grain-protein and hardness determinations and then run through the RVA.

Little or no association was found between grain-protein content and kernel hardness. Across both locations, kernel hardness was more negatively associated with the viscosity parameters than grain-protein was. Grain-protein is a quantitative measure of the absolute content of protein, whereas, kernel hardness is more qualitative, measuring the degree of association between the major endosperm components, gluten and starch (Norris et al., 1989). As viscosity provides an estimate of starch properties it is realistic that kernel hardness would influence the viscosity parameters more than grain-protein content. High kernel-hardness values were consistently associated with low viscosity values, especially for the parameter Peak1, Peak1-Low, and Peak1-Peak2 at the Ruggs site.

To be useful in a plant breeding program, these traits must accurately predict noodle quality. This study only partially examined this issue, as the sensory-evaluation test was not sensitive enough to determine small differences in appearance, texture, and taste. Extremely high coefficients of variation were obtained for the sensory evaluation parameters indicating only large differences were detectable. Furthermore, the relative ranking of cultivars did not change noticeably for the different sensory traits within the same location. It appears panel members tended to give each entry an overall low or high scores for all the sensory traits. Consequently, the individual sensory attributes were of little significance.

In the amylograph, starches are heated to 95°C, kept at a constant temperature for one hour, and then cooled. Oda et al. (1980) suggested that the difference in peak viscosity of a starch and the viscosity after holding at the maximum temperature for 10 min as measured in the amylograph was predictive of noodle texture. In this study, those variables corresponded to the viscosity parameter, Peak1-Low. However, no such trend was found between any of the viscosity parameters and the sensory evaluation traits. Because of the different sample groups these associations could not be analyzed statistically thus no conclusion can be reached as to the usefulness of the RVA for predicting udon-noodle quality. Further studies are needed for such an assessment. Other viscosity parameters such as the slope of the pasting curve at various intervals may be of interest. It would also be beneficial to reexamine the viscosity parameters measured in this investigation if a more sensitive sensory evaluation procedure can be developed. An experienced test panel is recommended for further investigations. The panel should contain five to seven people well trained in identifying the characteristics which determine udon-noodle quality.

Soft-kernel texture was the best indicator of noodle quality as measured by the sensory-evaluation panel. When compared to ASW flour the soft-kernel cultivars (Stephens, Entry 18, and Entry 36) in general produced good noodles. Entry 16 was a notable exception as this hard textured cultivar produced noodles of excellent quality as measured by the sensory-evaluation test.

In general, noodle quality changed between the two locations corresponding to a similar change in grain-protein percentage. However, as Stephens and Entries 7 and 16 increased their protein percentage their noodle quality decreased. Therefore, there may be an optimum range of grain-protein concentration. This might also be influenced by kernel hardness. The softest cultivar in this investigation (Entry 36) had a relatively high level of grain-protein at the Chambers site and acceptable noodle quality. Its grain-protein content decreased at the Rugg site but its noodle quality increased notably. These observations require further investigation before any conclusions can be reached.

A cultivar by location interaction was observed for kernel hardness, the viscosity parameter, Peak1-Peak2, and the three sensory-evaluation traits. For kernel hardness this interaction did not change the hardness classification of a cultivar, only the absolute values. The cultivar by location interaction for Peak1-Peak2 may be an artifact as it was a calculated value and neither of the measured parameters from which it was derived showed any interaction. If a sensory-evaluation test independent of cultivar by environment interactions can be developed, then selection based on any of the measured traits, except perhaps Peak1-Peak2, can be conducted at either of the two locations in this study. If the current sensory-evaluation method is maintained, then selection must be performed at both locations.

Currently, there is considerable interest expressed by Asian Rim wheat buyers in the Hard White Spring cultivar, Klasic. When the check cultivars used in this study, Klasic and Owens, are compared, differences were found between them for grain-protein percentage, kernel-hardness value, and several of the viscosity parameters, yet they produced noodles of similar quality. It should be noted, however, that Klasic's kernel-hardness value was only just large enough to classify it as hard (above 55 as measured by Near Infrared Reflectance spectroscopy).

It thus appears that the Pacific Northwest currently produces wheat acceptable for Japanese udon-noodle production. Furthermore, several experimental cultivars appeared to compare favorably with both Klasic, Owens, and the ASW flour, giving the Pacific Northwest a competitive position for the future. The plant breeders in the Pacific Northwest require specific selection criteria to continue the development of cultivars well suited for noodle production. Further attributes for good udon-noodle quality should be investigated and requirements for other noodle markets must be identified clearly. Finally, the usefulness of these attributes in a breeding program will depend on their mode of inheritance and gene action, which can only be determined by future genetic studies.

SUMMARY AND CONCLUSIONS

There is a large potential use for soft white wheat in the Asian noodle market. ASW wheat is currently favored for this end product. To meet the demands of Pacific Rim buyers, soft white wheat cultivars should produce noodles of similar or better quality than noodles produced from ASW wheat. Before breeding for this market can be initiated, the major attributes contributing to noodle quality must be defined, and methods for progeny evaluation developed.

In this investigation grain-protein percentage, kernel hardness, and six viscosity parameters measured on the Rapid Visco Analyzer were evaluated for their effectiveness in predicting Japanese udon-noodle quality. Advanced selections from the Oregon State University wheat-breeding program and Stephens, the most widely grown soft white wheat in the Pacific Northwest, were included in this study. The experimental material was grown at two locations to provide an estimate of cultivar by environment interaction under varying climatic and management conditions. Furthermore, two commercial cultivars and ASW flour were included as standards for noodle quality.

The following conclusions were reached based on the results of this investigation:

1. Based on the sensory evaluation, cultivars with soft kernels appeared to produce noodles of better quality.

2. Grain-protein concentration was not a good indicator of noodle quality as measured by the sensory-evaluation panel.
3. Each cultivar may have a range of protein concentrations at which optimal noodle quality is obtained. This may be influenced by kernel hardness or other unidentified factors.
4. The viscosity parameters measured by the Rapid Visco Analyzer were not predictive of noodle quality as measured by the sensory-evaluation panel. Other parameters such as the slope of the gelatinization curve at various intervals deserve investigation. If a more sensitive sensory-evaluation method is developed, the six viscosity parameters measured in this study should be reinvestigated.
5. Grain-protein, kernel hardness, and the viscosity parameters all had very coefficients of variation. Furthermore, only Peak1-Peak2 had an clear cultivar by environment interaction. Thus, selection for the other parameters could be conducted at either location.
6. Grain-protein concentration was not associated with kernel hardness. Kernel hardness had a more negative association with the viscosity parameters than grain-protein did. These association were influenced by the environment, as differences between locations were observed.

7. The sensory-evaluation test was not able to detect small differences among cultivars. Coefficients of variation were extremely high, indicating that the method must be improved for future studies. The panel members awarded overall high or low values across the sensory traits for each cultivar, so the relative ranking of cultivars did not change noticeably for surface appeal, texture, or taste. Consequently, no real distinction could be made between these traits. Future taste panels should consist of five to seven experienced panel members well trained in identifying characteristics that determine noodle quality.

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APPENDIX

Figure 1. Typical viscosity profile of whole-grain meal from wheat obtained with the Rapid Visco Analyzer (RVA). The values corresponding to Peak1, Low, and Peak2 were read off the digital output display on the RVA.

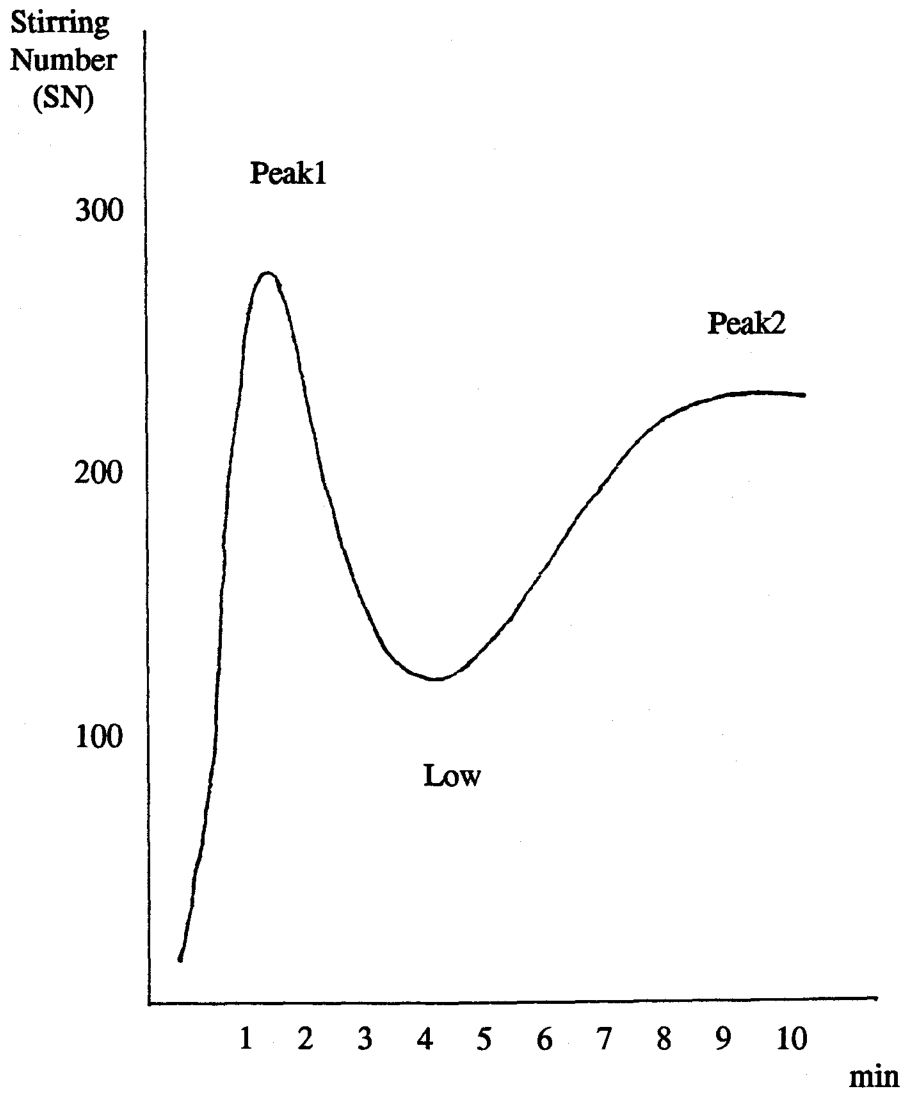

Figure 2. Example of the sensory-evaluation ballot used in this study. Noodles were judged on surface appeal, texture, and taste.

SAMPLE _______	SURFACE APPEAL	TEXTURE	TASTE
like very much	________	________	________
like moderately	________	________	________
like slightly	________	________	________
neither like nor dislike	________	________	________
dislike slightly	________	________	________
dislike moderately	________	________	________
dislike very much	________	________	________

Table 1. Description of named entries and pedigrees of experimental entries included in this study.

Stephens: Soft, white wheat. The most widely grown in the Pacific Northwest.

Entry 6: Riebesel 47/51 /Anza/3/Kavkaz/Hyslop//Yamhill/Tobari 66/4/Bow S

Entry 7: Triticum John Bingham 240-1834/Yamhill

Entry 8: Desprez 6301/Heines VII//Era/3/Buckbuck

Entry 16: Yamhill/Hyslop//Top/7 Candeal

Entry 18: Stephens/3/69-153/Yamhill,F3//67-237-69-24

Entry 36: OWW810038/6/Yamhill DW/Grana

Entry 55: Jingswon 6/Predgornaia//Jingswon 3/3/Bezostaja

Owens: Soft white spring wheat. Widely grown in the Pacific Northwest.

Klasic: Hard white spring wheat. Recently developed in California.

Table 2. Yield and testweight of experimental entries grown at the Chambers site during the 1990-1991 growing season.

Experimental Material	Yield (kg ha^{-1})	Testweight (kg hl^{-1})
Stephens	8065	94.6
Entry 6	7768	96.6
Entry 7	7371	88.9
Entry 8	6644	90.6
Entry 16	6153	93.8
Entry 18	7962	96.6
Entry 36	6805	91.1
Entry 55	8102	93.7
S.D.	1085	2.8
C.V.(%)	13	0.8

Table 3. Yield and testweight of experimental entries grown at the Rugg site during the 1990-1991 growing season.

Experimental Material	Yield (kg ha^{-1})	Testweight (kg hl^{-1})
Stephens	9189	93.4
Entry 6	5560	95.7
Entry 7	4575	91.4
Entry 8	6509	89.9
Entry 16	6024	93.4
Entry 18	7230	94.9
Entry 36	6288	92.5
Entry 55	7693	91.1
S.D.	2008	2.1
C.V.(%)	27	1.2

Table 4. Yield and testweight of check cultivars grown at the Rugg site during the 1990-1991 growing season.

Cultivar	Yield (kg ha^{-1})	Testweight (kg hl^{-1})
Owens	5967	91.3
Klasic	5845	94.1
S.D.	520	1.8
C.V.(%)	10	1.2

Table 5. Break- and reduction-roll settings during milling of soft and hard textured cultivars.

	Break Rolls		Reduction Rolls	
Kernel Character	Left	Right	Left	Right
Soft	7.5-8	3	3	1
Hard	12	4	4	1

Table 6a. Description of milling data collected for the experimental entries and two check cultivars, Owens and Klasic.

Wet Wt.: weight (g) of sample prior to milling

Mill. time: time (min) required to feed sample into mill

Brk. 1+2: combined weight (g) of mill streams from 1st and 2nd break rolls

Brk. 3: weight (g) of mill stream from 3rd break roll

Red. 1+2: combined weight (g) of mill streams from 1st and 2nd reduction rolls

Red. 3: weight (g) of mill stream from 3rd reduction roll

Bran: weight (g) of the bran mill stream

Set Off: weight (g) of the material lost through the air vacuum

Short: weight (g) of the shorts mill stream

Mill Score: measures consistency of milling operation. Should fall within a narrow range.

Tot. Prod: combined weights (g) of all millstreams plus set off

Mill Loss: material not accounted for (g): wet weight - total product

Extr. %: [(brk.1+2) + (red.1+2)] / tot. prod

Table 6b. Milling Data for the experimental entries and two checks, Owens and Klasic.

Experimental Material	Wet Wt.	Mill. Time	Brk. 1+2	Brk. 3	Red. 1+2	Red. 3	Bran	Set Off	Short	Mill. Score	Tot. Prod	Mill Loss	Extr. %
Stephens	1032	9.4	96	22	534	50	221	3	52	0.72	977	56	64
Entry 6	1049	8.7	85	15	520	59	251	7	49	0.69	985	64	61
Entry 7	1058	8.6	82	13	505	64	270	6	70	0.66	1009	49	58
Entry 8	1056	8.1	77	13	493	61	276	4	75	0.65	999	57	57
Entry 16	1053	8.2	82	13	499	51	271	5	68	0.66	990	64	59
Entry 18	1043	9.7	45	72	448	30	374	6	17	0.61	993	50	50
Entry 36	1037	10.2	358	24	454	34	233	6	55	0.68	912	85	62
Entry 55	1051	8.4	174	14	515	56	262	7	56	0.68	999	44	61
Owens	980	9.3	137	27	415	32	241	18	40	0.69	911	69	61
Klasic	1052	7.9	93	15	533	56	249	5	58	0.70	1010	42	62
S.D.	26	0.9	139	17	38	13	41	4	17	0.03	38	28	4
C.V.(%)	2	7.6	56	16	4	12	3	49	9	1.62	3	45	2

Table 7. Correction values for surface appeal, texture, and taste added to scores awarded the first day of sensory evaluation.

Sensory Trait	Correction Value
Surface Appeal	0.4732
Texture	0.6122
Taste	0.9715