Selection of quality Australian barley for the Japanese staple food market.

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Abstract

Approximately 150,000 tonnes of Australian malting quality barley valued at approximately $30,000,000 is exported annually for the Japanese staple market. However, barley selected for malting quality may not always meet Japanese requirements. This may put Australia's competitive "edge" at risk.

The first step towards improved selection of grain for the Japanese staple market is to measure pearling quality, since pearling is performed prior to the production of three important Japanese food products: miso, rice extender and shochu. Barley suitable for pearling must be uniform in size, shape and hardness.

Pearling methods obtained from Japanese processors were compared with grain uniformity tests using the Perten <u>S</u>ingle <u>K</u>ernel <u>C</u>haracterisation <u>S</u>ystem. Results indicate that the SKCS tests can be used to predict pearling quality of Australian barley from a diverse range of sites, providing a rapid screening tool. This paper describes the relationships between chemical components of grain, grain hardness and uniformity of hardness and measurements of pearling quality, and also discusses the effect of genotype and environment on pearling quality.

Introduction

In order to provide superior barley for the Japanese food market and offer better guidelines to breeders, agronomists and marketers, we need to understand the physical and chemical quality requirements of Australian barley for Japanese food products such as pearled barley for rice extender, miso and shochu production. In the past, qualitative, sensory and minimal quantitative analysis was used by Japanese processors to grade grain. Recently, strong collaboration has been established with a number of processors and the quality requirements of Australian barley for this market are now being assessed on a more quantitative basis.

Although malting barley meets many specifications for the Japanese food market, such as low screenings and protein content, variation within a single batch of grain may seriously affect pearling quality and downstream processing, particularly shochu manufacture. The shochu market is the most profitable of the Japanese staple foods to Australian producers.

Shochu is a fermented and distilled spirit of approximately 25% final alcohol content. Shochu can be produced from rice, sweet potato or barley. Barley for shochu is first pearled to approximately 65% yield, is then steeped, steamed and inoculated with a strain of Aspergillus which forms a white mould on the surface of the barley grain, collectively referred to as "Koji". The Koji mould breaks down the starch into simple sugars. The Koji (inoculated barley) is then mixed with water and yeast to allow fermentation of the sugars into alcohol which is then distilled. Sometimes different varieties of barley are used and the shochu produced from each variety is blended after distillation to produce different flavours.

Barley that is uniform in size and hardness will pearl uniformly (reducing losses to the processor) and will also hydrate uniformly during the steeping process. This is a major requirement for shochu and miso production, since a batch of grain that hydrates uniformly will also have a uniform pattern of starch gelatinisation during the steaming process. For shochu production this not only allows uniform penetration of the grain by the koji mould but also reduces the formation of "sticky" clumps of barley. Previously it was thought that high β-glucan concentration contributed to grain "stickiness" (Washington *et al.*, 1999), however it is more likely to be the result of over-gelatinisation of small grains. Formation of these clumps can reduce alcohol yield and result in off-flavours. Therefore uniformity of barley grain is an important quality requirement for both miso and shochu production and the pearling process in general. Shochu manufacturers prefer barley with very low protein (8-10%) since high protein can adversely influence flavour and reduce alcohol yield. Malting specifications for barley protein is 9-11.8%, therefore barley that has protein content less than 9% is discounted. If a shochu grade specification was available to growers, a greatly increased profit margin could be obtained for such barley. Conversely, malting barley that is exported for shochu may not be suitable due to its higher protein content and may be rejected by the Japanese. Canadian competition for this market is restricted by the fact that they have difficulty producing such low protein barley.

Pearling tests can be performed on barley to assess quality. However this can be time consuming and impractical at receival points. Hardness tests performed in Japan using a crushing device (KIYA) are also time consuming and impractical for large sample numbers. The purpose of this study was to investigate an alternative method for measuring grain uniformity. The Single Kernel Characterisation System (SKCS) was developed by Perten Instruments to determine the uniformity of wheat kernels in a small sample by measuring individual grain hardness, diameter, moisture and weight. This machine was employed to rapidly measure barley grain uniformity and the results were compared to pearling characteristics.

Materials and Methods

13 Types of barley grown at up to 21 different sites during 1999 (all lines/varieties) within South Australia and 11 varieties from Pinery and Maitland (SA) 1998 harvest were tested for grain hardness, moisture, weight and diameter using the Perten Instruments SKCS, situated at BRI, North Ryde NSW. Sub- samples, including samples from year 2000 harvest, were also pearled on a Satake grain tester, using a procedure adapted from Japanese barley processor, Takenouchi Barley Processing Company, Ltd. All samples were screened over a 2.2mm sieve prior to pearling (Japanese processors use a 2.4mm screen, however due to high "screenings" of some varieties, a 2.2mm screen was used to obtain adequate seed). Pearling was performed on a 40 gram sample for 6 minutes to give an approximate yield of 65% pearled product, as determined by weight lost after pearling. After pearling, the percentage of remaining kernels "%yield", screenings < 2.20mm "%<2.0mm" and broken kernels "%BK" were also determined.
Protein was determined with NIR and/or the LECO nitrogen combustion method.
β-glucan content was determined using the Megazyme total mixed linkage β-glucan determination enzyme assay (McCleary method). β-glucan was determined for whole and pearled barley as a percentage of dry weight.

Results and Discussion

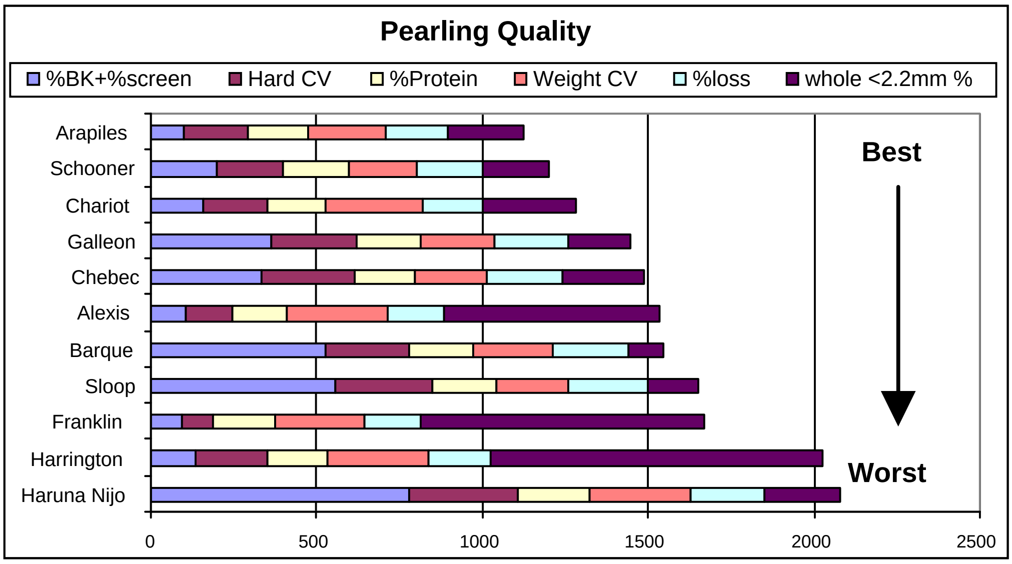
Many of the correlations between pearling characteristics and SKCS results were significant (Table 1). SKCS hardness had the strongest association with pearling quality. The coefficient of variation for hardness, "Hard CV" (a measure of uniformity) was also highly correlated with pearling quality. SKCS results also correlated well with Japanese KIYA hardness tests and appeared to be a better predictor of pearling quality in general. Interestingly, pearling quality was not significantly correlated with protein or grain weight or diameter for these samples (Data not shown).

Table 1. Correlation coefficients (r) for pearling, hardness and uniformity tests.

	SKCS Hard-ness	**SKCS** Hard **CV**	**KIYA** Hard-ness	**KIYA** Hard **CV**	Pearling Yield %	%BK + screenings ‡	Pearling time (mins)
SKCS Hardness	1	**-0.87****	**0.74****	-0.40	**0.54***	**-0.87****	**0.96****
SKCS HardCV		1	**-0.68****	0.47	**-0.78****	**0.77****	**-0.87****
KIYA Hardness			1	-0.25	**0.55***	**-0.60***	**0.83****
KIYA HardCV				1	-0.34	0.31	-0.35
% Pearling yield					1	**-0.62***	**0.56***
%BK + screenings ‡						1	**-0.79****
Pearling time (mins)							1

‡ % of Broken kernels plus screenings below 2.0mm after pearling, **CV** = Coefficient of Variation
SKCS = Single Kernel Characterisation System, **KIYA** = Japanese hardness tester
Samples include Schooner and Sloop from 8 South Australian sites from 1999.
*, ** = Significant ($p<0.05$, $p<0.01$), n = 16.

Figure 1. Overall undesirable pearling characteristics: Pinery + Maitland from 1998 (sum of all results, represented as %Schooner).



Samples averaged over 3 reps. All results were calculated as a percentage of Schooner before summing.
Figure 1 depicts undesirable pearling characteristics including; %Broken kernels plus screenings below 2.0 mm after pearling (%BK+%screen), coefficient of variation for hardness (Hard CV), % Protein, coefficient of variation for weight (Weight CV), % pearling loss (%loss) and whole grain screens below 2.2 mm (whole <2.2 mm%).
The 11 varieties tested exhibited diverse pearling quality at both sites and showed little variation between reps. All varieties performed similarly at both sites. The best three varieties overall were Arapiles (Victorian malt), Schooner (SA malt) and Chariot (UK malt).

Figure 2. Variation in pearling quality: Schooner from 21 sites (2000). Sum of broken kernels and screenings below 2.2mm after pearling.

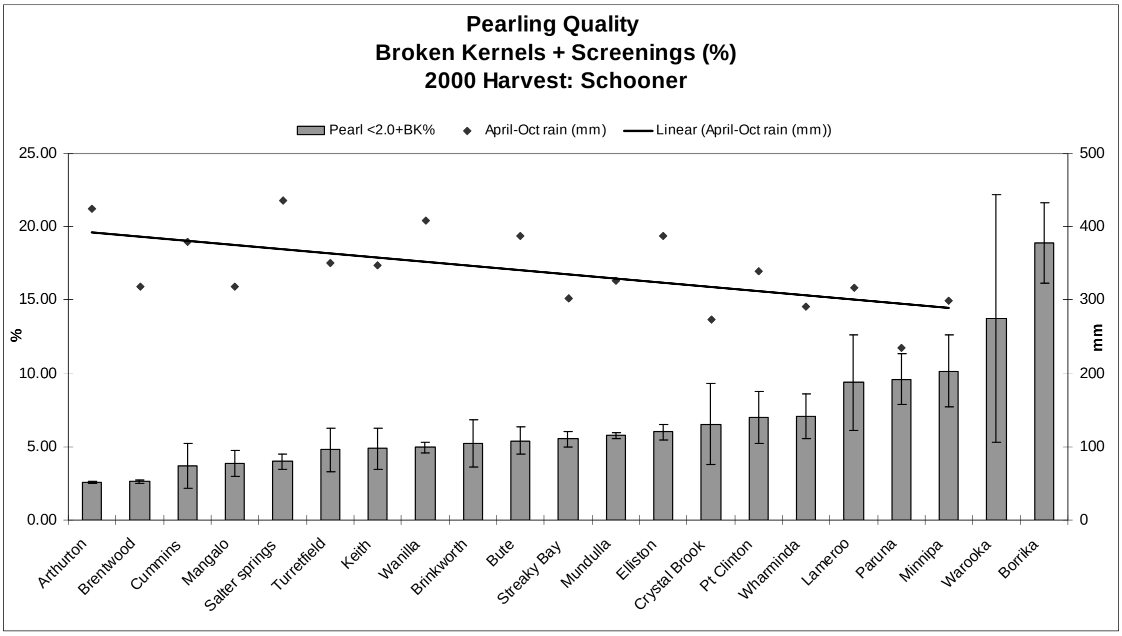


Figure 2 depicts the variation in percentage of broken kernels and screenings after pearling between Schooner grown at 21 different sites during 2000, with corresponding April-October average rainfall (mm). Schooner grown at sites with good soil, high rainfall and mild or coastal conditions generally produced grain of with fewer broken kernels and screenings after pearling. (e.g. Arthurton, Brentwood and Cummins). Conversely, Schooner grown in more marginal environments produced samples with more friable grains (e.g. Lameroo, Paruna and Minnipa). Foliar disease was widespread at Warooka and severe frost damage occurred at Borrika. (Hardness and Uniformity data not yet obtained. This data will be presented during conference).

Conclusion

A large number of varieties from a diverse range of environments over two years were tested and SKCS proved to be a valuable tool for predicting grain uniformity, which in turn, was a useful predictor for pearling quality. Assuming that pearling yield (%) and percentage of broken kernels and screenings below 2.0mm after pearling are the most important determinants of pearling quality, then the most useful predictor of these traits is the SKCS Coefficient of Variation for Hardness or HardCV ($r=-0.78$ and $r=0.77$ respectively, $p<0.01$. Table 1). Of the eleven varieties tested, Arapiles and Schooner were ranked highest overall (Fig. 1). Alexis and Chariot would be unsuitable for Australia since they are adapted for European conditions, Galleon was not acceptable due to high percentage of broken kernels and poor uniformity and Franklin grain tends to be small and low yielding in the low rainfall areas of SA and Victoria. Stirling (WA malt) has also proved to be a high quality pearling grain, however due its poor adaptation in SA, it was not included in trial sites and could not be directly compared to the varieties tested here.

Agronomic and climatic factors also influence grain uniformity. Hot, dry conditions or soils with poor moisture holding capacity (e.g. Paruna and Borrika, Figure 2) tend to reduce grain uniformity. Foliar disease may also have a detrimental effect (e.g. Leaf rust at Warooka, Figure 2). The effect of disease may have resulted in the large error between reps. Uneven tiller development, caused by drastic changes in the environment may be one of the causes of uneven grain development on a single plant. It is our belief that the relative rate and duration of starch, protein and β-glucan deposition during grain development, particularly in the grain filling period may be responsible for changes in grain hardness. Preliminary results (data not shown) suggest that hard grains contain less protein in the aleurone and more in the endosperm than soft grains. The aleurone proteins are laid down late in the grain filling period and stressful conditions (high temperature, low rainfall) are known to increase grain nitrogen. If a plant has produced tillers containing grains at different stages of development, then mature grains will be of uniform hardness, but later maturing grains may lay down proteins in a different manner, resulting in grains which will be of different hardness to the early maturing grains. Interestingly, for 11 varieties grown over 4 sites (2 reps) during 1999, whole grain protein was not correlated with hardness ($p=0.389$), but β-glucan was significantly and positively correlated with hardness ($p<0.001$). The correlation between hardness and β-glucan was independently observed, by researchers in the Takenouchi Co. laboratories, using the KIYA hardness test. Alexander *et al*., 1997, found that SKCS hardness varied significantly in Clipper grown at different sites in South Africa, even though nitrogen content was constant. They found a good correlation between hardness and steeliness ($R^2=0.749$), but the correlation was lower for mealiness ($R^2=0.526$). In this study, mealy grains were not necessarily soft. A number of waxy (low amylose) lines, which have a mealy appearance, were extremely hard (data not shown), suggesting that starch content has some influence over grain hardness. Structural studies performed by M Wallwork *et al* (1998) indicate that high temperature stress during grain-fill results in a endosperm starch structure that is compact in the centre, but less dense in the outer layer. Given that soft grains are more likely to be produced in hot dry environments, this "open" endosperm structure in the outer layers of the grain may be the reason for the grain "softness" resulting in kernels that are more easily broken, crushed and have a high pearling rate.

Although management of environment may be difficult or impossible in such cases, there is evidence to suggest that certain varieties may be less affected by changes in the environment than others with respect to grain uniformity. Schooner (SA), Arapiles (Vic) and Stirling (WA) are currently the favoured varieties for Shochu production. Out of these varieties, Schooner is the most widely adapted and agronomically out-performs both Arapiles and Stirling in the South Australian environment which is extremely diverse. It is important to spread the "risk" of failing to produce sufficiently uniform grain by sourcing from a diverse range of environments. The likelihood of producing just one variety for Shochu production is probably small, given that the larger Japanese processors prefer to blend shochu made from different varieties for flavour purposes.

An understanding of starch, protein and β-glucan deposition during grain development may give us some insight into those varieties that produce more uniform grain over diverse environments. This will not only be useful for the production of food barley, but also for malting barley.

The Perten SKCS 4100 has proven to be a useful tool in determining grain uniformity and in the future may allow easier selection of export cargoes for the Japanese food market. It may also prove useful in barley breeding programs to select and breed suitable improved varieties for pearling and shochu to succeed Schooner.

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