

Character Variation in Quality of Australian Barley for Alternative End Uses

J.M. Washington, A.J. Box and A.R. Barr

Department of Plant Science, Waite Campus, The University of Adelaide, Glen Osmond
SA 5064

Introduction

Traditionally, the Australian barley industry has concentrated on producing barley cultivars that have quality characteristics desirable for malting and therefore command a high price. Barley which does not meet these high standards tends to be sold for animal feed, a considerably less profitable market. High yielding barley with poor malt characteristics may also be grown for animal feed. Food and industrial uses for barley and/or its components also exist, but at present, the priority to breed barley for specific uses apart from malt has been neglected.

Australia's share of the Japanese malt market has fallen significantly in recent years due to increased exports from Canada, despite the doubling of beer sales in the past two decades. Canada is also leading the world in barley food and feed research. For Australia to remain competitive, we need to provide cultivars which are better suited to the particular requirements of Japanese brewers, Shochu manufacturers, pearled barley markets and other food and feed markets. It is to our advantage to foster the Japanese markets since they generally pay a higher price to all suppliers compared with world market prices (Review of the Barley Marketing Act 1993 – Centre for International Economics).

Research into these markets and testing and developing of cultivars for various end-use quality characteristics are the first steps in breaking into new markets. This paper reports our progress towards these goals.

Human Food

At present, very little barley is used in human food in developed countries. However, in many countries barley is used in traditional dishes, such as miso and finely pearled barley as a rice extender, for the production of soy paste and soy sauce in Korea or for the fermented drink Shochu in Japan. Barley is also roasted and used as a tea or coffee substitute, and wheat-barley flour mixtures used for making breads, biscuits, cakes and noodles. In the West Asia-North Africa region, barley is consumed as pearled barley in soups, flour in flat breads and ground grain in porridge. In Western countries, only small quantities of barley are utilised for human food. Some cultivars, particularly low amylose (waxy) types, are high in the non-starch polysaccharide (1→3),(1→4)-β-D-glucan (β-glucan), which is a major component of soluble fibre (Bhatty, 1993). The presence of dietary fibre (soluble and insoluble) and tocotrienols in barley have been shown to lower blood cholesterol and prevent diseases of the large bowel including colon cancer (Ikegami *et al.*, 1996; Peterson and Qureshi, 1997; McIntosh *et al.*, 1991 and 1996).

The positive nutritional properties of barley are numerous. With the production of new cultivars and processing methods and cultivars with high dietary fibre components it is hoped that inclusion into Western diets will increase. In the meantime, cultivars for export markets could be improved.

Based on our current understanding of human food requirements, our breeding priorities

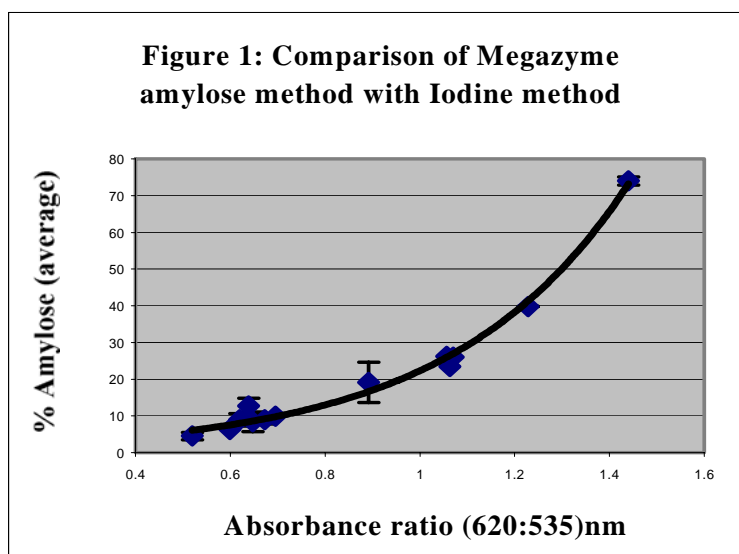
(ignoring agronomic traits) include hullless, waxy starch, high β -glucan, good cooking and pearling qualities, large plump grain, pro-anthocyanidin free and low polyphenol oxidase (to retain good colour after cooking).

Screening for germplasm with waxy starch and high β -glucan is commonly performed in the early stages of breeding selection. Therefore a fast method for determining waxy cultivars was investigated, followed by β -glucan testing with the conventional Megazyme™ β -glucan (mixed linkage) assay kit.

Developing and testing waxy cultivars

Waxy cultivars tend to have high total dietary fibre and produce flour with excellent food thickening properties due to their high water absorption capacity (Bhatty, 1997). Both high and low amylose barley starches exhibit extremes in swelling power and viscosity compared to normal starch (Bhatty 1993). These characteristics may be useful for specific products within the food and non-food industry. Waxy barley has a bright white endosperm, which is desirable for pearled barley particularly when used as a rice extender.

The amylose content of barley starch can be determined using a Megazyme™ kit, which is relatively expensive, slow and prone to human error. Iodine staining gives a qualitative guide as to waxiness and costs approximately 1cent/sample compared to \$3/sample for the Megazyme™ method. A method using iodine staining was adapted from Swanston (1995) and Hovenkamp-Hermelink (1988).



The rapid iodine method (available upon request) was compared to the Megazyme™ Amylose/Amylopectin assay kit method.

Regression analysis showed a strong relationship ($R^2 = 0.9549$) between the two methods. Amylose content can therefore be estimated from the ratio obtained from the iodine method with the regression equation $y=1.4935e^{2.7029x}$ (Figure 1). This procedure is recommended as a rapid screening method. It has been used to detect waxy and so-called “double waxy” types in crosses between normal and waxy types for the hullless breeding program. Confirmation of amylose content should be performed after final selection. This method will not detect amylose complexed with lipid, which is insoluble and stable above 90°C.

Genetic and environmental variation in β -glucan content

β -glucan has been shown to have a cholesterol lowering effect in humans (Ikegami *et al.*,

1996; McIntosh *et al.*, 1991) and has been associated with the deleterious effects of high viscosity in both the malting and feed industries. Therefore, β -glucan testing was performed on cultivars with malting, feed and food potential.

Different cultivars and breeding lines of barley were grown at Clinton (1997 and 1998), Hermitage (1997), Condoblin (1997 and 1998), Wagga (1998) and Callington (1998). β -glucan concentrations were obtained from each genotype at the different sites, using the Megazyme™ kit for mixed linkage β -glucans.

A significant environment effect (approximately 1% β -glucan) was observed for identical genotypes grown at different sites ($P < 0.001$). The difference between genotypes was approximately 2% and the range of β -glucan concentration for all genotypes across sites was 3-6%. The effect of environment will have a significant effect on actual β -glucan concentration for a particular genotype, but high and low β -glucan types can still be selected for within each environment. β -glucan testing is useful for selection of breeding lines with very high or low concentrations that are to be included in the breeding program, however not as a tool to estimate feed or malt quality.

Pearled barley and Shochu

Barley has traditionally been pearled to remove husk, and in some countries, to resemble rice as an extender. The act of pearling significantly reduces protein, lipids, fibre and trace elements (including the tocopherols or Vitamin E). Pearling is unnecessary when hullless barley is used as a food product and therefore, retains all of these nutrients. However, pearled barley is still favoured due to its faster cooking time and appearance. Barley water, obtained from cooking pearled barley, is a popular drink in many countries. In theory the bran fraction from pearled barley could be used as high fibre and nutrient food adjunct. Pearling of barley is also necessary for the production of a Japanese whisky called Shochu. Consultation with Japanese Shochu brewers has led to an increased understanding of quality characteristics desirable in barley for Shochu. The most desirable characteristics include large, plump grain, low protein and lipid content, uniform texture of endosperm (preferably mealy) and high starch content. There is increasing interest in the amount of amylose and its degradation by β -amylase. β -glucan and possibly arabinoxylan content may also be important, because high viscosity in the mash will cause the grains to stick together and prevent proper aeration around the grain. This will reduce the activity of aspergillus fungi, which enable starch breakdown into glucose.

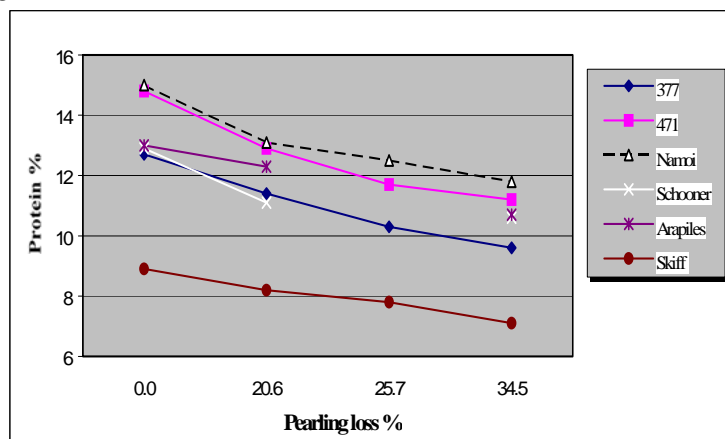
Initial selection of suitable types for pearling was based on grain size, plumpness and colour, which is important for food acceptability, followed by protein content (preferably low) and ease of pearling. We chose hullless grain because total grain weight, is not affected by a husk component. Unfortunately hullless types tend to be high in protein, therefore this may be of little benefit. Other important pearling qualities are uniformity of grain size and medium-hard grain. Koreans prefer a shallow crease and if used as a rice extender then the gelatinisation temperature should be similar to rice, as is the case for waxy types.

Initial pearling tests included measurement of grain weight and diameter, colour after pearling, time taken to pearl and protein loss (Figure 2). Waxy types were also included because they tend to be mealy and therefore absorb water more readily.

The hullless genotypes exhibited higher grain weights and “plumpness” than Namoi or the covered controls. (The sample of Skiff was obtained from a commercial pearler.). Similarly the brightness or colour score (L) after pearling was higher for hullless grain than covered. Waxy hullless cultivars had the highest colour score after pearling at 20% loss. Covered grain initially pearled faster than hullless grain due to the ease of husk removal. As more aleurone was removed from the grain, the pearling rate of hullless grain reached that of covered grain. The higher average protein content of hullless grain, results in a pearled grain with higher

protein content than covered grain that has been equivalently pearled (Figure 2). It must be noted that the amount of husk removed from covered grain is included in the pearling loss. This should be taken into account when comparing pearling loss of hulless and covered cultivars, particularly when considering protein loss.

Figure 2. Protein concentration of hulless cultivars 377 (lowest protein) and 471 (highest protein) compared to hulless Namoi and covered controls Schooner, Arapiles and Skiff, at different pearling ratios.



Traditionally, grain for Shochu is pearled to remove 30-35% of its weight. An optimum protein concentration for Shochu should be no more than 10-11%. Most of the cultivars tested here do not exceed this concentration when pearled to 35%. The protein concentration of the bran fraction indicated that when hulless types were pearled to 35% there was a reduction of protein in the bran compared to bran from 25% pearl. This suggested that endosperm was being removed from the grain and diluting the protein concentration. Therefore for hulless grain it is not necessary to pearl to this extent, thus maintaining a high yield of pearled grain as long as the protein concentration is not too high.

Further experiments are required to compare new covered cultivars with new hulless and waxy cultivars, particularly those with low protein concentration. An estimation of husk content (in the pearled bran fraction) should be calculated to accurately compare pearling losses between hulless and covered cultivars.

Hulless barley

One of the problems with available cultivars, mostly grown for malting and feed, is the presence of indigestible husk, which necessitates its removal prior to food preparation. This is achieved via pearling which is costly, laborious, produces a large amount of dust and waste products and removes potentially nutritious components from the barley grain. The natural alternative is to produce hulless cultivars for food. However, the introduction of a hulless barley into the Australian market has proved difficult because:

- yield has not matched that of covered cultivars,
- large quantities of grain are not available for pilot testing, and
- the absence of a suitable market/s.

Higher yielding cultivars with improved agronomy may be released from our breeding program in the near future and are expected to increase interest for growers and end-users. The line WI3107 is closest to release.

Factors influencing malting performance

Apart from food and feed, hulless barleys have potential malting value. High malt extracts have been achieved mainly due to the absence of husk. In the past, the malting performance of hulless barley has been erratic mainly due to problems with embryo damage, germination, high viscosity, low friability and high protein concentrations (Hughes *et al.*, 1997; Evans *et al.*, 1998). The absence of husk has reportedly caused filtration problems in the brewery. However, recent pilot studies using mash filtration has indicated that this can be overcome if a small amount of husk is included with high quality hulless malt (Evans *et al.*, 1999). A “gentler” harvesting of hulless barley would reduce embryo damage and increase husk content, which should reduce filtration problems.

A pilot study was conducted to assess the effect of malting protocol, embryo damage and environmental factors on the malting quality of Namoi. A covered malting variety, Schooner, was included as malt control and a sample of malted Namoi donated by Phil King (ABB), malted by Mont Stewart (Joe White Maltings) was included in the analysis. The experiment compared 3 malting protocols for 21 samples derived from yield trials in 3 states.

Malt protocols

“Protocol 1”) 7(8)9 hrs [steep (air rest) steep]@15°C, 96hr germination@15°C, 20hr kiln.

“Protocol 2”) 6(8)3 hrs @15°C [steep (air) steep], 48hr germination@15°C, 20hr kiln

“Protocol 3”) 6(8)3 hrs @15°C, 72hr germination@15°C, (addition of water @24 and 48hr germination), 20hr kiln.

Initial testing using all 21 samples, indicated that shorter steeping and germination times were effective for hulless barley. Due to lack of seed, only 13 sites were malted using “protocol 1 and 2” and 3 sites for “protocol 3”. We are currently assessing all 21 sites using the best protocol based on this pilot study.

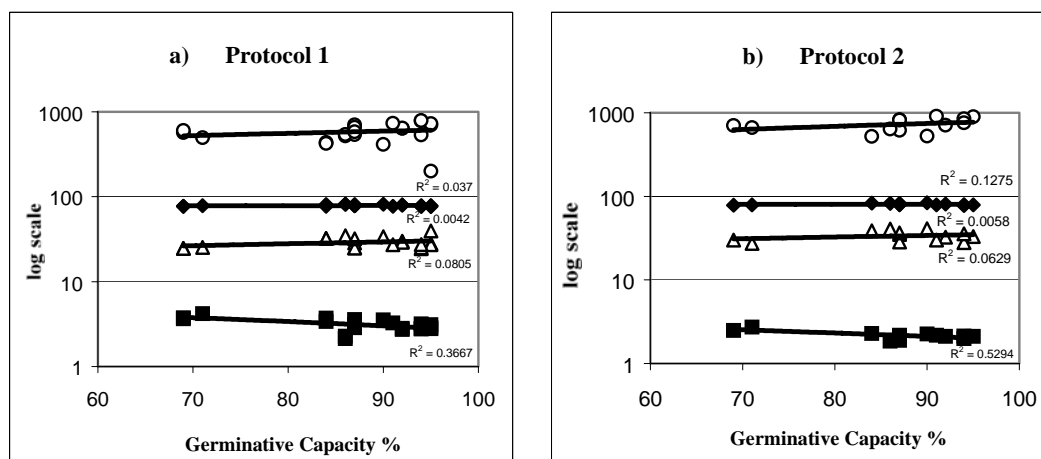


Figure 3. Relationship between germinative capacity and four measures of malt quality for 2 malt protocols: “Protocol 1” (Fig. 3a) and “Protocol 2” (Fig. 3b), see text for description of protocols. O=Diastatic power (DP), ◆=Extract Dry % (Ext), ■=Viscosity cP, △=Kolbach Index % (KI)

Germinative capacity of Namoi for all sites ranged from 69% to 96% and grain protein from 13% to 19%. The key findings were:

- Percent protein explained much of the between site variation in malt quality parameters, and had a much greater effect on malt quality than germinative capacity.
- Generally, samples with higher germinative capacity had lower viscosity, but little effect on extract, KI or DP. However, there were some sites that showed significant differences

in germination capacity, but had similar malt characteristics. This could not be explained by differences in protein concentration.

- The best modification of Namoi was achieved by using malting protocols, which have shorter steep and germination times, but with increased moisture during germination. The lack of husk presumably causes Namoi to hydrate and dehydrate faster than Schooner.

Results from “protocol 1” were quite similar to results from “protocol 3”. Kolbach indices of Namoi from “protocol 3” were slightly higher than “protocol 1”, however the opposite was true for Schooner. Extracts from both malt protocols were quite similar, although Schooner showed better performance with “protocol 1”. There appears to be a much greater site influence on malt quality than that caused by damage to the grain which is probably due to protein concentration. Namoi grown at Keith appeared to have a particular advantage over Namoi from other sites even though its germinative capacity was quite low (86%; due to embryo damage). This was probably due to its lower protein content. These results indicate that environmental conditions can significantly affect malt quality irrespective of embryo damage.

The commercially malted Namoi produced a high quality malt, superior to the Namoi and Schooner samples malted in our laboratory. It was produced from a similar malting procedure to “protocol 3”, modified by the addition of gibberellic acid. The malted barley, grown by Brian Hedt in Victoria, exhibited very little embryo damage due to a “gentle” harvesting (see Box *et al.*, 1999 BTS symposium proceedings, for more discussion of the effect of embryo damage on germination and coleoptile length). The results obtained from this malt suggested that it is possible to produce a minimally damaged hullless grain with high malting potential.

Genetic variation for malt quality in hullless barley.

10 Hullless lines grown at Brinkworth (mid north) and Yeelanna (Eyre Peninsula) and 30 hullless lines from Condoblin (NSW) and Hermitage (QLD) were evaluated for malting quality. The malt quality results showed significant differences between sites, but the hullless lines WI3152, WI3107 and, in particular, WI3044 performed exceptionally well compared to Schooner or covered controls. There appears to be considerable promise in producing high quality malt from hullless barley.

Post harvest dormancy and it's relationship to processing quality

A "moderate" level of post harvest dormancy reduces the risk of sprouting in the field before harvest. This can be a significant problem where there is rain just prior to harvest. However, if significant dormancy still exists greater than six months after harvest this can lead to poor germination in the field after sowing. In addition, if dormancy exists at the time of malting, then a significant reduction in germination and consequently malting efficiency will occur, resulting in poor malt yield. Sprouted grain is also undesirable for food and feed as it looks “bad”, is more prone to spoilage by microorganisms, and the taste is likely to be affected. Therefore it is necessary to characterise the post harvest dormancy of both parents and lines to get an indication of those lines which have "intermediate" dormancy and what level of dormancy is most suitable for the conditions mentioned above.

108 Stage 3 lines from both Callington and Brinkworth (1998 harvest) were tested for post harvest dormancy including hullless parents (Merlin, Morrell, Namoi, Richard) and covered parents (Barque, Galleon, Schooner and Skiff).

In general, husked lines (mean=59.3±35.86%, range =7.8% to 98%) showed greater post harvest dormancy than hullless (mean=86.2±14.37%, range =31% to 100%) lines. The covered variety, Galleon, was considerably more dormant than any other line. Hullless lines, were identified with significant dormancy at both sites. These include Morrell and selections

from Galleon crosses. Hence, it appears feasible that hullless lines can be bred with adequate dormancy for the southern cropping zones. High levels of dormancy, suitable for areas with increased incidence of rain during harvest, were not found.

Conclusion

The preliminary results presented here show promise for better malt, feed and food barley cultivars. It is hoped that with improved agronomy, they will replace less suitable cultivars. The improved quality characteristics should lower processing costs and increase value for growers, maltsters and food and feed processors. More research into the Asian markets of pearled barley and Shochu should provide high profits for varieties specifically produced for these industries. In the future we hope to expand our research into industrial and other commercial end uses

Acknowledgments

Our thanks to members of the S.A. Barley Improvement Program for technical assistance. Thanks to, Maggie Dowling and Ken Saint (ABB) for their assistance with obtaining information and samples and Andrew Beekman (ABB) for assistance with pearling trials and protein determinations. The Grains Research and Development Corporation supported this research.

References

- Bhatty, R.S. (1993). Pages 355 - 417 in: 'Barley: Chemistry and Technology' (eds. A.W. Mac Gregor and R.S. Bhatty).
- Bhatty, R.S. (1997) *Cereal Chem.*, 74(6):693-699
- Box, A.J., Jefferies S.P. and Barr A.R. (1999) Proceedings in press. Proceedings of the 9th Australian Barley Technical Symposium, Melbourne.
- Evans, D.E., Stenholm, M.K., Vilpola, A., Home, S and Hughes, G. (1998) *Master Brew. Ass. Am. Tech. Quart.* 35:189-195.
- Evans, D.E., Vilpola, A., Stewart, D.C., Home, S., Barr, A.R., Stenholm, K., Washington, J., Poyri, S. and Box, A. (1999) Proceedings in press. Proceedings of the 9th Australian Barley Technical Symposium, Melbourne.
- Hovenkamp-Hermelink (1988) *Potato Res.*, 31: 241-246
- Hughes, G.P., Hyde, M., Woll, S. and Gill, W.G. (1997) Pages 2:4.12 – 2:4.15 in: Proceedings of the 8th Australian Barley Technical Symposium, Gold coast.
- Ikegami, S., Tomita, M., Honda, S., Yamaguchi, M., Mizukawa, R., Suzuki, Y., Higuchi, M. and Kobayashi, S. (1996) *Plant Foods for Human Nutrition*, 49(4):317-328.
- McIntosh, G.H., Whyte, J., MaArthur, R. and Nestel, P.J. (1991). *Amer. J. Clin. Nutr.*, 53: 1205-1209.
- McIntosh, G.H., Leleu, R.K., Royle, P.J. and Young, G.P. (1996). *Journal of gastroenterology and hepatology*, 11(2):113-119.
- Peterson, D.M. and Qureshi, A.A. (1997) *Journal of the Science of Food & Agriculture*, 73(4):417-424.
- Swanston (1995) *J. Cereal Sci.*, 22: 265-273