

Market Opportunities for Waxy Hulless Barley Cultivars in Australia

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Abstract:

The nutritional value of barley in supplying a western diet with a high fibre, low fat and low GI alternative to other less nutritious grains is beginning to be realised. The availability of agronomically viable waxy hulless barley will enable Australian food processors to utilise this valuable food grain.

Processing techniques such as pearling, milling and flaking (rolling) enable barley to be utilised in a variety of food products. The availability of waxy hulless barley will provide food manufacturers with a fast cooking grain (whole or pearled) with excellent pearling and flaking quality with a high content of beta-glucan. This soluble fibre has been shown to lower blood cholesterol in humans thus reducing risk of heart disease. It has also been extracted for numerous end-uses, such as bio-films, wound dressings and nutritional supplements.

We have compared the physical grain quality, pearling, cooking, baking and flaking quality of Australian waxy hulless barley with other hulless and covered barleys. The quality attributes of waxy hulless barley will be discussed in the context of potential products and market opportunities. Other end-uses for waxy barley will also be discussed.

The South Australian Barley Improvement Program has bred waxy hulless barleys with considerable improvements in agronomy and food quality characteristics compared to older waxy cultivars. New waxy hulless cultivars will provide food processors with an alternative health related ingredient and will benefit farmers by offering a value-added grain to the food market.

Waxy hulless barley will also provide a nutritious, versatile food product aimed at improving the Australian diet.

Keywords:

Glycemic Index; Pitta bread; Organic barley; Lipxygenase; Tocols; Staling.

Introduction:

In Australia barley is mainly sold for malting (35%) and animal feed purposes (65%), very little is produced and sold for food purposes, except for export to the Japanese market (This market is growing 4-5% per annum). Currently in Australia, up to 10,000 tonnes/ha of hulless barley is produced for niche food markets, mainly supplying contracts for small, local millers of barley flour and pearled barley. Organic barley is commonly grown for this purpose. As dietary fibre is identified as being an important component of the human diet, the potential of barley as a food grain is beginning to be recognised.

Barley contains two types of starch, amylose and amylopectin. Three main groups of barley types have been identified with respect to their amylose content: Low or 'waxy' amylose (0 – 10%), Normal amylose (~25%) or High amylose (>35%). The waxy gene, *wax* (formerly called *glx* or *wx*) is located on chromosome 7HS. The waxy starch phenotype is conferred by various mutations at this locus that either preclude transcription or encode an inactive form of the starch synthase enzyme.

The endosperm of waxy barley has a mealy white appearance. This bright white colour is a desirable feature for pearled barley and products derived from milling. In addition, the changes that waxy starch undergoes when it is heated with water are responsible for the unique character of many of our foods. Some examples

are the viscosity and mouth-feel of gravies, and texture of some confectionaries, pie fillings and, to a lesser extent, baked products.

Compared to other cereals, barley contains high levels of beta-glucan, which are important contributors to dietary fibre. The waxy gene tends to be associated with elevated levels of (1→3, 1→4)-β-D-glucan. High β-glucan content in food has been shown to have numerous health benefits including lowering blood cholesterol and reducing colon cancer. High fibre content in foods also gives the consumer a feeling of “fullness” aiding in satiety, and as a consequence, may be useful in weight control. Overseas, beta-glucan has been extracted from waxy barley for uses in biodegradable films and wound preparations for burns.

There are currently no known waxy, hulless barley growers in Australia.

The SA Barley Improvement Program (SABIP) has been developing waxy barley genotypes for use in the food industry. Canadian researchers have successfully produced waxy barley tortillas with good consumer acceptance (1). The primary negative attribute was the dark colour of the product. Waxy barley starch gelatinizes at lower temperatures; this may reduce nutrient loss due to ‘over-cooking’. The soluble fiber in waxy barley behaves as a fat replacer (2) while the waxy starch has a natural anti-staling property and freeze-thaw stability. Cracked waxy hulless barley can be utilized in low-fat meats to improve texture and moisture.

The hulless waxy line WI3693 was developed from a three-way cross between Azhul, a waxy hulless cultivar (University of Arizona, US) and two CCN resistant, covered feed types, Barque and Keel (South Australian cultivars). Older waxy cultivars tend to be low yielding, susceptible to disease and have poor straw strength, however WI3693 is a medium height plant that is lodging resistant, has bright white grain and straw at maturity, has a similar plant maturity to Torrens but later than Schooner and also has resistances to cereal cyst nematode (CCN) and spot form of net blotch (sfnb).

This paper describes some food products that, potentially, could be made from waxy hulless barley and their quality attributes in relation to food acceptability and health. We will also discuss market interest generated by this unique barley.

Methods:

Barley samples:

All barley samples were obtained from the SABIP. The sample of “Euro” Oats was obtained from the Oat Breeding Program, SARDI, Waite campus. Due to gentle harvesting techniques employed with hulless barley (to reduce embryo damage), a small proportion of husk remains attached to some of the grain. These samples were de-hulled before processing as explained below.

Table 1. Barley lines and cultivars: Type, use and release date

Name	Type (Australian)	Use	Cultivar release date
WI3693	Waxy starch, Hulless, 2-row	Food	Potential release 2007
Torrens	Normal starch, Hulless, 2 row	Food/Malt	2001
Morrell	Normal starch, Hulless, 2-row	Food	1993
Namoi	Normal starch, Hulless, 2-row	Food/Malt	1992
Schooner	Normal starch, Covered, 2-row	Malt	1983

Pearled and cooked barley:

Five 2-rowed Australian barleys varying in husk and starch type (Table 1) were grown in three replicated trials at four South Australian sites (Brinkworth, Clinton, Yeelanna and Weetulta) during 2004. Barley samples (40 grams) were de-hulled using a laboratory scale oat de-huller (except for covered barley). The de-hulled sample was pearled in a Satake grain testing, mill model TM-05, until 20% (hulless types) or 35% (Schooner) of kernel was removed (approximately 2-7 minutes depending on sample). The sound kernels measurement was calculated as a percentage of whole pearled grain above a 2.0mm screen. SKCS hardness was measured using the Perten, Single Kernel Characterisation System at ABB Grain Ltd, on approximately 300 grains. New MG staining was performed as per method of Dr T Omori (SANWA SHURUI Co. Ltd., Japan. *Pers. Comm.*) 10 grams of pearled samples were cooked in a rice cooker for approximately 20 mins as per the method of Fastnaught *et al.*, 2002 (3). Samples were left in the warm cooker for 1 hr prior to colour

measurement. Whiteness (L value) of pearled samples prior to and after cooking were measured with a Minolta colorimeter using the CIE L*a*b* colour score.

Beta-glucan analysis:

Total mixed linkage beta-glucan was measured using the McCleary method, enzyme Assay kit, Megazyme, Australia.

Tocol analysis of pearled flour:

Supercritical Fluid Extraction was used to extract oil from waxy pearled flour (WI3693; Charlick, SA; 2003; 20% flour removed) as described in (4). Results are expressed as percentage of dry weight of pearled flour. Analysis of Tocopherols and Tocotrienols was performed at the National Measurement Institute, Australia, as described in (4). Results are expressed as ug/100g.

Flaked/Rolled barley:

500 grams of WI3693, Morrell (both grown at Charlick SA, 2003) and the oat cultivar “Euro” were rolled at BRI (Sydney, NSW). Prior to rolling, the samples were de-hulled (described above) and conditioned to a moisture content of 25%, approximately 12 hours before processing. Once conditioned, the grain was steamed at atmospheric pressure for 35mins. The steamed grain was then immediately passed through smooth flaking rolls on a Vario roller mill. The material was passed through the rolls for a single pass and another sample was passed through the rolls for two passes to produce a thinner flake. The gap on the mill was set to approximately 0.01mm. The flakes were then dried at 125°C for 15min and cooled at room temperature before packing. Screenings were measured on 50 grams of each flaked sample sieved (3 times) over 1.7mm, 2mm and 3.86mm Endecott sieves. The product above the sieve was weighed and recorded as a percentage of the whole sieved sample. Whiteness (L value) was measured as above.

Milling and Baking:

Samples of WI3693 and Morrell were de-hulled, as above, prior to milling in a laboratory scale Buhler mill, AGT laboratories, SA. Samples were not conditioned prior to milling. Moisture content was approximately 10%. Flour products were reconstituted to produce whole grain flour. The total mixed linked beta-glucan of Morrell flour was 4.1%, and WI3693 flour was 6.7%. Three types of pittas were made at Regency TAFE, SA containing either 50% waxy barley (WI3693) flour: 50% bakers flour, 50% hulless normal barley (Morrell) flour: 50% bakers flour and 100% bakers flour.

Results:

Agronomy:

In 2004, WI3693 yielded 93% of Schooner and 105% of Torrens averaged over 21 sites, with very even performances across 5 agro-ecological zones of South Australia. Grain size was 5% and 1000 kernel weight was 4% higher than Torrens. Grain size and 1000 kernel weight was 89% and 95% of Schooner respectively. WI3693 is resistant to lodging, cereal cyst nematode (CCN) and spot form of net blotch (sfnb).

Pearled and cooked barley:

To assess the level of pearling required to compare hulless and covered barleys, new MG stain was used to determine the amount of aleurone (blue) lost and endosperm (pink) retained. To achieve a pearling equivalent of 80% in hulless grain (Figure. 1c), the covered type (Schooner) was pearled to 65% or 35% loss (Figure. 1a). Schooner pearled to 80% still retained significant amounts of husk and aleurone (Figure. 1b)



a. Schooner 65%
pearled & stained



b. Schooner 80%
pearled & stained



c. WI3693 80% pearled
& stained

Figure 1(a),(b),(c). Pearled barley stained with new MG stain.

The waxy cultivar, WI3693 (designated as waxy in Figs. 2 & 3) performed well in pearling trials as assessed by percentage of sound kernels remaining after pearling (Figure. 2a). At all sites WI3693 had at least 80% sound kernels after pearling. This was higher than or equivalent to the sound kernels of both hullless and covered types. Environment plays a significant role in pearling quality; so four diverse sites and three plot replicates were analyzed. In previous years where pearling quality was generally poor, WI3693 performed better than any other cultivar tested and with greater uniformity (data not shown). The hardness results show that WI3693 is generally harder than the other varieties tested (Figure. 2b). Hardness contributes positively to pearling quality (5,6) and provides for greater pearling uniformity when environments change.

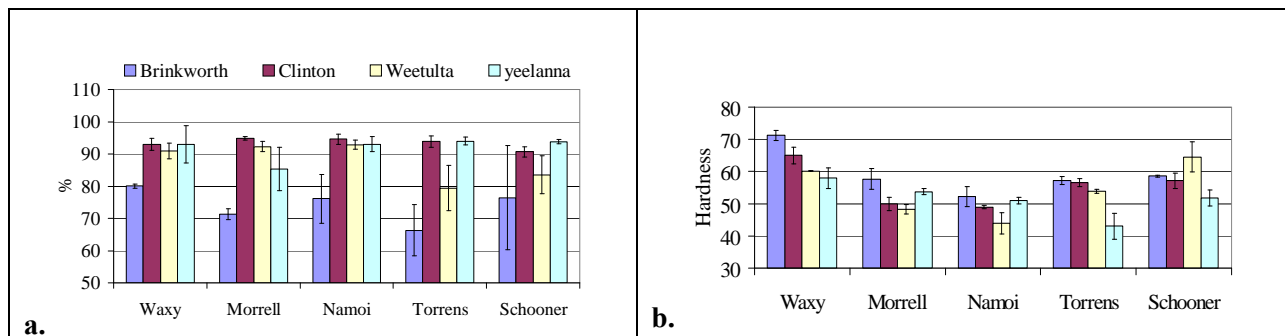


Figure 2(a) and (b). a) 2004 Sound Kernels b) 2004 Hardness (4 sites, 3 replicates)

Oil analysis of flour from WI3693 (Charlick, SA. 2003) pearled to remove 20% of the outer layer exhibited a high oil content of 11.2% when extracted using supercritical fluid extraction. Analysis of tocols demonstrates that significant concentrations of these valuable antioxidants (4) can be extracted from this waste product of pearling.

Table 2. Oil and Tocol content of WI3693

Sample	Treatment	Oil content % dwt	Tocol content mg/100g									
			α -T	β -T	γ -T	δ -T	α -T3	β -T3	γ -T3	δ -T3	Total T+T3	T:T3 ratio
WI3693	20% pearled flour	11.2	47	2.4	11	7.9	190	7.7	80	3.5	350	1:4

T=Tocopherol T3=Tocotrienol

Pearled barley whiteness (L-value) was measured before and after cooking (Figure. 3). The waxy line WI3693 was brighter than all other pearled cultivars tested with an average L-value of 75. After cooking, WI3693 exhibited the greatest decrease in brightness, however the L-value still averaged 71 over four sites and three replicates. Compared to results from Canadian varieties (7), the Australian cultivars produced a much whiter and brighter pearled and cooked product.

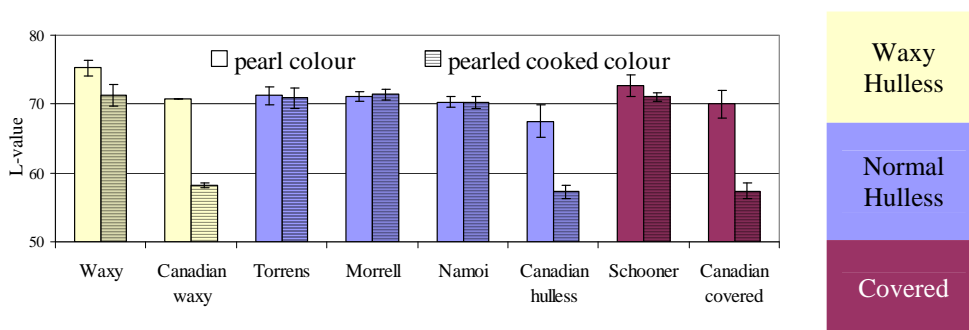


Figure 3. Whiteness of pearled and cooked barley. Result s are presented as average L-value of 3 replicates, 4 sites, 2004. Canadian results (7) are shown for comparison.

Total beta-glucan content of whole and pearled/cooked barley was measured. The beta-glucan content of WI3693 (waxy) ranged between 6 and 7 % (dwt) and was significantly higher than the other cultivars tested (Figure. 4). After pearling and cooking there was no significant change in beta-glucan content.

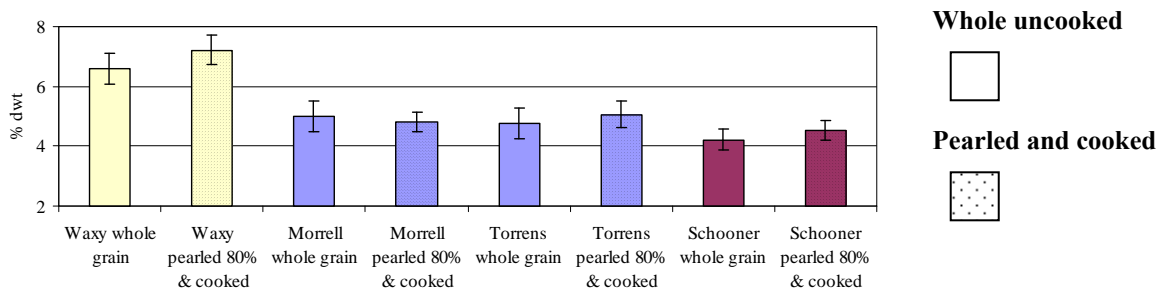


Figure 4. Beta-glucan content of whole and pearled/cooked barley. Average of 4 sites, 3 replicates, 2004.

Flaked/Rolled barley:

Rolling of WI3693 produced a thin white flake similar in colour to Morrell, but slightly darker than the oat product (Figure. 5 photo). Only WI3693 flakes were retained above all screens with greater than 80% efficiency (Figure 5 graph). Morrell also performed well, however, only 60% of the “pass 2” flakes were retained over the 3.86mm screen. The oat sample performed very poorly with very high screenings in all cases. The poor performance of oats was probably the result of the extreme rolling conditions compared to industry practice. However, it does demonstrate the resilience of WI3693 and Morrell during flaking.

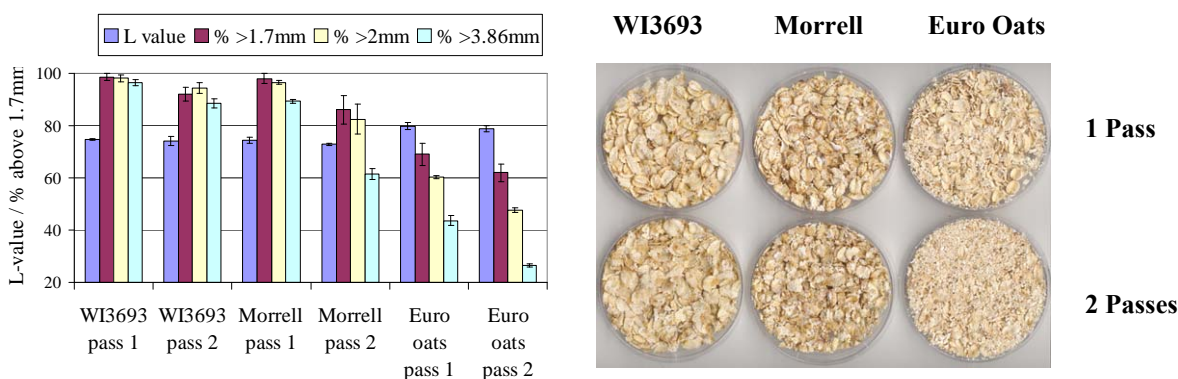


Figure 5. Rolled hullless barley and Oats: Whiteness and screenings

Barley flat-breads:

As expected the colour of the barley pittas were darker than the 100% bakers flour control (Figure. 6). However, the appearance of the 50% barley pittas were much more acceptable than the 100% barley pittas that were brown in appearance (data not shown). Visually, the 50% waxy pitta had slightly better colour than the 50% Morrell pitta. To investigate whether lipoxygenase could improve waxy barley dough colour, 2% soy flour (containing natural lipoxygenase) was added to the waxy barley flour (100%) dough. Colour measurements show that dough colour can be improved by the addition of a natural lipoxygenase (Figure. 6).

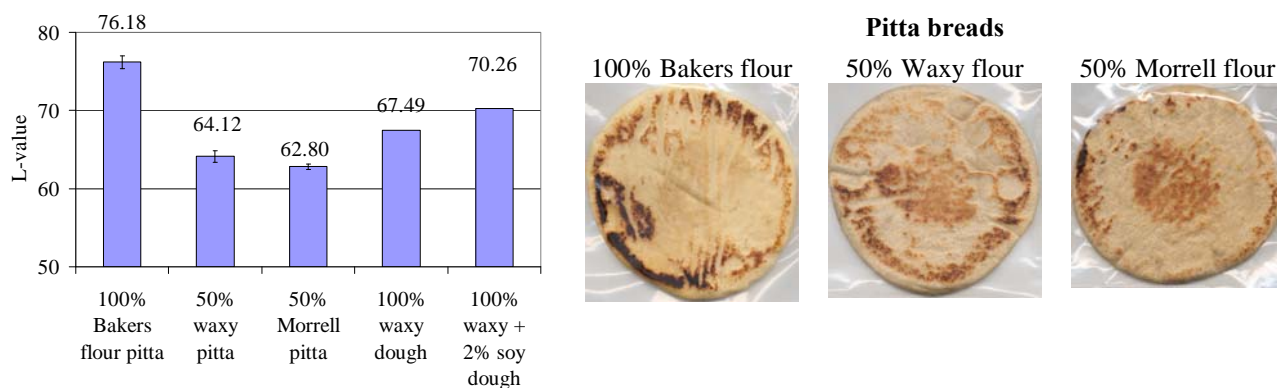


Figure 6. Whiteness score of pitta breads and waxy barley flour dough (Minolta L-value). Colour measurements were taken on the inside of the pitta pocket.

The waxy pitta had higher moisture, fat, ash and beta-glucan content than the other two pittas (Table 3). However, the carbohydrate and starch content were lower. Both barley pittas had similar fibre content, which was double that of the bakers flour control bread, however the beta-glucan component was significantly higher in the waxy pitta. The higher moisture is favourable to industry due to lower product cost per volume. The higher fibre, beta-glucan and lower carbohydrate content of the barley pittas, provides significant health advantages.

Table 3. Carbohydrate and beta-glucan analysis of Pitta breads

	50% Waxy barley flour	50% Normal barley flour	100% Bakers flour
Moisture %	41.6	40.5	35.6
Fat %	2.7	2.4	2.0
Protein (N x 5.7) %	8.6	8.4	8.6
Ash %	1.7	1.6	1.5
Total Dietary Fibre %	5.8	5.8	2.8
Carbohydrate (db) %	39.6	41.3	49.5
Total Starch %	37.5	39	47
Resistant starch %	ND	ND	ND
Total Beta-glucan %	3.94	2.76	0.43

ND=Not Detected, Detection Limit: Less than 0.5%

Conclusion:

The hullless waxy line WI3693 not only provides a nutritious alternative to other food grains such as oats and wheat, exhibiting low fat and high fibre content (including high beta-glucan), it also displays excellent physical properties in flaking, pearling and pitta-bread production. Compared to other normal starch hullless barleys, it also exhibits superior flaking, pearling and baking properties. Under extreme flaking conditions, WI3693 barley produced large, thin attractive flakes that exhibited very little breakage. This was in stark contrast to the oat product that showed extensive breakage leading to almost 80% loss of product after the second roll pass.

WI3693 whole milled flour incorporated at 50% into pitta breads, produced an acceptable product that pocketed well with a fibre and beta-glucan content more than 2 times and 9 times, respectively, than that of the wheat control. The high moisture content of this product is also attractive to manufacturers, who can save on ingredient costs. The high beta-glucan content of waxy dough results in a higher moisture uptake. There was also an indication that the waxy product staled slower than the normal starch barley product, although staling occurred more slowly in the wheat control. The issue of staling needs to be further investigated. The addition of 2% soy flour may further improve the colour of the barley product, which was already much brighter compared to products from varieties produced in Canada (7).

Barley has been shown to have a very low Glycemic Index (GI) compared to other grains (8) and incorporation of waxy barley flour into breads has been shown to improve glycemic control in Type 2 diabetics in a long-term study (9). This was attributed to the high beta-glucan content. A dietary intake of 5gm/day of beta-glucan was recommended by this study. In terms of the pitta breads produced in this study, a serving of 2 pitta breads would adequately supply this amount. The integration of whole grain hullless waxy barley into food products such as pitta breads may provide a high fibre, low GI, reduced carbohydrate alternative to 100% wheat based products that offer far less nutritional value. Waxy hullless barley also offers a low cost, value-added ingredient to the health conscious food producer and consumer. GI studies are currently underway by the ATN Centre for Metabolic Fitness, Adelaide, with an approach to aid in the community, the adoption of healthier food alternatives. Significant interest has been sought by food manufactures. Other foods and products made from WI3693 are currently under investigation.

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