VALUE OF THE TEST WEIGHT METHOD IN ASSESSING BARLEY QUALITY

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Abstract

This paper reports on the relationship between test weight (TW) and end-product quality; namely, malt and feed quality. The purpose was to gain an improved understanding of the TW parameter and its impact on quality; which we know is influenced by genetic, environmental and agronomic affects. Grain size has an interesting, yet complicated, relationship to test weight. In addition, test weight has a positive relationship to important malt quality traits, such as hot water extract and friability. However, there was little definable relationship between TW and cattle feed traits, including energy and daily gain. There is very little selection for TW in todays breeding programs, although data suggests some newer barley varieties have exhibited lower TW even when accepted into malt classifications. Test weight is a very old method that is included in the specifications of barley when delivered after harvest. It is based on a physical measure of kernel size and shape, as well as weight versus volumetric space. Growers can have deliveries downgraded if the grain fails to meet TW standards for malt or feed grades. The storage and sales of the grain are greatly affected by TWs. Bulk rail movements in Eastern Australia are now being charged on a wagon basis and not by actual weight of grain per wagon. This means that the amount of grain filling each wagon affects the commodity's value. The same situation applies to container exports as well as bulk grain. Buyers continue to place high emphasis on securing test weights in contracts. So what is the real basis for the quality aspects of TW? This paper explores them in more detail.

Introduction

Test weight (TW) (bulk density or hectolitre weight) is an industry standard for classifying malt and feed barley (NACMA). Minimum hectolitre weights are imposed in NACMA commodity farmer receival and trading standards, in cereal grains including barley, for a couple of major reasons: 1) a long standing industry belief that higher test weights are beneficial to millers/maltsters and feedlotters alike; 2) that grain is transported in 'volumetric' holds such as trucks, rail wagons, containers and ships' holds, yet the transport cost is charged on a 'by-weight' basis. The TW is a characteristic of a sample which will provide information for bulk grain handlers in stack management and to marketers to calculate the cost of supplying grain, and value it, via its market demand. With a greater understanding of test weights, and it's market driven value, industry agreed minimum test weight standards have been imposed in the NACMA commodity standards for barley, and this paper explores the relationship that a 'volumetric weight measurement' has on barley quality.

TW has been shown to be an influence of the growing environment (Molina-Cano *et al.* 1997), crop management, plant diseases such as Fusarium Head Blight (Smiley *et al.* 2005), pests such as Russian Wheat Aphid (Bregitzer *et al*. 2003) and genetic effects (Molina-Cano *et al.* 1997). These effects generally have a negative impact on yield, grain size and increased protein contents. Subsequently, a reduction in test weight is observed. Numerous studies have measured TW and related it to malt and feed quality (Oddy *et al.* 1990; Mathison *et al.* 1991; Hatfield *et al.* 1997; Perttila *et al.* 2000;

Wiseman 2001; Fox *et al*. 2007). Bregitzer and Raboy (2006) also showed the effects of low phytate content and test weight. In addition, anecdotal data from industry has suggested that lower test weight may be associated with pre-harvest sprouting.

Improvement in grain weight/size has been shown to have occurred through human selection rather than through evolutionary events (Ferrio *et al*. 2006). Grain quality traits such as grain size (Nasr *et al*. 1972; Fox *et al*. 2006) and protein content (Goblirsch *et al*. 1996; Emebiri *et al*. 2004) are traits selected for in breeding programs. Test weight is not usually measured or selected for. Studies have shown a genetic component for test weight with QTLs identified (Coventry *et al*. 2003).

The aim of this study was to detail the relationship between test weight and a number of barley quality traits.

Materials and Methods

Barley Samples

All cultivars tested were Stage III/IV trials grown at 31 sites over 4 years. The trial structure was as replicated trials, which had been designed in a latinised row column design of 2 reps by 144 entries. Grain from these trials was assessed for grain size, test weight and pre-harvest sprouting (5 sites only) as described below. Further, malt and feed quality measurements were made on subsets of these samples, with the replicate field plots being assessed for each cultivar.

Grain size

Grain size was measured according to the methodology described previously (Fox et al. 2006), where approximately 120g was sieved in a Sortimat for 1 min. The percentage of the grain size distribution was calculated based on the weight of four fractions, namely < 2.2 mm (screenings), 2.2 – 2.5 mm, 2.5 – 2.8 mm and > 2.8 mm. Retention was the combined total of > 2.5 and > 2.8 fractions expressed as a percentage.

Hectolitre Weight

Hectolitre weight (HLW) was determined using a Dickey-John GAC2100 where 500g of barley was poured into the top hopper. The grain was dumped into the cell where moisture and weight was measured. HLW was reported as kg/Hl.

Pre-harvest sprouting

Pre-havest sprouting was measured using the Falling Number method. In this method, a sample of grain (approximately 50 g) is ground in a hammer mill through a 0.8 mm sieve. Oven moisture was determined from this sample (European Brewing Convention 1998). This moisture value was then used to weigh, in duplicate, an equivalent amount of flour as described by the method (American Association of Cereal Chemists 1992). Weighed samples were mixed with 25 ml of water at room temperature. After the sample and water was mixed, plungers inserted into the tubes and then placed in the boiling water bath of the Falling Number instrument. The sample was mixed by the instrument with the plungers moving up and down through the sample, for 55 seconds after an initial five second rest. The plungers were released from the top position and the time for them to reach the base position was recorded in seconds. Results were displayed by the instrument and manually recorded.

Statistical Analysis

The model for analysing the combined grain data across the multiple environments is a linear mixed model. In this mixed model formulation, within-trial variation is modelled simultaneously with effects for genotype (G) (Gilmour *et al*. 1995). A factor analytic form is fitted to the variance of the interaction effects between cultivar and environment (GxE) (Smith *et al*. 2001) and this model has been shown to perform well for these types of MET data (Fox *et al*. 2007; Kelly *et al*. 2007). This same statistical model is adopted for the feed grain traits. Feed grain samples were processed in field order with no blocking or randomisation of duplicates. Error variance was then a pooled estimate for the field trial and feed trial stages of testing.

Each model was fitted using *samm* (Butler *et al*. 2002), a suite of Splus functions implementing the average information algorithm of Gilmour *et al.* (1995). In this software, the variance parameters were estimated using the residual maximum likelihood (REML) procedure of Patterson and Thompson (1971). Best linear unbiased predictors, (BLUPs) were obtained for the random effects and generalised least square estimates were given for the fixed effects. Principal components analysis and the resulting bi-plot were used to graphically display the inter-trait relationships.

Results

Test weight and grain size

The results from the analysis undertaken in this study show strong genetic and environmental effects for grain characteristics including test weight and plump grain. There was a range of grain characteristic values for all the commercial varieties induced by a diverse range of growing environments from extreme drought (and temperatures during grain fill) to high moisture sites.

Large plump grain generally had high test weight whereas small grain had lower test weight. For exceptional large grain, the test weight also showed a decrease due to the physical limitation of large grain filling a small volumetric space. This relationship has been observed over a number of years and is considered (Stuart) linked to the balance between grain shape and size affecting the amount of intergranular air spaces within the volumetric space being measured.

Table 1 shows the summary of commercial varieties grown in the Northern region since the year of their release, starting with Prior and including three promising lines, one from each BBA node that have been tested by the BBA Northern Node. Generally, test weight has been maintained but two genotypes, namely Gairdner and Fitzroy have shown to have decreased test weight compared to other genotypes. Three of the newer breeding lines, NRB03470, WABAR2209 and WI3416 have accepted test weight with the WABAR line having the highest averaged test weight of those genotypes compared and being that same as Schooner a commercial variety released in 1983.

Test weight and pre-germination

The results from the weathered grains and reduced grain weights study showed no relationship between test weight and Falling Number. There were only five sites tested for weather damage over the four years and three of these sites had most of the material above the 300 sec industry standard for FN. Further, one site (2003 Biloela) was severely moisture stressed during grain fill and subsequently had very low test weights. Therefore, no clear relationship could be seen between weather damaged grain as measured by FN and a reduction in grain weight as measured by TW.

However, to counter this lack of relationship in the above, is the observation from commercial intakes on germination loss and Falling Number measures taken in the differing malting grades of SC1 (min test weight of 67.5kg/hl) and the SC2 grade (min test weight of 65kg/hl) as imposed in NSW during the 1990s. Of these grades, germination loss was considerably higher in the SC2 grades at a range of sites, than in the SC1 grade. Falling Number results tended to show a higher proportion of lower numbers in the SC2 grade than in the SC1 grade. This observation was over a greater geographical area of NSW from Dubbo to the Victorian border of the variety Schooner, which is believed to have less dormancy than its northern NSW/QLD counterparts. This observation needs further exploratory work as it appears to point towards the need to understand this relationship in more detail over a wider geographical environment.

In 2001, the NACMA standard's committee lowered the 67.5kg/hl min limit for the No 1 grade of malting barley to 65kg/hl as the (now current) No 1 standard. There has been some general industry belief of a greater and more common occurrence of germination losses in barley in up-country storages since the lower test weight standard of 65kg/hl was imposed. This lends some weight to the belief that TW and quality are linked.

Discussion

Australian breeding programs have produced large grain size varieties and good test weights, in parallel to increased yield. However, both of these traits are influenced by genetics as well as growing environment. Both traits also show a high level of heritability hence, further gains could be made. While little attention is paid to test weight as a breeding selection tool, genetic gains can be made which would have positive flow on effects for quality classification due to the increased level of starch. However, excessively large grained varieties may cause problem for maltsters trying to hydrate the barley sufficiently within a four-five day germination period.

Anecdotical data has suggested that test weight may be decreased in barley that had been weather-stained prior to harvest. From the limited number of samples available in this study (only 5 sites), there was no apparent relationship between the level of weather damage and a drop in test weight. This was for both the data set as a whole or for an individual genotype, but limited to a study over a smaller geographical area. A number of factors must be considered when assessing these types of grain effects, including:

- timing of rainfall even,
- amount of rain,
- dormancy level of the genotype.
- Geographical area involved.

The BBA Northern Node has a semi tropical climate with dominant summer rainfall which increases the risk of weather damage to grain before harvest. Hence, selection for varieties with some dormancy is critical. During the 1970s when Clipper was the dominant variety being grown throughout Australia, the Barley Marketing Board of NSW had germination losses in approx one-third of their malting barley stocks held in northern NSW each year. The introduction of Grimmett in the mid 1980s with a moderate level of dormancy, solved this problem as there was a significant drop in germination losses since this variety's introduction. With the well known lack of dormancy in the variety Clipper, the stonger dormancy evidenced in Grimmett, plus the alpha-amylase testing of stocks that was conducted (by John Carn / John Stuart) during the mid-late 1980s showing sprout damage, the industry started to understand the importance of dormancy in this northern region. Consistently lower test weights of barley in the higher rainfall zones around Inverell/Delungra/Mt Russell and many areas of the Liverpool Plains (co-inciding with more regular germination losses) verses more western barely regions Moree – Walgett – Merrywinebone – Burren Junction, where more consistently higher test weights married with less germination losses, added weight that an examination needed to be conducted into test weight vs quality.

With the domestic industry requiring germinative ability of stocks to maintain in storages for more than 15 months, prior to malting, this issue is of widespread concern to marketers and maltsters alike. Further work is considered to be needed to continue to address the ongoing market concerns of malting barley germination losses during storage.

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Table 1. Summary of grain size and test weight for commercial genotypes and best advanced line from each BBA node grown in Northern Region (ordered in time of release)

Genotype	SCR (% < 2.2 mm)	Ret (% > 2.5 + PG)	PG (%>2.8mm)	HLW (kg/Hl)
PRIOR	12.9	42.8	7.9	67.2
CLIPPER	7.7	60.2	19.5	68.9
SCHOONER	4.5	73.6	30.3	69.7
GRIMMETT	9.4	60.1	19.0	68.2
TALLON	10.8	51.8	12.6	68.2
SKIFF	8.9	57.5	16.2	68.6
KAPUTAR	10.8	59.8	20.1	65.2
MACKAY	8.8	60.9	19.1	68.5
TANTANGARA	12.0	50.7	10.8	67.5
BINALONG	11.3	50.9	11.8	68.4
COWABBIE	7.3	67.6	29.3	68.9
GAIRDNER	8.8	57.2	15.4	67.9
FITZROY	7.8	66.9	28.6	65.8
GROUT	4.8	69.2	23.2	68.6
BAUDIN	8.0	63.4	26.1	68.1
CAPSTAN	12.2	55.1	22.3	64.5
Highest HLW lines from three BBA nodes				
NRB03470	4.3	76.7	41.5	69.2
WABAR2209	4.2	71.0	26.3	69.7
WI3416	5.0	77.3	46.6	68.4