Water uptake of barley is related to kernel endosperm hardness by SKCS

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Abstract:

Barley with hard endosperm is often described as 'steely' by the malting industry as the endosperm is characterised by a vitreous appearance. These grains are thought to be a factor affecting the modification of barley during malting by restricting water and enzyme movement across the endosperm. This can leads to under-modification of malt with high levels of undegraded β-glucans and proteins. Under-modified malt can cause poor lauter tun run-off rates and slow filtration rates in the brewing process, and increases the potential for haze formation in beer. The most common method currently used in the industry to determine barley endosperm hardness is by visual assessment however, this method may be subjective and requires training. In this study a number of methods for determining barley endosperm hardness were assessed and their relationship with water uptake was compared. The methods included the Perten Single Kernel Characterization System (SKCS), a visual rating system, a fracture mechanics technique and light transflectance (LTm).

SKCS hardness values for whole barley were highly correlated with visual assessment of the endosperm ($r = -0.802$; $p<0.01$) and also significantly correlated with LTm ($r = -0.700$; $p< 0.01$). Barley water uptake (%) in first 12 hr of steeping and SKCS hardness values were significantly correlated ($r = -0.73$; $p<0.01$). The visual assessment of barley ($r = +0.604$; $p<0.01$) and LTm ($r = +0.417$; $p<0.01$) values showed poorer correlations with water uptake in barley. Correlations between barley protein and barley hardness were generally not significant.

These results demonstrate that the SKCS is a reliable method for measuring barley hardness and the SKCS values may be useful in predicting barley-malting performance.

Key Words:

Barley, steely, mealy, SKCS, hardness, water uptake

Introduction

Uniformity of barley endosperm modification is an essential feature of malt quality. The key factor for uniform modification is homogeneity of the endosperm of raw barley (1). However, the starchy endosperm of barley grain is not uniform in composition (2). The endosperm of steely grains is physically harder in structure, shows slower rate of water uptake during steeping, and poorer distribution of enzymes during malting. These characteristics lead to a variable degree of cell modification in the endosperm during malting (3,4). Batches of unevenly modified malt contribute to well known problems in the brew house such as low yield, poor lauter run-off rate, poor filtration rates and hazy beer (3,5). The factors controlling steeliness / mealiness of barley are not fully understood (6). It has been suggested that the grain protein and β-glucan content and the proportion of small and large starch granules may have an effect on steeliness / mealiness of barley (3,4,7).

At present there is no widely accepted quantitative method for determining the levels of mealiness or steeliness in barley. Traditionally it has been assessed qualitatively by visual inspection, and more recently techniques such as light transflectance have been developed (8) to assess the endosperm structure (steeliness & mealiness) of individual grains of barley. In this technique, laser light passing through the grain is measured and the quantity is dependent on the packing style of the endosperm. Mealy grains hinder light transflectance through increased scatter, and grains with steely structure transmit more light (8). It has been demonstrated that there is good correlation between the LTm and visual assessment (8,9).

Another characteristic of steely grains is they are described as hard or tough. Therefore it may be possible to assess barley steeliness by measuring their hardness. The single kernel characterization system (SKCS) was developed to classify wheat, based on kernel texture, or hardness. Single kernels are crushed as they pass through a wedge-shaped cavity between a smooth crescent surface and a coarse-toothed rotor. The crescent is a lever supported by a load cell that measures a force vector from the crushing action (10,11).

The aims of this study were to investigate the relationships between the visual assessment of mealiness of barley with that determined by LTm and two methods of measuring hardness – the SKCS and the Instron Universal hardness tester, which has been used to measure wheat hardness (12). We have also investigated the correlation of these values with water uptake in barley.

Methods:

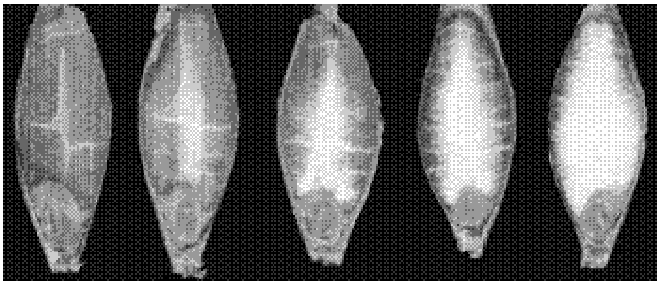
Barley Sampling & Preparation
Commercially grown (2001 season) Australian barley (*Hordeum vulgare L.*) varieties were obtained from South Australia, Western Australia, Victoria and Queensland. Samples were screened (Vibro type VS 1000) and seeds of 2.2 to 2.5 mm were selected. Each sample was conditioned to 13.5 ± 0.5% moisture content by equilibration over saturated aqueous lithium chloride at 20 ± 2º C for three weeks prior to undertaking all hardness tests. Protein content was determined using the Leco protein analyser (13).

Fracture Mechanics
An Instron Universal Hardness Tester (1100), originally designed to measure the toughness of solid materials, was used to measure the endosperm hardness of barley in this study. In this system a load cell measures the hardness of the seed when force is applied to crush it. Barley grain was placed one kernel at a time on a steel plate and compressed slowly (0.5mm/min) with 1KN power using a stainless steel probe with a diameter of 4mm fixed to the cross bar. Following the second indication of fracture the sample was unloaded by raising the Instron cross head. Compression was continued in several loading-unloading cycles until the grain was completely fractured. The energy dissipated during fracture was obtained by measuring the area under the resulting loading-unloading curve.

Single Kernel Characterisation System 4100
One hundred and fifty kernels of barley from each sample were submitted to the SKCS under normal operating parameters and conditions (Perten Instruments). Individual kernel weights, the force deformation profile during the crushing of the kernel and conductivity were measured against time. That information was algorithmically processed to provide the weight, size, moisture and hardness of each barley kernel. The higher the SKCS value the harder the barley sample.

Light Transflectance
LTm measurements were performed as described in Woonton *et al.* (9). Barley kernels (97 kernels) were mounted in the slots of a disc and loaded into the rapid Light Transflectance meter (Brewing Research International, United Kingdom). The transflectance value for transmission of light through the seed was measured, recorded and the percentage of mealy grains calculated. The LTM index was calculated (8,9) where the higher the LTm index the more mealy the sample.

Visual Assessment
Visual assessment was performed as described by Woonton *et al.* (9), where barley grains are sanded to expose the endosperm, which is visually rated according to the mealiness. For each sample forty barley kernels were embedded dorsal side up into plasticine blocks (Photo Technic Sàrl, France). Blocks were sanded with an automated MicroFluo belt sander (Photo Technic Sàrl, France) until the inner endosperm was fully exposed. The area of each exposed endosperm was visually observed and rated between 100% (very mealy) and 0% (very steely). An illustration of visual ratings is given in Figure 1 (9).



0% 25% 50% 75% 100% Mealy

Figure 1. Illustration of visual ratings of barley endosperm

The visual mealiness was calculated from visual assessment of each sample using the following equation.
Visual Mealiness (V.M) = (100% x A) +(75% x B) + (50% x C) + (25% x D) + (0% x E)%
A,B,C,D and E are the total number of grains in each category.

Water Uptake of Barley

Samples were weighed (100 g) and placed into an enclosed mesh basket and steeped in a distilled water bath at 18º C for 12 hr. After 12 hr the grains were removed and placed between two filter papers (Whatman Grade 1) to remove excess surface water. This step was repeated until the surface water was completely removed. The kernels were weighed and the percentage of water uptake in first twelve hours of steeping was calculated. Each sample was analysed in triplicate.

Statistical Analysis

The kernel hardness of each sample as determined by the four different methods was statistically compared with total kernel water uptake (12h), protein content of barley and malting quality such as total extract, friability and Kolbach Index. Simple linear correlations between barley endosperm hardness measurements and water uptake and protein content of barley were performed using the statistical package 'SPSS, Version 10.0'.

Results & Discussion:

Kernel Endosperm Hardness Measurements

Analysis of 80 barley samples demonstrates that hardness determined by SKCS was found to be significantly inversely correlated with mealiness determined by visual assessment (Figure 2; $r = -0.802$, $p < 0.01$). Similarly, hardness determined by SKCS was also significantly inversely correlated with mealiness determined by LTm (Figure 3; $r = +0.70$, $p<0.01$). This data demonstrates that there is a strong relationship between visual steeliness of the kernel and the SKCS hardness of the barley kernel and therefore SKCS index may be a useful measure of steeliness.

Barley hardness as determined by the Instron Hardness Tester was found to be poorly correlated with other methods of steeliness / hardness measurement. This is likely due to the smaller sample size used in this experiment (20 kernels) and/or low sensitivity of the load cell for the Instron equipment used in this experiment.

Endosperm Hardness and Protein content of Barley

It was observed that the correlations between barley protein content with all hardness measurements were very low ($r = + 0.1165$ for the LTm; $r = - 0.05$ for SKCS; and $r =- 0.04$ for Visual assessment). It has been suggested that the kernel protein content relates to the endosperm structure in cereals (14,15) but the role of grain protein on hardness of cereal endosperm is not always clear (16). In wheat protein fractions such as puroindolines may be more important than the content for controlling kernel endosperm hardness (17). In barley, it has been reported that for the Steptoe/Morex population, the puroindoline homologs in barley accounted for approximately 22% of the genetic variation in grain hardness (18). In addition, starch granule size and proportion, amylose, amylopectin content and pentosans content such as β glucan and arabinoxylan may also be factors in affecting the hardness of the endosperm (19,5). Therefore, further work needs to be done to determine the role of the components of barley with the steeliness and hardness of barley.

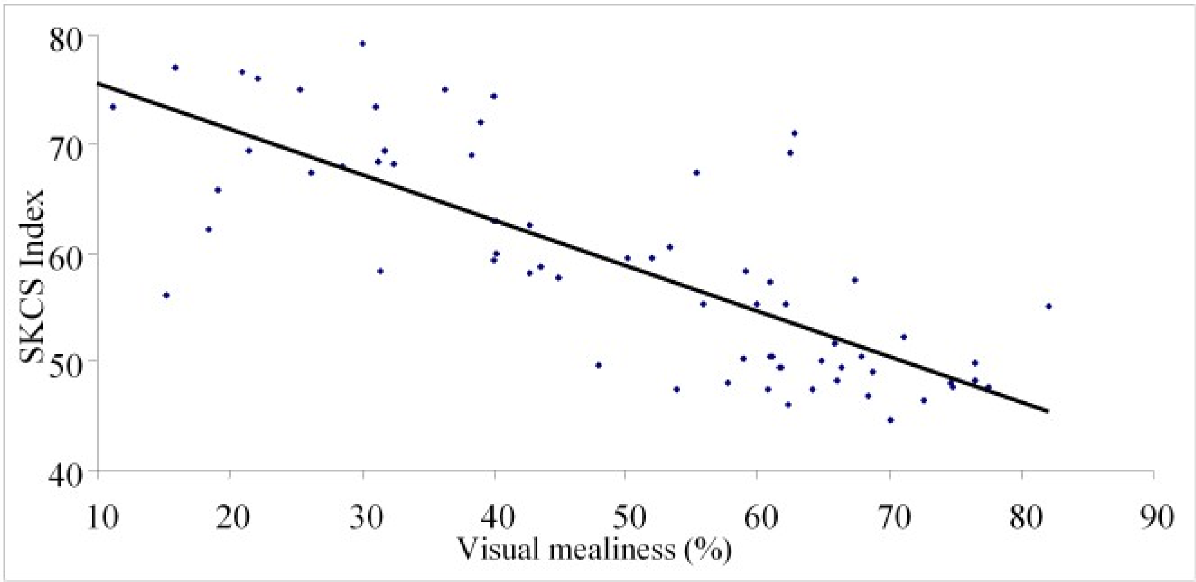


Figure 2. Relationship between SKCS index and visual mealiness (r = - 0.802; n=80)

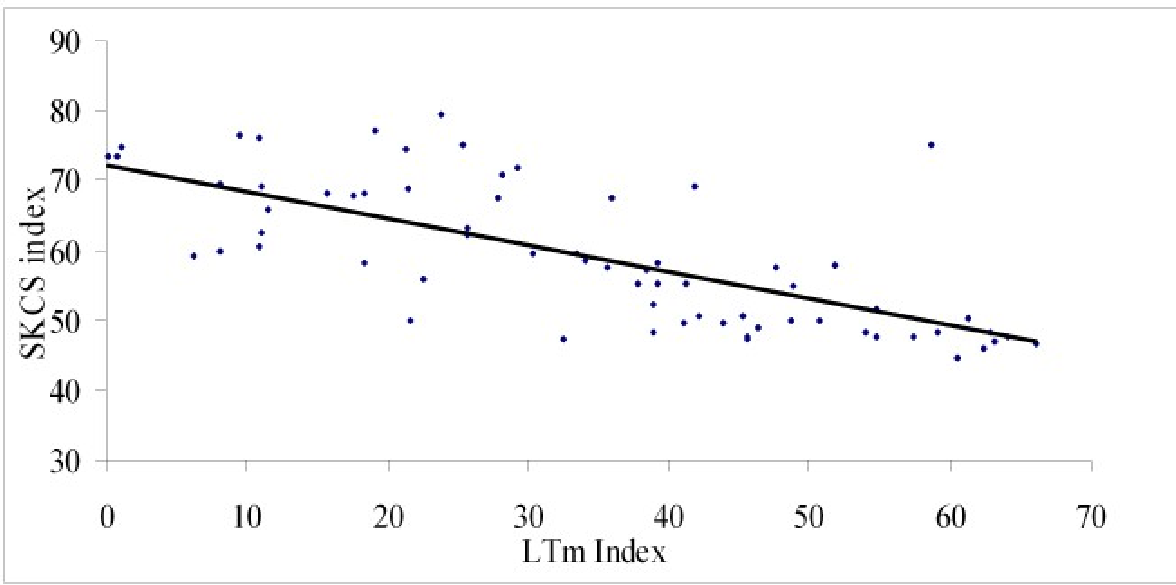
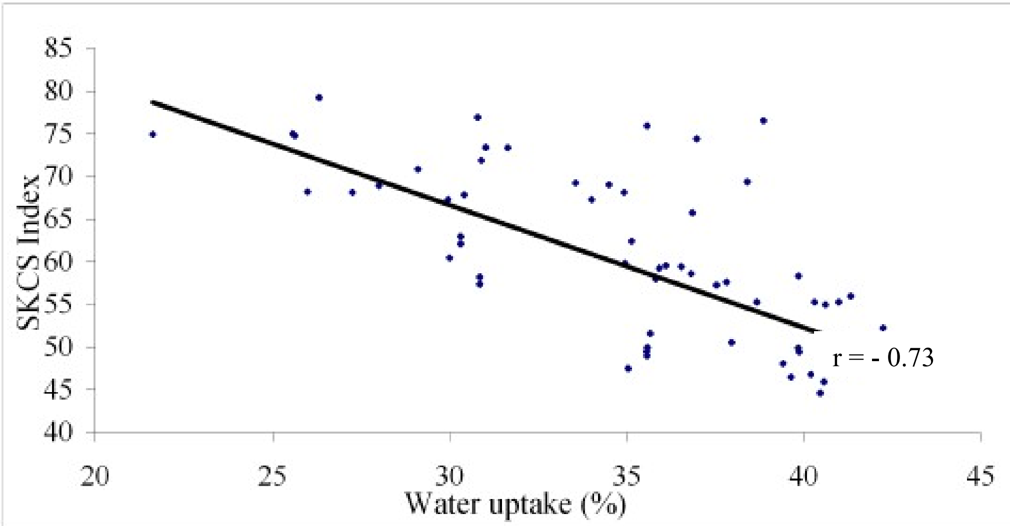


Figure 3. Relationship between SKCS and LTm Index (r = -0.7; n=80)

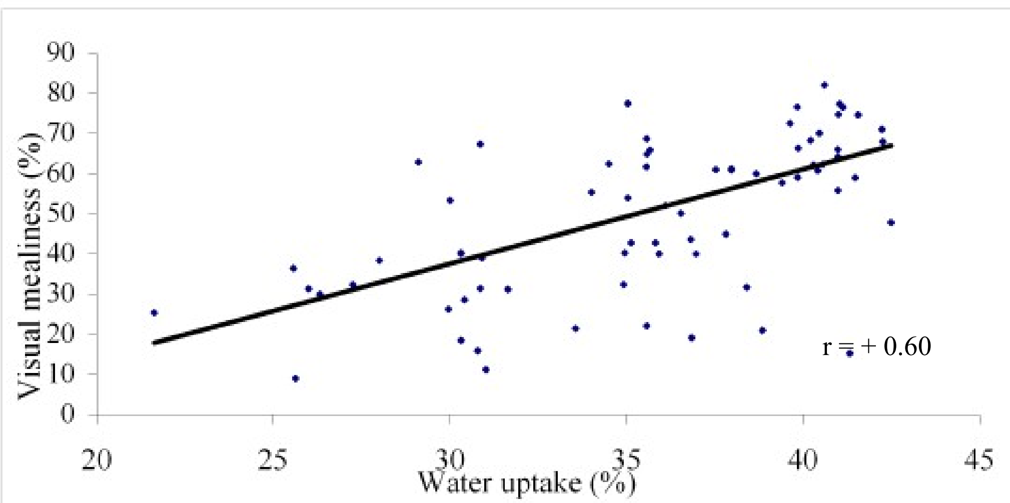
Kernel Water Uptake and Hardness

The relationships between water uptake and steeliness/hardness measurements by three different methods are given in Figure 4. The strongest correlation was observed between SKCS index and water uptake ($r = -0.721$, $p<0.01$). Weaker but still significant correlations were observed between water uptake and visual mealiness (0.604, $p<0.01$) and water uptake and LTm index ($r =0.417$, $p<0.01$). Fracture mechanics measurements using the Instron Hardness tester demonstrated very weak and statistically non-significant correlation with water uptake of barley kernels.

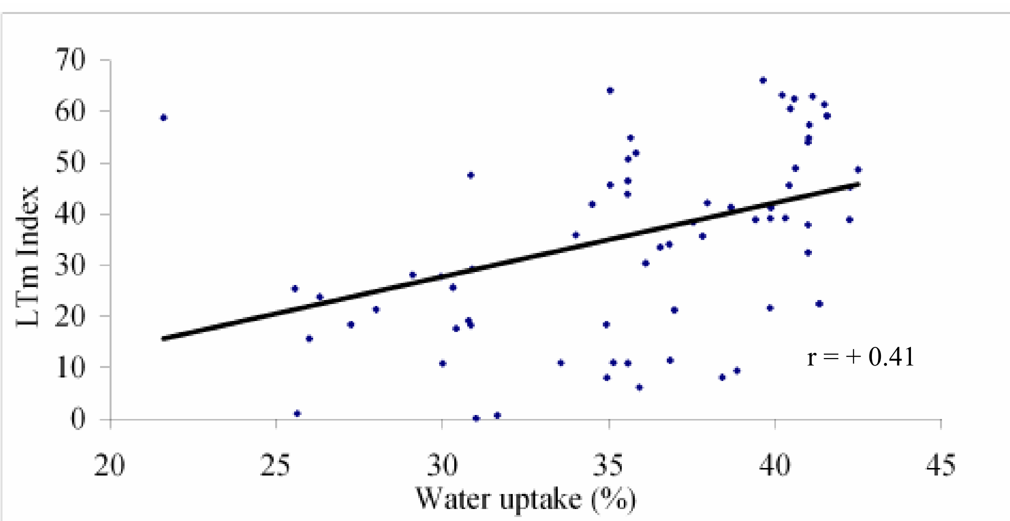
The endosperm structure is a significant factor in barley water uptake (20). The water uptake and diffusivity in cereal endosperm is significantly affected by the vitreousness of the endosperm (21). The steely areas in the endosperm are reportedly closely associated with higher concentrations of β-glucan and grain protein (22) and this restricts the water distribution across the endosperm (23). As the SKCS index increased, substantial decreases in water uptake was observed for the 12-hour period tested. These results demonstrate that the SKCS hardness may be a useful determinant of water uptake by barley.



SKCS Index
Water uptake (%)
r = - 0.73



Visual mealiness (%)
Water uptake (%)
r = + 0.60



LTm Index
Water uptake (%)
r = + 0.41

Figure 4. Relationships between kernel hardness measurements and water uptake during steeping (n = 80)

Conclusions:

It is concluded from this study that: a) there is a strong relationship between the measurement of the endosperm hardness by SKCS and steeliness by visual assessment; b) there is a very good relationship between the measurement of the endosperm hardness by SKCS and kernel water uptake; and c) that SKCS can provide a rapid, quantitative and accurate prediction of steeliness/mealiness of the endosperm of barley kernels.

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