Estimating Barley Character for *Shochu* Using a Single Kernel Characterization System (SKCS)

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ABSTRACT

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The SKCS (Single Kernel Characterization System) is a device for measuring the physical properties of whole grain. Using the SKCS, the physical properties of barley produced in Australia in 2001 were examined in relation to their suitability for *shochu* production (*shochu* is a Japanese clear distilled beverage with an alcohol content of ~25%). The hardness of whole grain showed a positive correlation with pearling, but negative correlations with both broken kernel ratio and conversion power. Softer endosperms facilitated crushing and fermentation (i.e. fermentation potential). From these correlations, quality characteristics of barley for *shochu* could be deduced. The measurement of barley hardness with the SKCS is important in the evaluation of barley for *shochu* production and the hardness of the whole grain could be used as one indicator in the evaluation of barley. The procedure can be carried out locally and rapidly.

Key words: Barley, hardness, *shochu,* 'Single Kernel Characterization System', SKCS.

INTRODUCTION

Two-rowed barley is generally used as a raw material for barley *shochu. Shochu* is a Japanese clear distilled beverage with an alcohol content of ~25%. Currently, in Japan, most of the raw barley for *shochu* is imported from Australia as two-rowed barley for food use. The annual import volume is approximately 160–180 thousand tons. The quality control of two-rowed barley in Australia is performed in some states similar to that of barley for *shochu.* However, it is basically an evaluation for malt production and no appraisal is performed by the *shochu* manufacturers. Therefore, it cannot be said that a quality classification of two-rowed barley suitable for barley *shochu* is in place.

The basic method of *shochu* manufacturing involves barley pearled approximately 70% from whole grain (unpolished barley) as the raw material, The production process consists of four stages: material treatment (imbibition and steam boiling), *koji* stage, fermentation, and distillation (Fig. 1). The quality evaluation of barley for *shochu* must be performed on both pearling and fermentation characteristics. In the conventional methods of evaluating the pearling and fermentation characteristics, actual production processes have been reproduced on a small scale, including a pearling examination, a digestion examination of barley *koji* and a fermentation examination[4,5,8]. In the pearling examination, about 70% pearling and the related yield of pearled barley are considered to be important. In the digestion examination of barley *koji,* the amount of citric acid generated by *Aspergillus kawachii* and the digestiveness of the *koji* are evaluated from the amount of citric acid present. A specific level is required to prevent *moromi* (mash) from rotting. Digestiveness, an indicator of conversion power (a result of multiplying the saccharification power by the digestion power) is important. The higher a conversion power the barley material exhibits, the better it is considered to be. Because barley *koji* is equivalent to malt in the whiskey production process and is used as a source of various enzymes, the digestion examination of barley *koji* is deemed as an important test allowing one to examine fermentation suitability in advance.

However, current methods are inefficient because they are time consuming. In addition, it has been difficult to perform the above-mentioned methods in Australia, because of problems relating to equipment and experience. Since evaluation methods were inefficient, it was necessary to establish a routine evaluation method/indicator for barley that would be suitable for *shochu* production.

Generally evaluating the material characteristics of whole grain, i.e. the chemical properties such as raw protein content, starch content, raw fat content and minerals; and the physical ones such as specific gravity and particle-size distribution, is considered important. This report focuses on whole grain characteristics using barley produced in Australia in 2001 and a device called a SKCS (Single Kernel Characterization System)[1,3,6,7]. This allowed the measurement of hardness, weight, diameter and water content of whole grain and has been adopted primarily for the quality classification of wheat. Here, we report the results of an evaluation by first identifying the physical properties of the whole grain, i.e., the solid-state properties of whole grain, pearled barley properties obtained by conventional pearling examination, and fermentation performance as indicated by the digestion properties of barley *koji.*

MATERIALS AND METHODS

Test samples

Samples (139 batches) of barley produced in Australia in 2001 were tested, after storing in a cooler at 4°C for one month, to perform moisture control. Specifications are given in Table I.

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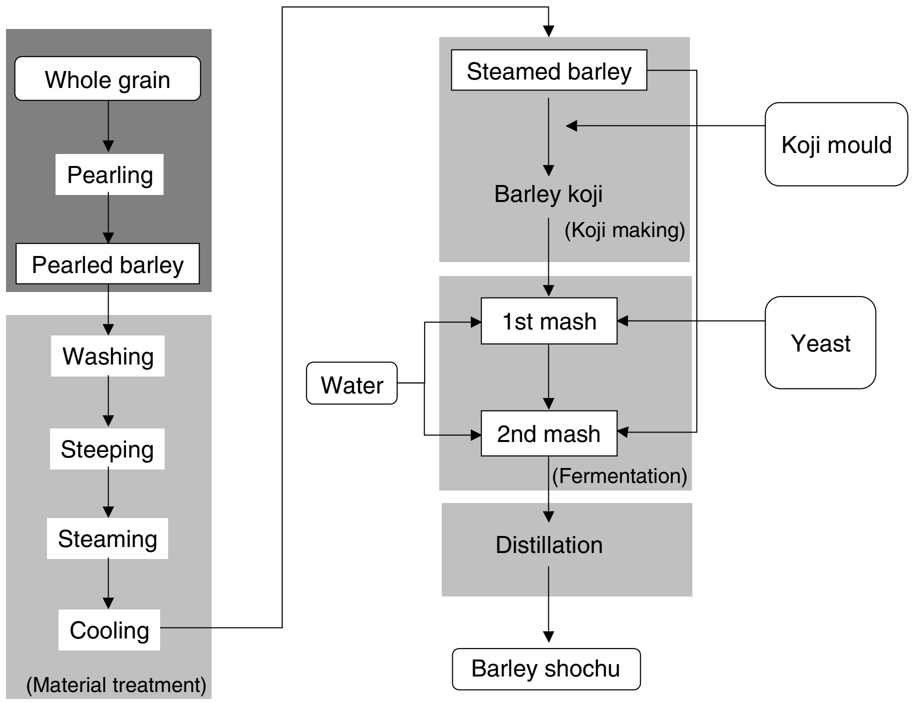

Fig. 1. Diagram of the process to produce barley *shochu.*

Physical properties of barley

The Single Kernel Characterization System (SKCS 4100) (Perten Instruments, Springfield IL) was used for measuring the physical properties of the whole grains. After randomly choosing 20 g of whole grains, the hardness, weight (mg), diameter (mm) and water content (%) values of 300 whole grains were measured with the SKCS 4100, to obtain the average and standard deviation of these 300 grains.

Pearling characteristics

Pearling examination was performed using the Test Mill TM-05 (Satake Corporation, Hiroshima, Japan). Using a revolving speed of 1,450 rpm, a roller count of 40, and whole grain samples of 150 g per examination as pearling conditions, the pearling was performed for two minutes with the given method. Then, the pearled sample was prepared by bran removal with a 2.0 mm mesh screen. The pearling operation is shown in Fig. 2. The pearling yield and the relevant broken kernel ratio, highly regarded in the pearling properties, were calculated as follows:

$$\text{Pearling yield}\,(\%) = \frac{\text{Sound kernel weight}}{\text{Whole grains weight (150 g)}} \times 100$$

$$\text{Broken kernel ratio}\,(\%) = \frac{\text{Broken kernel weight}}{\text{Pearled barley weight}} \times 100$$

Table I. Varieties of barley in this study.

Variety	Harvest area	No. of samples
Stirling	Western Australia	33
Schooner	South Australia, Victoria	88
Alapiles	Victoria	18
Total		139

Fermentation characteristics

Digestion examinations and citric acid producing power of barley *koji* was performed to assess fermentation properties. *Koji* was produced by using barley samples pearled at a pearling rate of 65% using a Thermo-Hygrostat LH-30 (Nagano Science Equipment MFG. Co., Ltd., Japan) The digestion examination was conducted using barley *koji* and was based on the method of Horie et al.[2] Citric acid producing power was assayed by the measurement of the acidity of the *koji.*

RESULTS

Physical property distribution of whole grains and physical characteristic for each variety

For the whole grain samples provided, the distribution of physical properties and physical characteristics for each variety were examined. For the moisture value, no data is given since moisture control was performed.

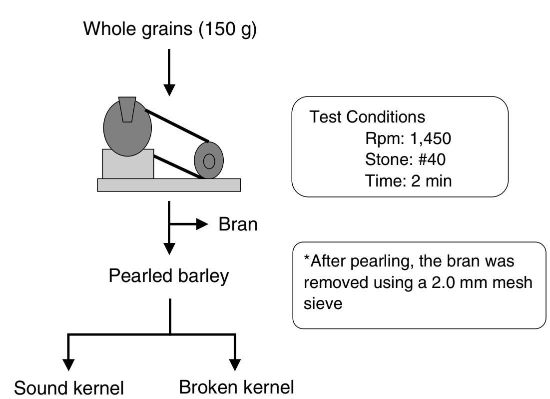

Fig. 2. The pearling process.

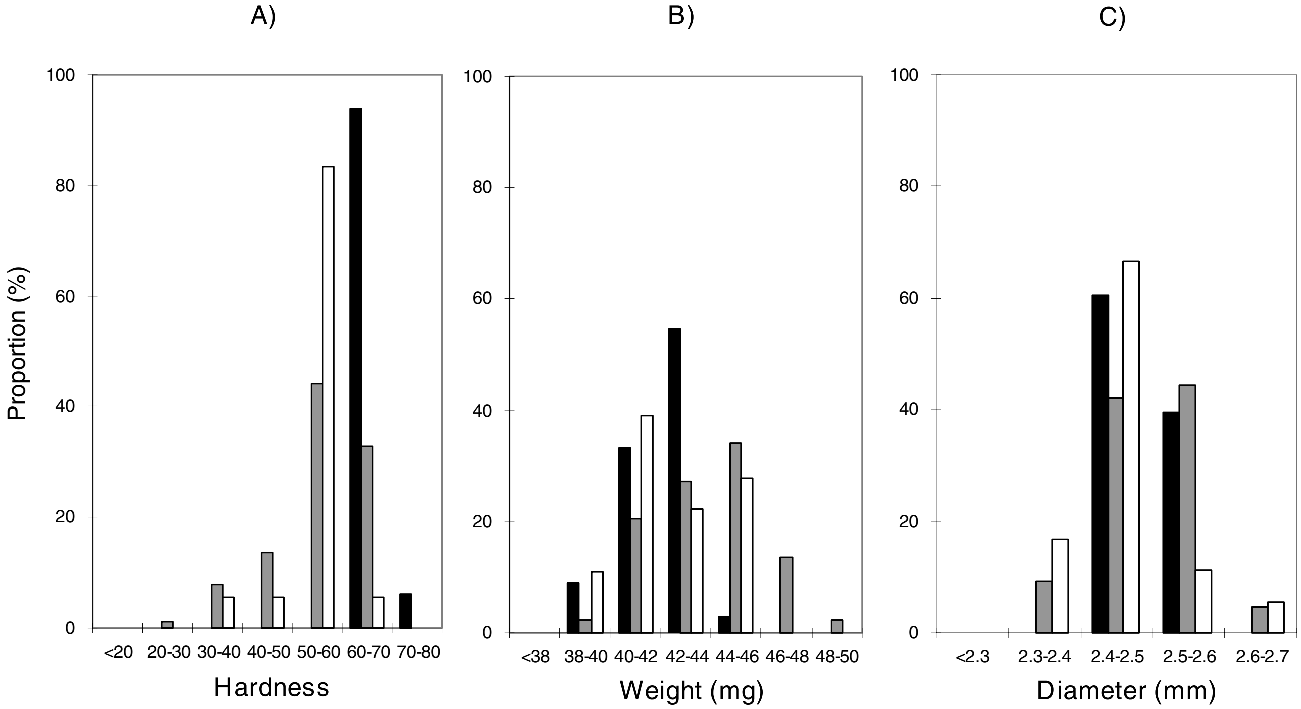

Fig. 3. Distribution of physical characteristics of whole grains in each variety. Stirling (■); Schooner (■); Alapiles (□). A) Hardness, B) weight, C) diameter.

1) Hardness distribution of whole grains. The hardness distribution of whole grains for each variety is shown in Fig 3A. Seven hardness classifications from below 20 to below 80 were adopted. Approximately 83% of total samples lay within the hardness range of 50 to 70. The average hardness and standard deviation of the total sample was 56.98 and 8.76, respectively (Table II). Looking at each variety, e.g. with Stirling, the hardness level of 60–70 was the most frequent, being 94% and that of 70–80 was the next best at 6%. The average hardness and standard deviation of Stirling was 65.41 and 2.83, respectively. For Schooner, the hardness level of 50–60 was the most frequent at 44% and that of 60–70 was the next best at 33%. The remaining samples lay within the hardness range of 20 to 50. The average hardness and standard deviation of Schooner was 54.44 and 8.70, respectively. For Alapiles, 83% of the samples were below the hardness level of 50–60 but showed a range of hardness levels of 30–40, 40–50 and 60–70 each at 6%. The average hardness and standard deviation of Alapiles was 53.93 and 5.73, respectively.

Comparison among varieties using the average and standard deviation values showed the following result: higher hardness and narrower hardness distribution of Stirling; lower hardness and wider hardness distribution of Schooner. For Alapiles, the hardness was found to be almost the same as that of Schooner and the hardness distribution lay between that of Stirling and Schooner.

2) Weight distribution of whole grains. The weight distribution of whole grains is shown in Fig. 3B. Seven classifications, from below 38 mg to below 50 mg, were adopted. The level of 42–44 mg was the most frequent at approximately 33% and the levels of 40–42 mg and 44–46 mg were the next best at approximately 26%, respectively. Looking at each variety, it was found that the most frequent levels of Stirling, Schooner and Alapiles were those of 42–44 mg for (55%), 44–46 mg (34%) and 40–42 mg (39%), respectively. The average weights of Stirling, Schooner and Alapiles were 42.09 mg, 43.80 mg and 42.36 mg, respectively (Table II). Comparison among varieties using the average and standard deviation values indicated a relatively low weight per grain for Stirling, higher weight per grain for Schooner and an in-between weight for Alapiles. For the weight distribution, Schooner, Alapiles, and Stirling showed the widest, the second widest and the least, respectively.

3) Diameter distribution of whole grains. The diameter distribution of whole grains is shown in Fig. 3C. Five diameter classifications from below 2.3 mm and below 2.7 mm were adopted. Of total samples, 89% lay within the diameter range of 2.4 mm to 2.6 mm. Looking at each variety, it was found that the most frequent levels were Stirling (61%) 2.4–2.5 mm, Schooner (44%) 2.5–2.6 mm and Alapiles (67%) 2.4–2.5 mm. The average diameters of Stirling, Schooner and Alapiles were 2.49 mm, 2.49 mm and 2.46 mm respectively (Table II).

Table II. Physical characterisics of whole grains in each variety.

Variety	Hardness*	Weight* (mg)	Diameter* (mm)
Stirling	65.41 ± 2.83	42.09 ± 1.31	2.49 ± 0.04
Schooner	54.44 ± 8.70	43.80 ± 2.04	2.49 ± 0.07
Alapiles	53.93 ± 5.73	42.36 ± 1.80	2.46 ± 0.07
Total	56.98 ± 8.76	43.21 ± 2.03	2.49 ± 0.06

*Mean ± SD.

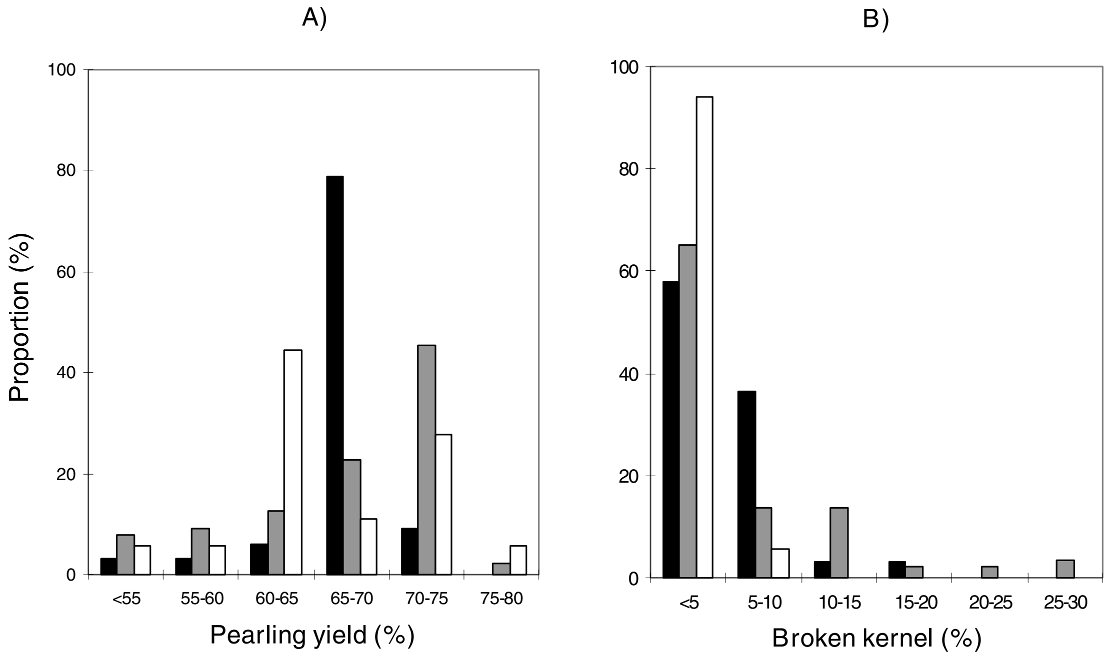

Fig. 4. Distribution of pearling characteristics of whole grains in each variety. Stirling (■); Schooner (■); Alapiles (□). A) Pearling yield, B) broken kernel.

Pearling characteristics, distribution of whole grains and pearling characteristic for each variety

For the whole grain samples, the distribution of pearling characteristics for each variety was examined.

1) Pearling yield distribution of whole grains. The pearling yield distribution of whole grains is shown in Fig. 4A. Six pearling yield classifications from below 55% to below 80% were adopted. About 86% of total samples lay within the pearling yield range of 60% to 70%. Looking at each variety, it was found that the most frequent levels of Stirling, Schooner and Alapiles were those of 65%–70% for (79%), 70%–75% for (45%) and 60%–65% for (44%), respectively. The average pearling yields of Stirling, Schooner and Alapiles were 66.9%, 67.1% and 65.7%, respectively (Table III).

2) Broken kernel ratio distribution of whole grains. The broken kernel ratio distribution of whole grains is shown in Fig. 4B. Six pearling yield classifications from below 5% to below 30% were adopted. Over 90% of total samples lay within the broken kernel ratio below 10%. For each variety, the most frequent levels were below 5%, each frequency was 55% (Stirling), 64% (Schooner) and 94% (Alapiles), respectively. The average broken kernel ratios of Stirling, Schooner and Alapiles were 5.30%, 5.54% and 1.97%, respectively (Table III).

Fermentation characteristics distribution of whole grains and fermentation characteristics for each variety

For the whole grain samples, the distribution of fermentation characteristics for each variety was examined.

1) Conversion power distribution of whole grains. The conversion power distribution of whole grains is shown in Fig. 5A. Eight comprehensive power classifications from below 950 to below 1300 were adopted. The most frequent level ranged from 1050–1100. Looking at each variety, it was found that the most frequent levels of Stirling, Schooner and Alapiles were those of 1050–1100 (33%), 1100–1150 (30%) and 1050–1100 (44%), respectively. The average conversion power readings of Stirling, Schooner and Alapiles were 1029, 1116 and 1097, respectively (Table III).

2) Acidity distribution of whole grains. The acidity distribution of whole grains is shown in Fig. 5B. Five acidity classifications from below 4 to below 8 were adopted. Approximately 92% of the total samples lay within the pearling yield range of 4 mL to 7 mL. Looking at each variety, the average acidity values of Stirling, Schooner and Alapiles were 5.6 mL, 5.4 mL and 5.0 mL, respectively (Table III).

Table III. Pearling and fermentation characteristics of each variety.

Variety	Pearling yield* (%)	Broken kernel* (%)	Conversion power* (–)	Acidity* (mL)
Stirling	66.9 ± 3.21	5.30 ± 3.06	1029 ± 56	5.58 ± 0.91
Schooner	67.1 ± 7.37	5.54 ± 6.38	1116 ± 82	5.42 ± 0.71
Alapiles	65.7 ± 7.03	1.97 ± 1.36	1097 ± 49	4.95 ± 0.72
Total	66.9 ± 6.62	5.02 ± 5.47	1093 ± 82	5.39 ± 0.79

*Mean ± SD.

Table IV. Correlation coefficient for relationships between the whole grain physical characteristics and *shochu* characteristics.

	Hardness	Weight	Diameter
Pearling yield	0.63**	0.09	0.00
Broken kernel ratio	–0.45**	0.03	0.03
Acidity	0.08	–0.10	0.03
Conversion power	–0.56**	0.00	–0.16

** Significant at 1% level.

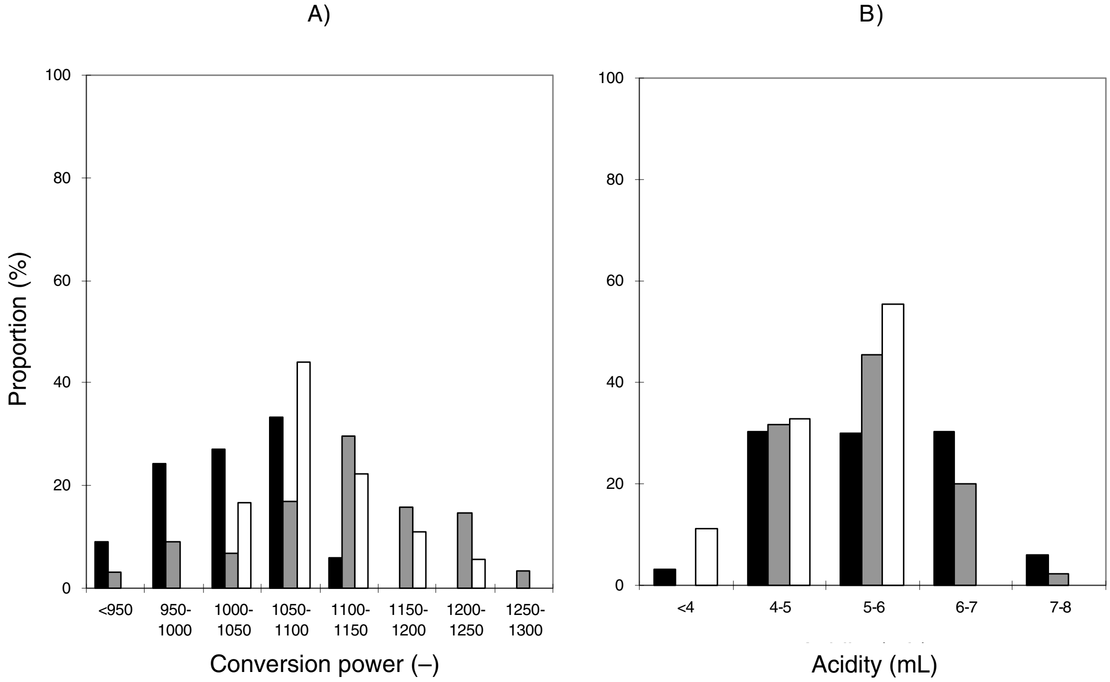

Fig. 5. Distribution of fermentation characteristics of whole grains in each variety. Stirling (■); Schooner (■); Alapiles (□). A) Conversion power, B) acidity.

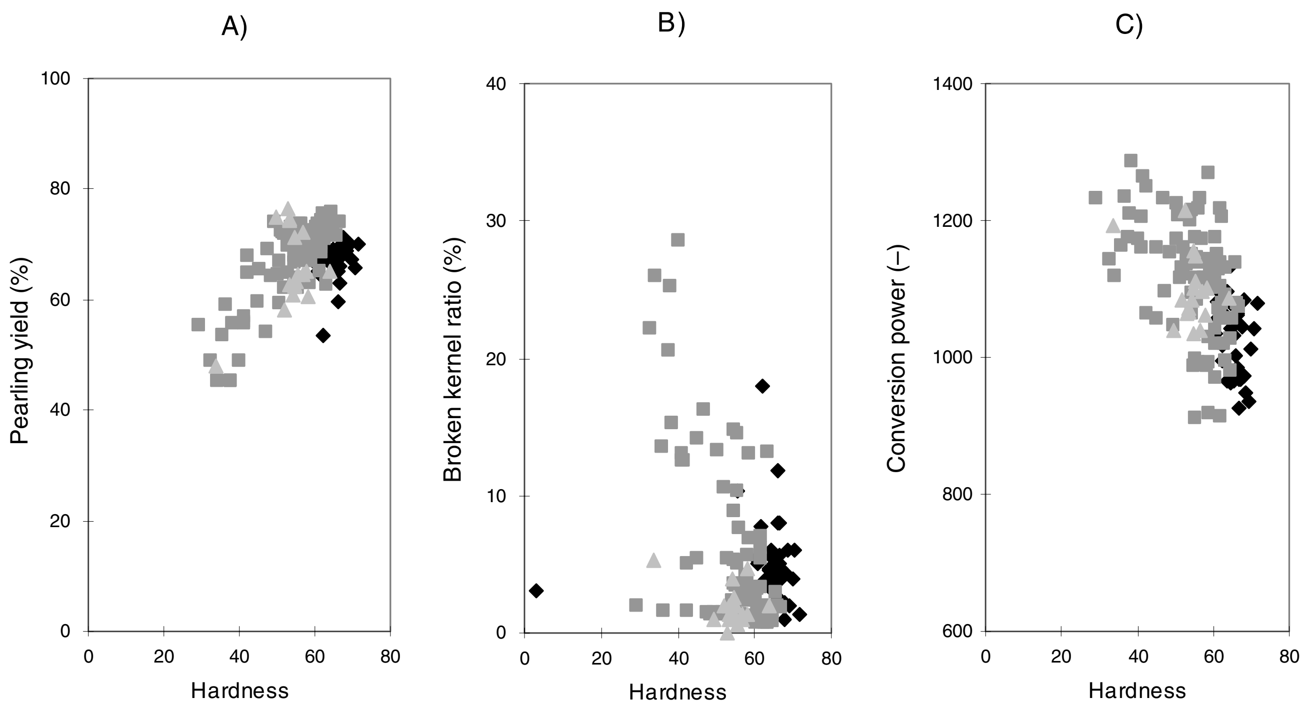

Fig. 6. Correlation between hardness and pearling/fermentation characteristics in each variety. Stirling (◆); Schooner (■); Alapiles (▲). A) Pearling yield, B) broken kernel, C) conversion power.

Correlation between the physical properties of whole grain and the pearling and fermentation characteristics

The coefficient of correlation between the physical properties of the whole grain and the pearling and fermentation characteristics are shown in Table IV. Comparisons among the physical property values, pearling yield and broken kernel ratio indicated a correlation with the hardness of the whole grain. A relatively high positive correlation was observed between the hardness of the whole grain and the pearling yield (Fig. 6A). Between the hardness of the whole grain and the broken kernel ratio, a negative correlation was observed (Fig. 6B). However, no correlation was found between the weight of whole grain, diameter of whole grain and pearling characteristics (Table IV).

Comparisons between the physical property values, the acidity from *koji* and conversion strength indicated a negative correlation between the hardness of the whole grain and the conversion strength (Fig. 6C). No correlation was observed with any other physical property. For acidity from *koji,* no correlation was observed with the physical properties.

DISCUSSION

Results presented revealed that the hardness of whole grain influences pearling and fermentation characteristics. In the samples studied the hardness characteristics were observed for each variety. Results suggest that although varietal characteristics are important in determining hardness, environmental factors are also important. Further work is required to assess the relationship between varietal and environmental factors on hardness and the relationship between hardness and fermentation properties of the pearled grain.

In the pearling industry, barley with a higher pearling yield and the relevant lower crushing rate is generally regarded as good material. The greater the hardness of normal barley, the greater the high-pearling yield and the resistance to crushing. Therefore, the results suggest that barley with higher hardness appears to be the more advantageous in regard to pearling performance.

On the other hand, in the manufacture of barley *shochu,* barley with a higher conversion strength of barley *koji* is considered to be the better material[4,5]. Therefore, the results suggested that barley with lower hardness seems to be the more advantageous in regard to fermentation performance. Namely, fermentation suitability appears to depend on the hardness of the unpolished barley. This difference in the conversion strength of *koji* due to hardness may influence *moromi* control, and the *shochu* quality itself.

The hardness of the whole grain showed a correlation with pearling and fermentation characteristics. Therefore, pearling yield, broken kernel ratio and conversion power trends of barley material may be used as one indicator to evaluate the characteristics of barley for *shochu.* In the selection of material that is suitable for *shochu,* the measurement of hardness using SKCS can be performed in a few minutes, allowing easy and rapid selection of many samples at one locality for the production of either *shochu* or pearled barley.

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