Differences in the Cooking Quality between Two Adzuki Varieties Harvested in Australia and Stored at Different Temperatures

Jun Kato*, Adel M Yousif**, Hilton C Deeth**, Masahisa M Suzuki***, Nola A Caffin** and Takashi Meguro*

The differences in the cooking quality of adzuki beans between two varieties 'Erimoshouzu' (leading variety in Japan) and 'Bloodwood' (leading variety in Australia), harvested in Australia and stored for 6 months at 10°C and 30°C, were investigated. The L* (lightness) and the b* (yellowness) values of the bean colour of 'Bloodwood' were a little higher than those of 'Erimoshouzu'. The b* values for the non-sugared Ann (bean paste) made from 'Bloodwood' were higher than those for 'Erimoshouzu'. The WIRB (weight increase ratio by boiling) was smaller for 'Bloodwood' than 'Erimoshouzu'. The mean particle size of Ann made from 'Bloodwood' was larger than that of Ann made from 'Erimoshouzu'. The sensory differences of Tsubu-ann (sugared bean paste containing whole beans) between varieties were significantly distinguished by the Japanese panel but not the Australian panel. Both Japanese and Australian panels detected significant sensory differences in the characteristics of Tsubu-ann made from 'Bloodwood' stored at different temperatures. The perceived colour of Tsubu-ann made from 'Bloodwood' was darker than that from 'Erimoshouzu'. There were few cross-cultural differences in perception of colour, smell, hardness and astringency. However, there were differences between the Japanese and Australians panellists in their preferences for the products. It was found that the bean quality of 'Bloodwood' was similar to that of 'Erimoshouzu'. However the cooking quality between these two varieties was different and that the sensory differences of Tsubu-ann made from 'Bloodwood' beans stored at different temperatures were larger than those from 'Erimoshouzu'.

key words : adzuki bean, variety, cookability, storage, sensory difference

INTRODUCTION

Cultivation of adzuki beans in Australia commenced in the early 1970 s. In 1980 s, the New South Wales Agriculture Department released 'Bloodwood' (Desborough 1980), which became the major variety in Australia for nearly 20 years. 'Bloodwood' was originally bred as 'Hikarishouzu' in Hokkaido. It is similar to 'Erimoshouzu', which is the leading variety for adzuki production and for commercial application in Japan, with respect to colour, size and appearance of the beans. The bean colour, bean size and cooked bean flavour of 'Erimoshouzu' are favoured by processors and consumers. Therefore, since the quality of 'Bloodwood' is quite similar to 'Erimoshouzu', traders and manufacturers in Japan prefer 'Bloodwood' to adzuki beans imported from China.

In Australia, adzuki beans are planted according to the demand and the prices of adzuki beans in the market principally according to those in Japan. The quality information of 'Bloodwood' compared with

* Hokkaido Central Agricultural Experiment Station
** School of Land and Food, The University of Queensland Gatton College, Australia
*** School of Mathematical and Physical Sciences, The University of Queensland, Australia

'Erimoshouzu' is important for Japanese traders and manufacturers. In this paper, the differences in the cooking quality between adzuki varieties 'Erimoshouzu' and 'Bloodwood', after storage for six months at different temperatures, are described.

MATERIALS AND METHODS

1. Storage Conditions

Two adzuki varieties, 'Erimoshouzu' and 'Bloodwood', harvested in Queensland, Australia in 1997, were used in the storage trial. Twenty kg batches of cleaned and size-graded beans in 40 L drums were stored in constant temperature rooms at 10±1°C and 30±1°C in the University of Queensland Gatton College. The humidity of the storage drums were maintained at 65±3%. Beans were withdrawn at 6 months and stored at −18°C for 5 months before the cooking for sensory tests was performed or they were sent to Japan by air for quality evaluation. The characteristics related to bean quality and cooking quality were investigated at Hokkaido Central Agricultural Experiment Station within a month of sending the samples to Japan.

2. Determination of Characteristics Related to Bean Quality

The moisture content of the beans was calculated by determining the loss of weight at 105°C for 24 h. The 100-beans weight was calculated by weighing 3 sets of 100 beans and indicated on a dry weight basis.

For measurement of the bean colour, beans were placed in glass cells of 30 mm diameter, with adjustment in the orientation of the beans to avoid reflection from the hila of the beans. CIELAB L*, a*, b* colour values of the bean were determined with a Tokyo Denshoku TC-1800 MK II Colour Analyser (Tokyo Denshoku Corporation, Tokyo, Japan) using a C 2 illuminating light source with the 2 degree eyesight mode. The bean colour of each sample was determined by taking the average readings of 20 different lots of beans from the same sample batch. Chroma (C*) was calculated by the following formula (1).

$$C^* = (a^{*2} + b^{*2})^{1/2} \quad (1)$$

3. Determination of Characteristics Related to Cooking Quality

The weight increase ratio by boiling (WIRB) of the beans was calculated by the following formula (2) after weighing the beans boiled at 98°C for 70 minutes using an autoclave.

$$\text{WIRB} = \text{weight of boiled beans/weight of dry basis} \quad (2)$$

Non-sugared Ann (non-sugared bean paste without the bean coat) was prepared using the same cooking conditions as the determination of WIRB. After boiling, the beans were crushed through a stainless steel sieve (0.5 mm aperture) using a wooden spoon to remove the bean coats and separate the Ann particles (cotyledon cells). The Ann particles were suspended in water, and the supernatant decanted 3 times with a large amount of water to remove the debris.

The average Ann particle size was measured by a laser diffraction particle size analyser (SALD-1100, Shimadzu, Tokyo, Japan).

For the measurement of the non-sugared Ann colour, Ann was filled in the glass cell of 30 mm diameter and CIELAB L*, a*, b* colour values were determined. The non-sugared Ann colour of each sample was determined by taking the average of the readings of 6 different lots of Ann from the same sample batch.

4. Preparation of Bean Paste (Tsubu-ann)

The Tsubu-ann (bean paste with sugar-infused whole beans), which was used for the sensory tests, was prepared in a traditional manner by a professional Japanese sweets maker in Australia. Four hundred grams of each sample was boiled in pots. After boiling, cool water was added to the pots to promote the softening of beans. The beans were reheated and the water was changed twice to reduce the astringency of beans. Four hundred grams of sugar was added to the pots when the beans became soft enough to be able to be crushed by fingers. Heating was continued until the viscosity of the Tsubu-ann increased to the desired level which the sweets maker determined by tasting. The final weights of the Tsubu-ann samples were adjusted that all samples had similar moisture contents. The

Table 1. Cooking conditions of adzuki beans stored for six months[A]

Variety	Storage Temp. (°C)	Boiling Time before Sugar Adding (hr : min)	Total Cooking Time (hr : min)	Final Weight (g)
Erimoshouzu	10	2 : 00	3 : 15	1,260
Erimoshouzu	30	3 : 00	4 : 30	1,280
Bloodwood	10	2 : 00	3 : 40	1,250
Bloodwood	30	3 : 00	4 : 50	1,270

[A] Initial weight of each sample was 400 g, and 400 g of sugar was added to each sample.

Table 2. Characteristics related to the quality of adzuki beans stored for six months[A]

Variety	Storage Temp. (°C)	Bean Moisture (%)	100-beans weight (g)	Bean Colour		
				L*	a*	b*
Erimoshouzu	10	11.8±0.1[a]	10.6±0.1[a]	26.3±0.5[a]	19.4±0.5[ab]	9.4±0.4[a]
Erimoshouzu	30	11.1±0.2[b]	10.5±0.1[a]	24.5±0.4[b]	19.1±0.3[a]	7.6±0.3[b]
Bloodwood	10	12.1±0.1[a]	10.6±0.1[a]	26.9±0.3[c]	19.6±0.4[b]	10.0±0.5[c]
Bloodwood	30	11.8±0.1[a]	10.4±0.2[a]	25.3±0.5[d]	19.1±0.5[a]	9.4±0.4[a]

[A] Data represent mean±SD, means which share no common following letters differ significantly at P=0.05.

cooking time and the final weights of the samples were recorded and are shown in Table 1.

5. Sensory Tests

Untrained Japanese people living in Australia and Australian students and staff from the Gold Coast College of Business served as panellists. The mean age of Japanese panellists was 46.5 years (n=20), and 75% of them were females. The mean age of the Australian panellists was 33.4 years (n=20), and 85 % of them were females. The sensory difference tests were evaluated using a modified triangle test (Gacula and Singh 1984). The first stage of the test involved identification of the odd sample. The second stage was a comparison of the colour, bean smell, hardness and astringency of the samples, as well as an indication of the preference for these samples. The samples of Tsubu-ann were served at room temperature.

The characteristics of Tsubu-ann were also evaluated by the professional Japanese sweets maker who prepared the Ann.

RESULTS AND CONCLUSION

1. Differences in the Bean Quality

The physical characteristics related to the bean property of 'Erimoshouzu' and 'Bloodwood' stored at 10°C and 30°C for 6 months are shown in Table 2. The moisture content of 'Erimoshouzu' stored at 30 °C was lower than that of other samples. However, the differences in moisture content between varieties were small. The differences in moisture content between the beans stored at different temperatures were also small, probably because the relative humidity (65%) was maintained constant during the storage. The 100-beans weight between varieties and between beans stored at different temperatures showed no differences.

The bean colour between varieties and between the beans stored at different temperatures showed significant differences. The L* (lightness) and b* (yellowness) values for the bean colour of 'Erimoshouzu' stored at 10°C were a little lower than those of 'Bloodwood' stored at the same temperature. However, they were much higher than those of beans stored at 30°C. The differences in the a* (redness) values between varieties and between beans stored at different temperatures were small. On representation of the bean colour using two-dimensional colour mapping (Kato and Meguro 1998), it was found that the differences between the colour of beans stored at different temperatures were larger than the differences between varieties, and that the colour had shifted dark by storing at higher temperature (Fig. 1).

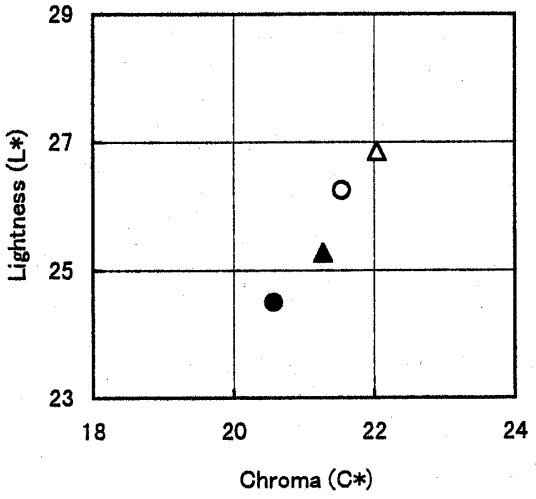

Fig. 1. Two-dimentional colour mapping of adzuki varieties: Erimosyouzu' (stored at 10°C, ○ and 30°C , ●) and 'Bloodwood' (stored at 10°C, △ and 30°C, ▲) for six months

2. Differences in the Cooking Quality

It has been reported that the characteristics of adzuki beans such as bean colour, bean size and cookability are different between the varieties (Kato et al. 1992), and the effects of storage on cookability are also different between the varieties (Hatai 1982). The WIRB, the mean Ann particle size and the non-sugared Ann colour of 'Erimoshouzu' and 'Bloodwood' stored at 10°C and 30°C for 6 months are shown in Table 3.

The WIRB of 'Erimoshouzu' stored at 10°C was larger than that of 'Bloodwood' stored at the same temperature. The WIRB of beans stored at 30°C was smaller than those of beans stored at 10°C for both varieties, although the differences in moisture content between the beans stored at different temperatures were small. This means that the cookability of adzuki beans decreases after storage at high temperature. This is also reflected in the different cooking times of these beans. The cooking time of 'Erimoshouzu' stored at 10°C, which had the largest WIRB, was the shortest, while the cooking time was longest for 'Bloodwood' stored at 30°C, which had the smallest WIRB. WIRB is an important characteristics of beans which is related to the cookability, and is also positively correlated ($r=0.93$) with the yield of Ann (Kato et al. 1996). Kato and Meguro (1997) reported that WIRB of adzuki beans decreased greatly after storage at 30°C, and the decrease was larger than that of common beans. Generally, the 'Hard-To-Cook' (HTC) phenomenon occurs when beans are stored at high temperature (Jones and Boulter 1983; Moscoso et al. 1984; Aguilera and Rivera 1992; Liu et al. 1992). Our results suggest that the effect of temperature on the HTC phenomenon was larger for 'Bloodwood' than for 'Erimoshouzu'.

There is a positive correlation ($r=0.92$) between the 100-beans weight and mean Ann particle size among Japanese adzuki beans (Kato et al. 1994). The mean Ann particle size of 'Bloodwood' was larger than that of 'Erimoshouzu', but no difference was observed on the 100-beans weight between these varieties. These results do not agree with the previous report. It suggests that the size of cotyledon cells for 'Bloodwood' is larger than that for 'Erimoshouzu'. The differences in genetic background or growing conditions, such as planting and harvesting time, temperature of maturing period and the system of irrigation, may affect the development of

Table 3. Characteristics related to the cooking quality of adzuki beans stored for six months[A]

Variety	Storage Temp. (°C)	WIRB[B]	Ann particle Size (μm)	Non-sugared Ann colour		
				L*	a*	b*
Erimoshouzu	10	3.02±0.01[a]	98.6±0.6[a]	41.6±0.1[a]	7.4±0.1[a]	5.6±0.1[a]
Erimoshouzu	30	2.73±0.11[b]	98.7±0.7[a]	40.3±0.1[b]	7.1±0.1[b]	7.3±0.1[b]
Bloodwood	10	2.84±0.01[b]	103.7±0.2[b]	41.6±0.1[a]	7.5±0.1[a]	7.4±0.1[b]
Bloodwood	30	2.48±0.03[c]	104.3±0.8[b]	40.1±0.1[b]	7.7±0.1[c]	8.4±0.1[c]

[A] Data represent mean±SD, means which share no common following letters differ significantly at $P=0.05$.

[B] WIRB, Weight Increase Ratio by Boiling.

cotyledon cells.

The mouthfeel of Koshi-ann (smooth bean paste without the bean coat) becomes smoother when the mean particle size of Ann is smaller, and 5μm difference in the mean particle size is detectable by the human palate (Kato et al. 1994). Thus the Koshi-ann made from 'Erimoshouzu' would be expected to have a smoother mouthfeel than that made from 'Bloodwood', because the mean Ann particle size of 'Erimoshouzu' was about 5μm smaller than that of 'Bloodwood'.

There were no differences between the L* values for the non-sugared Ann colour of 'Erimoshouzu' and 'Bloodwood' stored at the same temperature, but they decreased during storage at 30°C. There were no differences between the a* values for the non-sugared Ann of 'Erimoshouzu' and 'Bloodwood' stored at 10°C. The b* value for the non-sugared Ann colour of 'Erimoshouzu' stored at 10°C was the lowest, and that of 'Bloodwood' stored at 30°C was the highest. The b* values for the non-sugared Ann of both varieties increased considerably by storing at 30°C. Hatai (1989) also reported that the brightness of non-sugared Ann colour decreased and the yellowness increased by storing adzuki beans at high temperature. Generally, the purplish Ann colour is favoured by Japanese consumers. Ann with high b* value is brownish and this colour is not favoured. In this respect, the Ann colour of 'Erimoshouzu' is considered to be better than that of 'Bloodwood', and the Ann colour of beans stored at 10°C is considered to be better than that of beans stored at 30°C.

It was found that the bean physical quality of 'Bloodwood' was similar to that of 'Erimoshouzu', but the cooking quality between these two varieties was different.

3. Sensory Distinction of Tsubu-ann

Sensory tests of Tsubu-ann made from the beans of different varieties and stored at different temperatures were performed in order to investigate the effects of bean quality on the cooking quality of their sweetened products. Usually, Japanese processors adjust the cooking conditions during Ann manufacture according to the characteristics of beans. Therefore, in this study, the cooking time of each bean sample was adjusted individually (Table 1). The cooking time of 'Erimoshouzu' stored at 10°C was the shortest, and that of 'Bloodwood' stored at 30°C was the longest. The cooking times of 'Bloodwood' were longer than those of 'Erimoshouzu' stored at the same temperatures. The cooking times of beans stored at 30°C were about 1 hour longer than those of beans stored at 10°C with both varieties. The beans stored at 30°C needed further boiling to make them soft enough for Tsubu-ann comparing to those stored at 10°C.

Table 4 shows the results of sensory tests of Tsubu-ann obtained by the Japanese and Australian panels. The sensory differences between varieties were distinguished significantly ($P<0.05$) by the Japanese panel, but were not differentiated by the Australian panel. The sensory difference between Tsubu-ann made from 'Bloodwood' stored at 10°C and 30°C was differentiated significantly by both the Japanese ($P<0.01$) and Australian ($P<0.05$) panels. However, the sensory difference between Tsubu-ann made from 'Erimoshouzu' stored at different temperatures was not differentiated by either panel. It was found that the sensory

Table 4. Sensory distinction between the bean paste (Tsubu-ann) made from adzuki beans stored for six months[A]

Comparison pair	Japanese panel (n=20)		Australian panel (n=20)	
	Correct (%)	Probability	Correct (%)	Probability
Erimoshouzu 10°C : Bloodwood 10°C	60	*	40	NS
Erimoshouzu 30°C : Bloodwood 30°C	60	*	35	NS
Erimoshouzu 10°C : 30°C	45	NS	40	NS
Bloodwood 10°C : 30°C	80	* *	55	*

[A] Sensory tests were performed by modified triangle tests.
*$P<0.05$; **$P<0.01$; NS, not significant.

differences of Tsubu-ann made from 'Bloodwood' stored at different temperatures were larger than those of Tsubu-ann made from 'Erimoshouzu' stored at different temperatures.

The probability for distinction between different samples of Tsubu-ann was higher with the Japanese than the Australians. This may be related to cross-cultural food differences as all the Japanese panellists had experienced eating Ann products more than 10 times, but all the Australian panellists had experienced eating them less than 5 times.

4. Sensory Differences in the Characteristics of Tsubu-ann

For the next stage of the sensory tests, the characteristics of Tsubu-ann were compared, using only the data from the panellists who could distinguish correctly between the samples at the first stage. The results of the comparison of colour, bean smell, hardness, astringency and preference between Tsubu-ann made from different varieties are shown in Fig. 2, and those between Tsubu-ann made from the beans stored at different temperatures are shown in Fig. 3.

The colour of Tsubu-ann made from 'Bloodwood' was perceived to be darker than that of 'Erimoshouzu' by more than 50% of both the Japanese and Australians panellists (Fig. 2). The colour of Tsubu-ann made from beans stored at 30°C was evaluated as darker than that of Tsubu-ann made from beans stored at 10°C by the Japanese and Australians for both varieties (Fig. 3).

The colour of sugared Ann is correlated with that of non-sugared Ann (Kato et al. 1992). The non-sugared Ann colour of 'Bloodwood' had high b* values and was brownish. The non-sugared Ann colour of beans stored at high temperature had low L* values and high b* values. Therefore, the colour of Tsubu-ann made from these beans was evaluated as dark, even though the cooking times of the bean samples were varied. The professional sweets maker who prepared the Ann gave her opinion that the colour of Tsubu-ann made from 'Erimoshouzu'

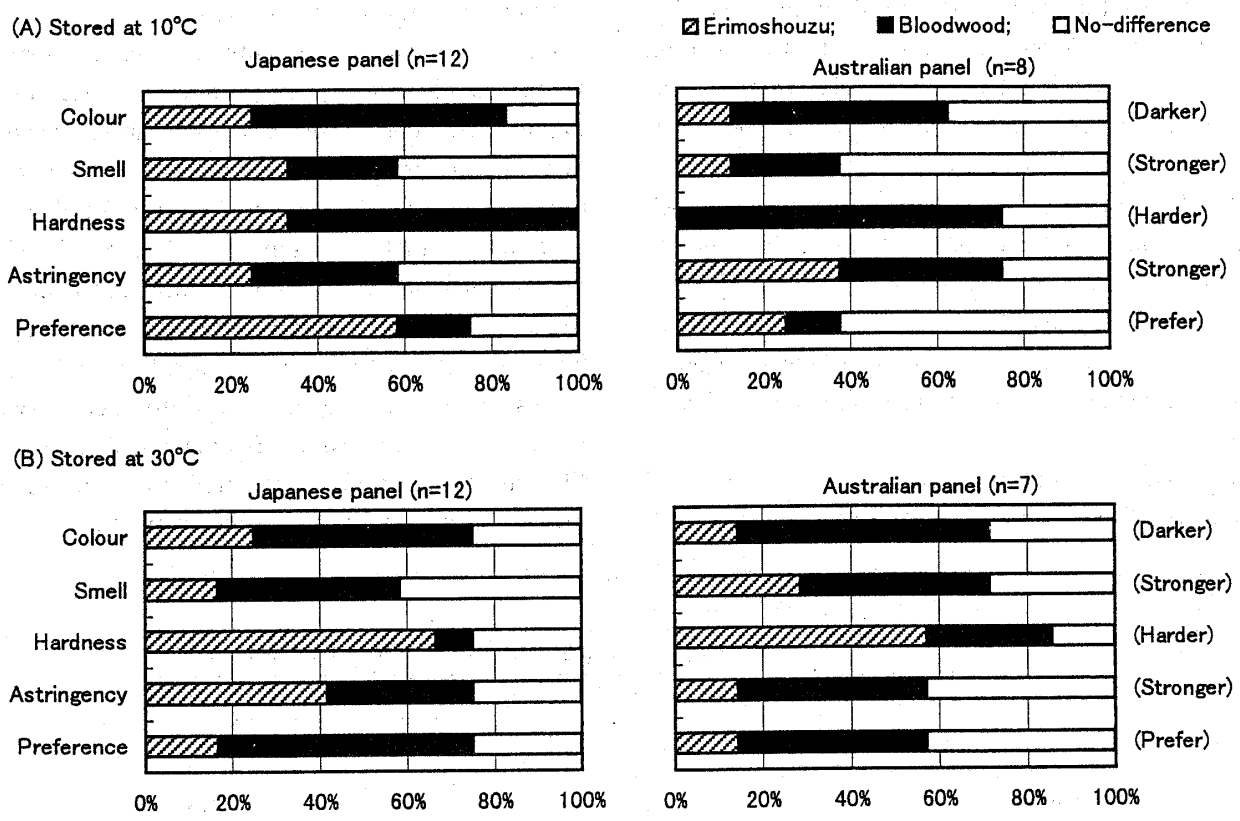

Fig. 2. Sensory differences in the characteristics between the bean pastes (Tsubu-ann) made from different varieties stored at 10°C (A) and 30°C (B) for six months.
Only the results of panellists who crrectly distinguished samples in the triangle tests are included.

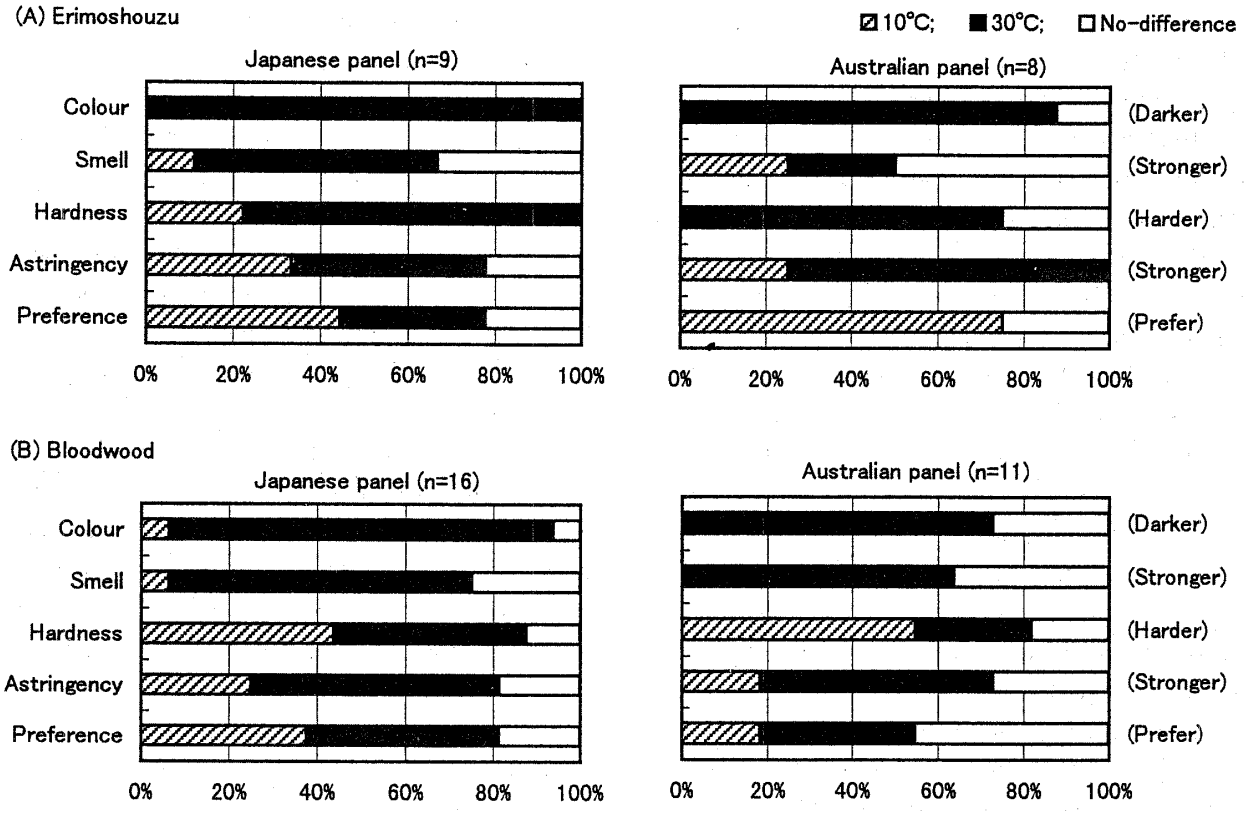

Fig. 3. Sensory differences in the characteristics between the bean pastes (Tsubu-ann) made from Erimoshouzu (A) and Bloodwood (B) stored at different temperatures for six months.
Only the results of panellists who crrectly distinguished samples in the triangle tests are included.

as purplish, and that of 'Bloodwood' as red-brownish. It was considered that the colour differences on Tsubu-ann were derived from the differences between varieties and storage temperatures of the original beans. Taira et al. (1989) also reported that sensory differences were observed between the colours of Ann made from different varieties. The colour is considered to be one of the important factors to distinguish between different Tsubu-ann samples.

The hardness of Tsubu-ann made from 'Bloodwood' was evaluated as greater than that of 'Erimoshouzu' by about 70% of both panels when the beans were stored at 10°C (Fig. 2). Tsubu-ann made from beans stored at 30°C was harder than that of beans stored at 10°C by more than 70% of both panellists with 'Erimoshouzu' (Fig. 3). Kasai et al. (1989) reported that the hardness was the most important characteristic for evaluating the quality of boiled seasoned soy beans, and was also considered to be one of important factors determining the quality of Tsubu-ann, although the hardness of sweetened adzuki products is able to be controlled to some extent by adjusting the cooking conditions.

No difference was observed in the bean smell between the varieties, and about half of both panels indicated 'no difference' when the beans were stored at 10°C (Fig. 2). However, the bean smell of Tsubu-ann made from beans stored at 30°C was shown as stronger than that of Tsubu-ann made from beans stored at 10°C by more than 50% of the Japanese panellists with 'Erimoshouzu', and more than 50% of both the Japanese and Australians with 'Bloodwood' (Fig. 3).

No difference was observed between the astringency of the Tsubu-ann made from these two varieties (Fig. 2). The astringency of Tsubu-ann made from beans stored at 30°C was perceived to be stronger than that of beans stored at 10°C by more than 70% of Australian panellists with 'Erimoshouzu,' and more than 50% of both panellists with 'Bloodwood' (Fig. 3).

The bean smell and the astringency of Tsubu-ann made from beans stored at 30°C tended to be stronger than those of Tsubu-ann made from beans stored at 10°C, but no difference was observed between the varieties. However, the professional sweets maker who prepared these Ann gave her opinion that the smell of Tsubu-ann made from 'Erimoshouzu' to be better than that of 'Bloodwood', and observed that the astringency of Tsubu-ann made from 'Bloodwood' remained in the aftertaste. These results suggest that there are differences between varieties in smell and astringency. Tokitomo and Kobayashi (1988) reported that there were differences between the varieties in the smell of boiled adzuki beans. Astringency of adzuki beans is related to tannin which polymerizes and becomes hard to extract from beans which are stored for a long time or in unfavourable conditions (Sievwright et al. 1986; Stanley 1992). Japanese Ann processors reduce the astringency of beans by changing the boiling water several times according to the quality of beans.

From the preference indications, about 60% of the Japanese panellists preferred 'Erimoshouzu' when the beans were stored at 10°C, but the Australian panellists indicated no difference in preference between varieties (Fig. 2). More than 70% of Australian panellists preferred the Tsubu-ann made from beans stored at 10°C with 'Erimoshouzu', but no difference was observed for the preference between Tsubu-ann made from beans stored at different temperatures among the Japanese panellists (Fig. 3).

The sensory differences of Tsubu-ann between varieties were distinguished significantly by the Japanese, but were not significantly by the Australians. However, the characteristics of Tsubu-ann such as colour and hardness were evaluated similarly both by Japanese and Australians. Prescott et al. (1997, 1998) reported that there were no cross-cultural differences between Japanese and Australians in their perception of the sensory intensity for sweetness, sourness, saltiness and bitterness of general foods. However, the liking for sweetness levels was different between Japanese and Australians, and was dependent on the context of the product and familiarity with the product (Laing et al. 1994).

It was concluded that the bean quality of 'Bloodwood' was similar to that of 'Erimoshouzu'. However, the cooking quality between these two varieties was different, and that the sensory differences of Tsubu-ann made from 'Bloodwood' beans stored at different temperatures were larger than those from 'Erimoshouzu'.

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異なる温度で貯蔵されたオーストラリア産アズキ2品種の調理特性の差異

加藤　淳*,　Adel Yousif**,　Hilton Deeth**,
鈴木雅久***,　Nola Caffin**,　目黒孝司*

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オーストラリアで収穫され，10°Cおよび30°Cで6ケ月間貯蔵されたアズキ2品種「エリモショウズ」（日本主要品種）および「Bloodwood」（オーストラリア主要品種）の調理特性の差異について検討した。種皮色のL*値（明度）とb*値（黄味度）は「エリモショウズ」よりも「Bloodwood」でやや高かった。生アンのb*値は「エリモショウズ」よりも「Bloodwood」で高かった。WIRB（煮熟増加比）は「エリモショウズ」に比べ「Bloodwood」で低かった。平均アン粒径は「エリモショウズ」よりも「Bloodwood」で大きかった。品種間の官能的差異については，日本人パネルにのみ

* 北海道立中央農業試験場
** クイーンズランド大学ガトン校，オーストラリア
*** クイーンズランド大学，オーストラリア（現　電気通信大学）

有意に識別された。貯蔵温度の異なる「Bloodwood」より作られたつぶアンの食味については，日本人およびオーストラリア人パネル共に有意差が認められた。つぶアンの色に関しては，「エリモショウズ」に比べ「Bloodwood」は暗いと評価された。つぶアンの色，香り，硬さ，渋味の知覚に関しては，日本人とオーストラリア人パネルの間に差は認められなかったが，嗜好に関しては両者間で差異が認められた。「エリモショウズ」と「Bloodwood」の外観品質は類似していたが，両者の調理特性は異なっていることが判明した。また，貯蔵温度の異なるアズキより作られたつぶアンの食味に関しては，「エリモショウズ」よりも「Bloodwood」で大きな差異が認められた。

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