

Cultivar differences in New Zealand “Kabocha” (buttercup squash, *Cucurbita maxima*)

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Abstract This research investigates the sensory and compositional differences of six cultivars of buttercup squash (*Cucurbita maxima*)—‘Ajihei’, ‘Delica’, ‘Emiguri’, ‘Kofuki’, ‘Miyako’, and ‘T133’—using a combination of sensory analysis and physical measurements of viscosity and colour (Minolta Chromameter (CR 200) recording L*, a*, b* values) and biochemical measurements of glucose, fructose, maltose, sucrose, starch, and dry matter (DM) content. The results obtained clearly indicate significant differences in all sensory attributes except for sweetness, nutty flavour, and fibres. Similarly all physical properties and chemical measurements except for starch content are significantly different. A principal component analysis of the sensory data shows that the textural attributes are the main source of cultivar differences for these cultivars. DM and starch content are significantly correlated with the principal sensory dimension indicating its importance in influencing most of the sensory properties. The lack of correlation of sugars, and the significant correlation of textural properties with perceived sweetness suggests the influence of squash texture and cell wall properties modifying the perception of sweetness and flavour. Overall ‘Emiguri’ and ‘Delica’ are the most similar squash cultivars. ‘Kofuki’, the most dry

and crumbly cultivar, is different from these two cultivars.

Keywords buttercup squash; *Cucurbita maxima*; Kabocha, sensory; sugars; starch; dry matter; colour; viscosity; texture; flavour; sweetness

INTRODUCTION

New Zealand “Kabocha” (buttercup squash, *Cucurbita maxima*, Kabocha in Japanese) is a dominant player in the Japanese market with a market share amounting to 61% by volume of the total squash imports (Anon. 2000). Many studies have been conducted to understand the intricacies of this important New Zealand crop, to increase exports and maximise financial returns. A number of studies have contributed to our understanding of the quality of New Zealand squash. These studies have been directed at the effects of plant densities on yield and fruit size (Douglas et al. 1990); the factors influencing the occurrence of storage rots (Hawthorne 1990); comparison of the incidence of storage rots among cultivars (Hurst et al. 1995); the changes in composition and sensory properties during fruit development and storage (Harvey et al. 1997); carbohydrate metabolising enzymes at different stages of growth (Irving et al. 1997, 1999); the effects of storage and cooking on texture (Ratnayake et al. 1999); the factors contributing to perceived sweetness (Corrigan et al. 2000); the mechanism of starch degradation (Irving et al. 1999); and the effect of postharvest heat treatment (Bycroft et al. 1999).

Several cultivars with quality characteristics that match the needs of the overseas markets have been developed. Apart from evaluating the yield, maturity, and storage of these new cultivars, investigation of the differences in sensory properties is also important to estimate the economic benefits. Descriptive sensory analysis, which involves the selection and training of human subjects to accurately and consistently provide a sensory description of

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products by assessing the intensities of a series of sensory attributes, allows us to quantify sensory differences between cultivars and is also useful in validating results obtained from instrumental and chemical analyses.

The following work was conducted with the objective of developing an approach for comparing cultivars to increase our knowledge and understanding of the sensory differences, and their relationship to chemical and physical differences of squash cultivars. The sugar, starch, dry matter (DM) content, CIELAB parameters, and viscosity measurements of these cultivars have been quantified and correlated with sensory properties.

MATERIALS AND METHODS

Plant material

The six squash cultivars ('Delica', 'Emiguri', 'Miyako', 'Ajihei', 'Kofuki', 'T133') for this research were grown in two replicate field plots at Crop & Food Research's Pukekohe site near

Auckland, New Zealand. The seed was sown on 15 November 1999, with crop spacing of 800 mm between plants and 3 m between rows. Fruit were harvested on 7 March 2000, when considered to be commercially mature by the amount of brown corky material on the stalk (King & Wishart 1990). They were packed into 75-litre vented produce crates and transported within 24 h to the Crop & Food Research site in Palmerston North where they were stored in a temperature-controlled room at $12 \pm 1^\circ\text{C}$. Fruit from Field plot 1 were held for 4 weeks and fruit from Field plot 2 for 5 weeks to manage the scheduling of sensory panels. They were then assessed by the sensory panellists and sampled for chemical and viscometric analysis. Colour measurements were done after 6 weeks of storage.

Sensory evaluation

Sample selection and preparation

To replicate the sensory assessment, six rot-free fruit per cultivar (3 fruit/field plot) were selected from storage and tagged 1 day before the start of the sensory evaluation. The plots were evaluated

Table 1 Definitions of the sensory attributes evaluated in cooked squash (*Cucurbita maxima*).

Attribute	Definition
Orange colour	Mid scale = colour of carrot 1, Light; 7, Dark
Cutting behaviour	Judge this while removing the skin from the sample. Does the skin cut cleanly away, or does the squash flesh crumble? 1, Cuts cleanly; 7, Crumbles when cut
Squash flavour	Intensity of characteristic squash flavour in the sample 1, No flavour; 7, Full flavour
Sweetness	Intensity of sweetness in the sample 1, Not sweet; 7, Very sweet
Buttery flavour	Intensity of buttery flavour in the sample 1, None; 7, Strong
Nutty flavour	Intensity of nutty flavour (as in roasted chestnuts) in the sample 1, None; 7, Strong
Hardness (initial bite)	Force required to compress a 1 cm slice of sample against the roof of your mouth with your tongue 1, Soft; 7, Hard
Crumbliness (initial 3–4 chews)	In the initial 3–4 chews does the sample crumble apart or stay together? 1, Not crumbly; 7, Very crumbly
Moistness (during chewing)	While chewing the sample does it feel moist in your mouth, or does it have a mouth drying effect? 1, Dry; 7, Moist
Mouthfeel (before swallowing)	During chewing does the sample remain as separate particles in your mouth, or does it form a smooth paste? 1, Discrete lumpy particles; 7, Smooth paste
Fibres (before swallowing)	Presence of detectable fibres in the sample 1, None; 7, Lots

separately over a period of 3 consecutive days on 2 consecutive weeks. Six fruit, one per cultivar, were evaluated each day with panellists evaluating one piece each from each fruit. The fruit were prepared by cutting one squash fruit per cultivar into stalk to calyx segments 25 mm across at the widest point, with the use of a Bosch electric multisaw with a 100 mm blade. The placenta and seed were removed, and the segments trimmed by hand to a uniform length of 40 mm, width of 20 mm, and depth of 15 mm and cooked by steaming as described by Corrigan et al. (2000).

Panel training

A group of 13 panellists attended five training sessions lasting 1½ h each. On the first day, the panellists were briefed on the protocols for sensory evaluation. This was followed by group discussions directed by the panel leader to identify the attributes to be tested and define the scale end descriptors. The refinement of the score sheet and definitions continued until the panellists were satisfied with the score sheet and understood each term completely. Three to four samples were rated at each training session and results compared and discussed until panel agreement was reached using the rating scale. The panellists were trained to evaluate 11 sensory attributes in cooked squash. The definitions of these attributes are given in Table 1.

Different three-digit random code numbers were used to label the samples at each session. Samples were served 5 min after cooking and were evaluated in individual booths under white light. The order of sample presentation was based on a Williams Latin square design (Macfie et al. 1989). Reverse osmosis water was provided to cleanse the palate between samples.

Chemical analyses

Samples for chemical analyses were taken from the same fruit used for sensory evaluation. Mesocarp tissue free of seeds, placenta, and skin was taken from two stalk-to-calyx segments on opposite sides of each fruit, avoiding the ground spot. These two samples were finely chopped, combined, weighed, frozen, freeze-dried, and weighed again. They were then ground in a coffee grinder to a fine powder and stored at -20°C.

Dry matter

Percentage DM was determined as described by Hurst et al. (1995) on the sample taken as described above.

Starch analysis

Carotenoids were extracted from 100 mg of freeze-dried and ground squash sample with 5 ml of methanol:chloroform:water (MCW 12:5:3 v/v/v, Hurst et al. 1995) for 10 min at room temperature, vortexing every 3 min. The mixture was then centrifuged at 3000 rpm at room temperature for 5 min in a bench centrifuge and the supernatant was discarded. This process was repeated 5 times until the pellet was white. The remaining chloroform was rinsed out by adding 5 ml methanol, vortexing, centrifuging as above, and discarding the supernatant. The pellets were stored at -20°C until required for starch analysis.

The frozen pellets were thawed and dried in a speed evaporator (Speed Vac® Plus) for 25 min. The pellets were resuspended in 0.5 ml 8M HCl and 2 ml dimethylsulfoxide and heated at 60°C for 1 h, vortexing every 10–15 min. After heating the tubes were cooled on ice and neutralised with 0.5 ml of 8M NaOH. The sample was then made up to 10 ml with 0.112M sodium citrate buffer (pH 4.0), and clarified by centrifuging at 2600 rpm for 5 min. The supernatant was transferred to a clean tube and diluted 10-fold with citrate buffer before being enzymatically analysed in duplicate for total starch with starch UV-method kits (Boehringer Mannheim Biochemicals Catalogue 1998).

Sugar extraction and analysis

10 mg samples of freeze-dried ground squash were extracted in 1 ml of 62.5% methanol for 60 min at 55°C, vortexing every 15 min. The mixture was cooled and centrifuged at 2600 rpm for 3 min. The supernatant was recovered into 1 ml vials for High Performance Liquid Chromatography (HPLC) analysis. This analysis was done as described by Lewthwaite et al. (1997). Recognition of each sugar was based on HPLC retention time. Detector response to all sugars was linear over the concentration range 0–20% (w/v). Standard sugars showed less than 2% variability in individual sugar concentrations between triplicate injections of the same sample. The raw squash samples were analysed for sugars as previous work has indicated no significant differences in the sugar content of cooked and raw squash (Corrigan & Sutton 1998, pers. comm.).

Viscosity measurements

Duplicate samples were taken from the freeze-dried ground samples of the fruit used for sensory evaluation. These samples were further ground in a

coffee grinder and put through a 300 μm sieve. The moisture content of these samples was determined, and sufficient distilled water was added to reconstitute them to their fresh weight equivalent.

A Paar Physica UDS 200 Universal Dynamic Spectrometer equipped with precise temperature control was used to measure viscosity using a 25 mm diam. cone-plate (K21) with a 1 degree slope and a 0.05 mm truncated tip. Samples were placed between the cone and plate, and the gap between these two reduced to 0.05 mm to spread the sample evenly around the measuring area. Excess sample spreading 0.5 mm beyond the radius of the cone was removed, and 1–2 drops of olive oil were applied to the sample edge to prevent excess water loss during testing. After the sample was loaded, it was heated to 50°C for 2 min before testing to allow a consistent starting temperature. The test was done in two phases. In the first phase, a constant shear rate of 0.5 s^{-1} was used and the sample temperature was increased at 2.5°C/min from 55.3 to 70.3°C. Shear stress and viscosity as a function of temperature were recorded. Peak viscosity for each sample was obtained from this phase. In the next phase, the shear rate was increased linearly from 0.1 to 10 s^{-1} over 50 s at a constant temperature of 50.3°C and viscosities (1–3) at three shear rates (0.5, 1.0, 5.0 s^{-1}) were measured.

Instrumental colour measurements

The flesh colour (L^* , a^* , b^*) of six fruit (different from those fruit used for sensory, chemical, and viscometric analysis) from each cultivar (3/field plot) was measured using a Minolta Chromameter (CR 200) as described by Bycroft et al. (1999). Two slices from diagonally opposite sides of each fruit were measured.

Statistical analysis

Genstat 5 release 4.2 for Windows (Genstat 5 Committee 1995) was used for statistical analysis. REML (Residual Maximum Likelihood/Restricted Maximum Likelihood) was used to analyse the sensory data as some panellists missed some sessions which resulted in an unbalanced data set. Cultivar was a fixed effect, and the random effects were panellist, and fruit within session within day within field plot. When a random effect was negative and caused difficulty in getting the REML algorithm to converge it was removed from the model.

Analysis of variance was performed on the chemical and physical data. A principal component analysis (PCA) was done on the sensory data (panel

means per cultivar) and the chemical and physical measurements were then correlated with the first and second principal components (PCs). Sugar data were transformed using a natural log transformation for glucose, a square root transformation for fructose and a squared transformation for sucrose to achieve constant variance. Because of the differing variances in maltose values between cultivars (which were not related to the means), a Kruskal-Wallis one-way analysis of variance was done to compare maltose levels in the cultivars. Regression analysis was used to assess the contributions of DM and starch to viscosity.

RESULTS

Sensory evaluation

Average attribute scores obtained from sensory evaluation are listed in Table 2. These indicate significant differences between cultivars for all attributes except for sweetness, fibres, and nutty flavour.

The sensory panel scores show significant differences ($P < 0.001$) in the orange colour of cooked squash cultivars, with 'Kofuki' rated as lighter orange in comparison to 'Delica', 'Miyako', 'Emiguri', and 'Ajihei'. 'T133' is in between these two groups. 'Kofuki' was rated as significantly different ($P < 0.001$) in cutting behaviour to 'Delica', 'Emiguri', and 'Miyako'.

Squash flavour of 'Kofuki' was significantly ($P < 0.01$) lower than all other cultivars except 'Ajihei'. The differences in sweetness between cultivars were not significant. Differences in buttery flavour were significant ($P < 0.05$) with 'Kofuki' being the least buttery and 'Delica' and 'Emiguri' the most.

'Delica' and 'Emiguri' are significantly different from 'Kofuki' and 'Ajihei' in sensory hardness, crumbliness, and moistness.

To reduce the complexity of understanding the interrelationship of these 11 sensory attributes and their relationship with the cultivars, a PCA was done. The loading and scores of the first two PCs were plotted against each other as shown in Fig. 1.

The first two PCs explain 98.4% of the variance. The first PC separates 'Kofuki' from 'Delica' and 'Emiguri', with the remaining cultivars in the middle. This component is positively associated with hardness, crumbliness, and cutting behaviour and negatively associated with mouthfeel, moistness, colour, and squash flavour. The second PC explains further variation in colour of these cultivars.

This plot also indicates the correlation of attributes. Cutting behaviour is positively correlated with crumbliness and hardness ($r = 0.908$, $P < 0.001$; $r = 0.865$, $P < 0.001$ respectively) and negatively correlated with moistness ($r = -0.882$, $P < 0.001$). Crumbliness is positively correlated with hardness ($r = 0.919$, $P < 0.001$) and negatively correlated with moistness ($r = -0.932$, $P < 0.001$) and mouthfeel ($r = -0.944$, $P < 0.001$). Squash flavour is positively correlated with sweetness ($r = 0.708$, $P < 0.001$), butteriness ($r = 0.584$, $P < 0.01$), and moistness ($r = 0.735$, $P < 0.001$). The flavour attributes all have low loadings on the first PC, whereas the textural attributes (except for fibres) have large positive or negative loadings. This indicates that the textural attributes are the main source of cultivar differences for these cultivars.

Physical and chemical measurements

The results of chemical analysis, viscosity measurements, and CIELAB coordinates are listed in Tables 3, 4, and 5 respectively.

Sugar, starch, and DM analyses

The differences in glucose, fructose, and sucrose among these squash cultivars are highly significant ($P < 0.001$, $P < 0.002$, and $P < 0.005$ respectively). The ratio of glucose to fructose in 'Delica', 'Emiguri', 'Kofuki', and 'T133' is close to 1:1. Corrigan et al. (2000) reported similar findings in other cultivars including 'Delica'. 'Kofuki' and 'T133' are significantly lower in glucose and

fructose and higher in sucrose than 'Delica' and 'Emiguri'. The levels of maltose found are low for all cultivars. 'Delica' is significantly lower in DM than 'Kofuki', 'Ajihei', and 'T133' ($P < 0.029$). There are no significant differences in starch content between cultivars.

Viscosity

'T133' had a significantly higher viscosity than 'Delica', 'Emiguri', and 'Miyako' for all four viscosity measurements (Table 4). This may be because of a result of differences in DM content between 'T133' and the other cultivars. The temperatures corresponding to the measured peak viscosity for the different cultivars were in the range of 64.5–66°C. All samples showed a shear thinning behaviour with viscosity decreasing as shear rate increased from 0.5 to 5 s⁻¹.

Colour measurements

The L* values indicate 'Delica' and 'Miyako' have a darker flesh than 'Kofuki'. Redness, measured by a* values, is significantly lower for 'Kofuki' in comparison to all the other cultivars. 'Emiguri' and 'Kofuki' are significantly higher in b*(yellowness) value than 'T133', 'Delica', and 'Miyako' (Table 5).

Correlation of physical and chemical measurements with sensory scores

Physical and chemical measurements were correlated with sensory data to identify and evaluate factors that are related to sensory perceptions, and

Table 2 Average scores of sensory attributes for the six squash (*Cucurbita maxima*) cultivars. (All scores input on a 7-point scale, refer to Table 1 for end descriptors. NS, not significant; d.f., degrees of freedom; LSD, least significant difference.)

Attributes	Ajihei	Delica	Emiguri	Kofuki	Miyako	T133	d.f.	LSD	P values
Appearance									
Orange colour	5.3	5.6	5.1	2.9	5.6	4.1	452	0.7	<0.001
Cutting behaviour	3.6	2.4	2.8	4.1	2.9	3.4	448	0.8	<0.001
Flavour									
Squash flavour	4.5	4.9	5.0	4.1	4.6	4.6	449	0.4	<0.01
Sweetness	4.3	4.6	4.8	4.1	4.2	4.5	452	–	NS
Buttery	3.4	3.7	3.5	3.1	3.3	3.3	454	0.3	<0.05
Nutty	3.0	2.8	2.7	3.2	3.1	2.9	448	–	NS
Texture									
Hardness	4.4	2.7	3.0	4.8	3.8	3.3	451	1.0	<0.001
Crumbliness	3.9	2.4	2.7	4.7	3.4	3.5	452	1.0	<0.001
Moistness	3.1	4.6	4.5	2.9	3.7	3.8	452	1.0	<0.01
Mouthfeel	4.5	5.6	5.3	3.8	5.0	4.8	452	0.8	<0.001
Fibres	1.5	1.5	1.6	1.7	1.5	1.5	448	–	NS

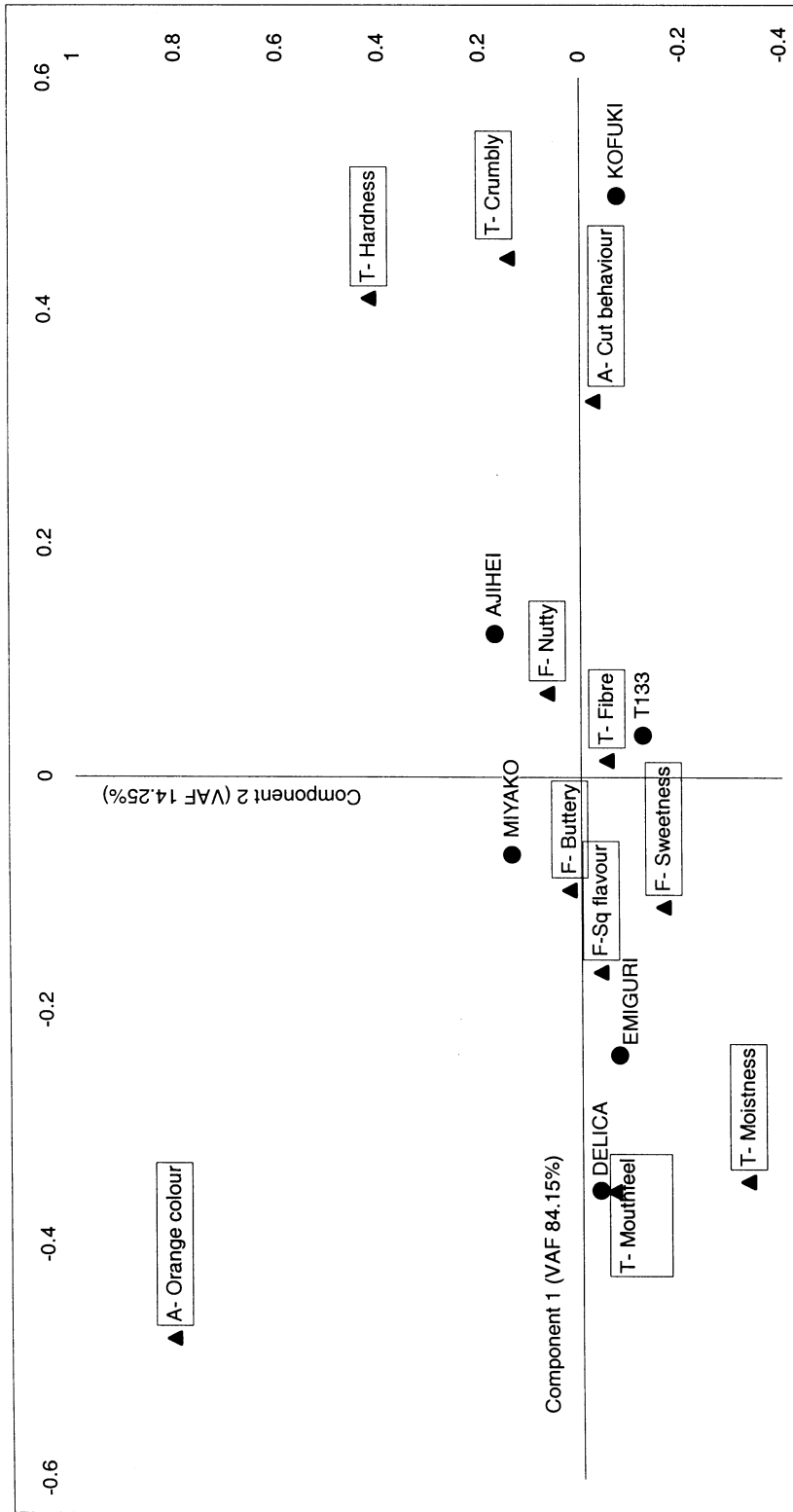


Fig. 1 Scores (●, cultivars) and loadings (▲, sensory attributes) of the first two principal components. (VAF, variation accounted for.)

their usefulness in explaining sensory attributes. A graphical representation of these relationships was obtained by correlating the physical and chemical values with the first two PCs obtained from PCA of the sensory data (Fig. 1). This is shown in Fig. 2.

The sensory assessment of colour is positively related to a^* measurement and negatively related to L^* and b^* . However, the correlation coefficients do not indicate a significant relationship. As shown in the correlation plot, colour parameter L^* is positively correlated with b^* ($r = 0.887$, $P < 0.001$).

Table 3 Average sugar, starch, and dry matter (DM) contents of six uncooked squash (*Cucurbita maxima*) cultivars. (NS, not significant; NA, not applicable; LSD, least significant difference; average ranks, with the Kruskal-Wallis test the data is ranked, and the average of the ranks for each treatment is the basis for comparison.)

Biochemical measurements*	Ajihei	Delica	Emiguri	Kofuki	Miyako	T133	LSD	<i>P</i> values
Glucose	6.06	12.69	12.48	3.18	6.03	2.71	NA	NA
Log transformed	(1.77)	(2.48)	(2.34)	(0.95)	(1.43)	(0.91)	0.70	<.001
Fructose	4.96	11.70	11.09	2.93	4.94	2.43	NA	NA
Square root transformed	(2.20)	(3.36)	(3.15)	(1.61)	(1.98)	(1.51)	0.97	0.002
Maltose	1.87	2.35	2.32	2.67	2.25	2.68	NA	NA
Average ranks	(5.4)	(16.0)	(14.8)	(22.2)	(12.2)	(22.4)	6.0	0.021
Sucrose	48.87	35.78	39.42	52.89	51.18	58.77	NA	NA
Squared transformed	(2478.0)	(1358.0)	(1697.0)	(2853.0)	(2728.0)	(3471.0)	1071.9	0.005
Starch	110.0	83.5	95.0	112.2	105.6	106.5	–	NS
DM (%)	33.19	27.01	28.85	32.93	30.05	33.03	4.36	0.029

*Sugar and starch contents are expressed as mg/g fresh weight.

Table 4 Average readings of viscosity measurements for the six uncooked squash (*Cucurbita maxima*) cultivars. (LSD, least significant difference.)

Viscosity (Pa S)	Ajihei	Delica	Emiguri	Kofuki	Miyako	T133	LSD	<i>P</i> values
Peak viscosity	2554	1320	1768	2216	1896	3002	944	0.018
Viscosity-1	2150	1056	1530	2272	1512	2832	877	0.005
Shear rate 0.5 s ⁻¹								
Viscosity-2	1463	676	995	1512	1059	1797	593	0.008
Shear rate 1.0 s ⁻¹								
Viscosity-3	674	256	404	652	437	747	263	0.005
Shear rate 5.0 s ⁻¹								

Table 5 Average readings of CIE L^* , a^* , b^* colour measurements for the six uncooked squash (*Cucurbita maxima*) cultivars. (Colour measurements: L^* (0 = black, 100 = white); a^* (– = green, + = red); b^* (– = blue, + = yellow); LSD, least significant difference.)

Colour measurements	Ajihei	Delica	Emiguri	Kofuki	Miyako	T133	LSD	<i>P</i> values
L^*	63.69	61.91	63.78	65.58	61.58	63.54	2.27	0.01
a^*	18.88	18.52	18.23	15.99	19.30	20.52	1.27	<0.001
b^*	70.51	68.93	72.56	72.49	68.0	68.91	2.62	0.002

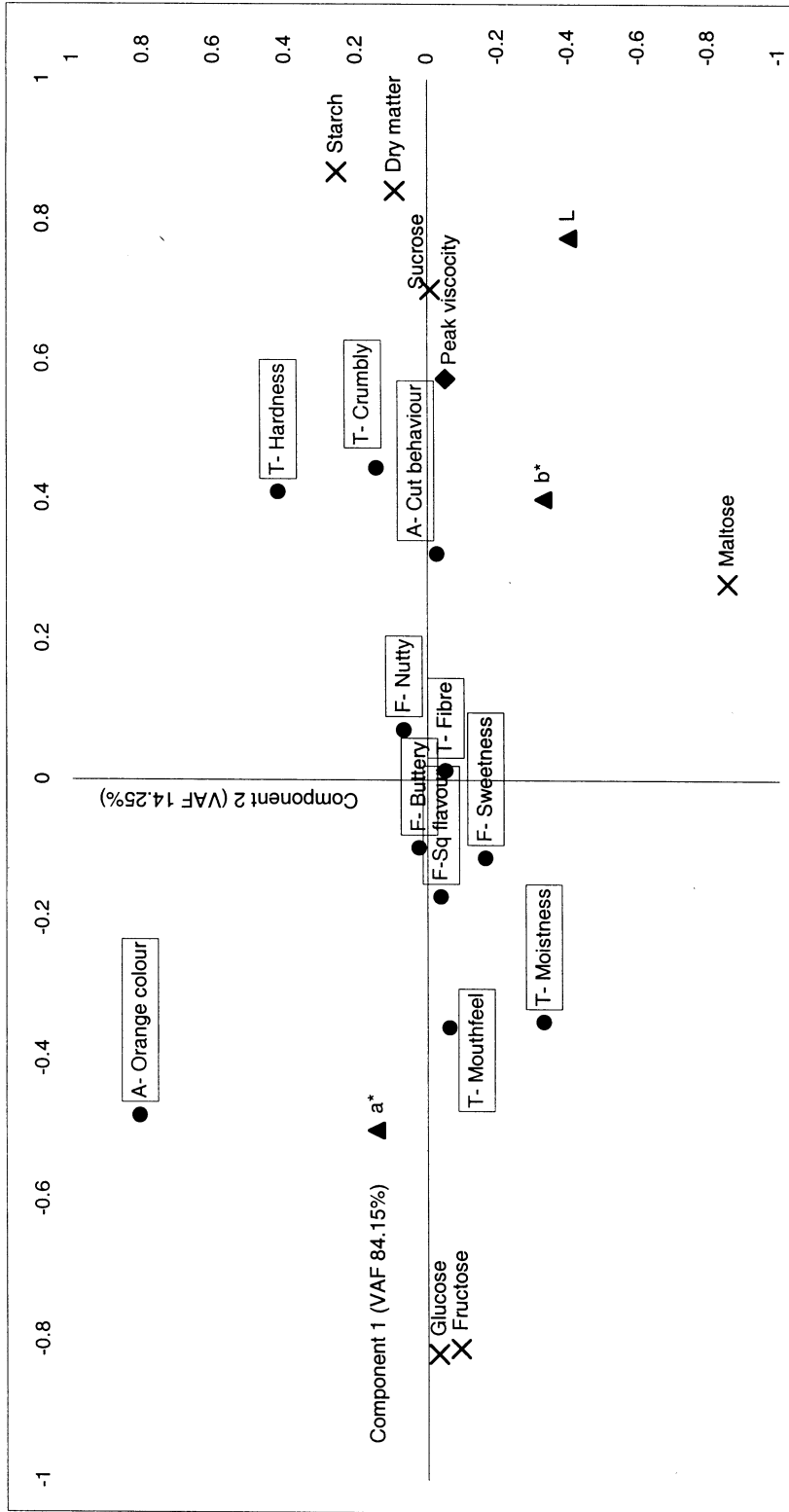


Fig. 2 Correlation of physical and chemical data with the first two principal components of Fig. 1. (●, sensory attributes; ▲, CIELAB colours; X, chemical measurements; ◆, viscosity; VAF, variation accounted for.)

Only the correlation of peak viscosity with the first two PC axes obtained from PCA of sensory data is shown in Fig. 2 because all the viscosity measurements are correlated with the sensory attributes of cutting behaviour, crumbliness, hardness, moistness, and mouthfeel. Peak viscosity is positively correlated with cutting behaviour, crumbliness, and hardness, and negatively correlated with moistness and mouthfeel (Table 6).

There is no clear indication of the relationship between sugars and panel sweetness from the plot as expected because Table 2 shows no differences between cultivars for sweetness. Corrigan et al. (2000) found that in high starch cultivars glucose and fructose are negatively correlated with sucrose. The starch content of some cultivars studied here are higher than those studied by these researchers and a similar relationship has been observed. Maltose is associated with the second dimension indicating very little association with the sensory dimension.

Starch and DM content influence most of the sensory attributes in squash. Starch ($r = 0.868$) and DM ($r = 0.841$) are significantly correlated with sensory dimension 1 (Fig. 2). The correlation coefficients also indicate a significant relationship between starch, DM, and textural properties (hardness, moistness, crumbliness). However, the

relationships between DM and textural properties are much stronger than with starch. The correlations of percentage DM with hardness ($r = 0.774$), crumbliness ($r = 0.782$), and moistness ($r = -0.824$) are highly significant ($P < 0.001$). In comparison, the correlations of starch with hardness ($r = 0.541$, $P < 0.01$), crumbliness ($r = 0.58$, $P < 0.01$), and moistness ($r = -0.424$, $P < 0.05$) are moderately significant.

DM and starch content were related to viscosity. Quadratic and interaction terms were not significant when added to the regression model. The results in Table 7 indicate that the influence of DM is greater than that of starch for all the viscosity measurements. For the peak viscosity data, including starch in the regression model after DM does not explain any more variation, thus only DM is required. The differences in the variability accounted for by the regression models for viscosity-1 through to viscosity-3 (66.4, 73.4, 81.2 respectively) can be attributed to the different shear rates used for measuring these parameters. Increasing the shear rates ($0.5\text{--}5.0\text{ s}^{-1}$) also results in slightly higher correlation between the objective measurements of viscosity (1–3) and sensory measurements of texture. These results enable us to recommend the use of a shear rate of 5.0 s^{-1} , instead of a lower shear rate, to

Table 6 Correlation coefficients of sensory measurements with viscosity.

	Peak viscosity	Viscosity-1	Viscosity-2	Viscosity-3
Crumbliness	0.772	0.697	0.723	0.763
Cutting behaviour	0.812	0.745	0.759	0.772
Hardness	0.747	0.655	0.701	0.722
Moistness	-0.823	-0.715	-0.756	-0.771
Mouthfeel	-0.735	-0.682	-0.706	-0.727

Table 7 Regression coefficients (and significant levels) for explaining viscosity from dry matter (DM) and starch content.

Viscosity	Adjusted R^2	Constant	DM	Starch
Peak viscosity	79.2	-3970 ($P < 0.001$)	197.6 ($P < 0.001$)	–
Viscosity-1 Shear rate 0.5 s^{-1}	66.4	-3942 ($P < 0.001$)	215.1 ($P < 0.001$)	-7.98 ($P = 0.096$)
Viscosity-2 Shear rate 1.0 s^{-1}	73.4	-2782 ($P < 0.001$)	147.7 ($P < 0.001$)	-5.19 ($P = 0.068$)
Viscosity-3 Shear rate 5.0 s^{-1}	81.2	-1376 ($P < 0.001$)	67.86 ($P < 0.001$)	-1.85 ($P = 0.088$)

determine the viscosity differences in cultivars measured (by shear stress as a function of shear rate) at a constant temperature of 50.3°C (after the heating phase).

DISCUSSION

The colour of the cultivars assessed by sensory panellists show 'Kofuki' is significantly different from the other cultivars.

The CIE L^* , a^* , b^* parameters have been used in studies relating to squash maturity (Harvey et al. 1992) and heat treatment of squash (Bycroft et al. 1999). This research shows significant differences in the L^* , a^* , b^* values between cultivars. The colour of 'Kofuki' is lighter and more yellow, with less redness than the colour of 'Miyako'. The a^* values obtained for 'Delica' in this experiment are close to the values (20–24) obtained from the same cultivar grown in the Pukekohe during the 1992/93 season (Harvey et al. 1997). However, there is no evidence that these CIELAB parameters are correlated with the sensory colour measurement and they should not be interpreted in sensory terms. The sensory panellists assessed the appearance of cooked squash and the L^* , a^* , b^* measurements were done on uncooked squash. The fruit used in both these assessments and the storage time were also different, which may have reduced the correlation. CIELAB measurements could be used to distinguish colours between cultivars, however, to relate these differences to sensory measurements a significant relationship between objective and subjective measurements needs to be established. Perhaps it may be useful to look at brightness of colour (dark...light) and differences in shades of orange (yellow...orange) separately while doing sensory assessment.

Flavour includes the olfactory sensations, gustatory sensations, and the chemical feeling factors such as astringency (Caul 1957 cited in Meilgaard et al. 1987). The correlation of sweetness ($r = 0.708$, $P < 0.001$) with squash flavour suggests that sweetness could have a significant influence on the perception of squash flavour. This is similar to the results of Hurst et al. (1995).

Sweetness of buttercup squash has an important influence on consumer preferences (Harvey et al. 1992). Sucrose has been shown to be the most important sugar in predicting the sweetness of squash, but the inclusion of glucose and fructose improves this prediction (Corrigan et al. 2000). The

correlation coefficients obtained here do not indicate significant correlations between sweetness and sugars. One reason for this could be that the textural properties of these cultivars interfere with the chemical stimuli and taste bud interaction. To explain this, correlation coefficients need to be examined. Sweetness is positively correlated with moistness ($r = 0.553$, $P < 0.01$) and mouthfeel ($r = 0.663$, $P < 0.001$), and negatively correlated with hardness ($r = 0.577$, $P < 0.01$). The cultivars (e.g., 'Delica', 'Emiguri') that are moist, soft, and have a smooth pasty mouthfeel may have spread more easily on the surface of the tongue in comparison to the drier cultivar (i.e., 'Kofuki'), stimulating a larger surface of the tongue more quickly. Moistness would facilitate the initial binding of taste molecules with the receptor cells before mixing with saliva. The cell walls which contribute to textural properties may also have an effect in the release of sweetness components. All these factors may have affected the processes involved in the perception of sweetness, contributing to the lack of correlation with the sugar content. The effects of textural properties on the perception of sweetness of buttercup squash needs further investigation. Because of the strong correlation between flavour and sweetness, a similar effect could also occur when assessing squash flavour.

Texture is a complex sensory attribute (Brennan 1988) and it is important for consumer acceptability in many foods. PCA of the sensory data indicates that textural attributes are the main source of cultivar differences for these cultivars. When all five textural attributes measured by sensory panels are compared 'Delica' and 'Emiguri' are very similar. 'Kofuki', and to a lesser extent 'Ajihei', are very different from 'Delica' and 'Emiguri'. 'Miyako' and 'T133' have textural properties that are balanced between the two extremes of 'Delica' and 'Kofuki'. Consistency of food influences the evaluation of taste (Urbanyi 1983). The results of this experiment indicate that texture influences the perception of sweetness and flavour.

The significant correlation of DM with the textural properties and sugars is an indication of its importance in influencing most of the sensory properties. Starch content of squash also influences sensory properties but is not as significant as DM. Hence from this we could predict a drier, harder, crumblier texture for cultivars high in DM and starch content.

The viscosity measurements indicate significant differences between cultivars and all samples showed a shear thinning behaviour with viscosity

decreasing as shear rate increased from 0.5 to 5 s⁻¹. These measurements are significantly correlated with DM and with the sensory measurements of cooked squash texture. This indicates the potential use of this objective measurement to predict some of the sensory properties of squash texture. However, this method has to be tested on more cultivars (with extreme textural differences) to confirm its reliability.

In conclusion, of the fruit tested here 'Emiguri' and 'Delica' are the most similar. 'Kofuki', the most dry and crumbly cultivar, is different from these two cultivars. Sensory evaluation of these squash cultivars by trained panellists quantifies the sensory differences, and the chemical analyses quantify the compositional differences. However, this does not necessarily give an indication of consumer acceptance or preferences with regard to these cultivars in Japan. Although yield, quality, storage characteristics, and disease resistance are some of the attributes that needs to be taken into consideration during the development process of new cultivars for future markets, it can be argued that sensory attributes are the most important factor needing attention because of their significant influence on acceptance by consumers. Each sensory attribute exerts a different level of importance, in terms of overall consumer acceptability. Hence sensory attributes of squash that influence Japanese consumer preferences need to be identified to obtain maximum benefit from this research. This will allow us to optimise the attributes important to preference formation via breeding programmes. We can then target different cultivars to suit consumer needs and preferences and so enhance the business advantage of the squash growers.

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