Relationship between taste composition and sensory evaluation ratings of fruits

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要　旨：14 種類の果実を取りあげ，果実成分を機器によって測定するとともに，甘味強度や酸味強度，おいしさを官能評価の手法を用いて評価して機器測定値との関係性を明らかし，法則を提示した。「糖度と甘味強度」の間には，相関係数 r= 0.540，回帰直線 y= 0.169x+1.950 が得られた。糖度から甘味強度を有意に予測できると考えられた（p< 0.05）。「pH と酸味強度」の間には，相関係数 r= − 0.812，回帰直線 y= − 1.490x+10.039 が得られた。この式は，pH から酸味強度を予測する際，役立つといえる（p< 0.001）。「甘味強度とおいしさ」の間には，相関係数 r= 0.815，回帰直線 y= 0.567x+2.422 が得られた。この式は，甘味強度からおいしさの評価を予測する際，役立つといえる（p< 0.001）。「酸味強度とおいしさ」の間には，相関係数 r= − 0.611，回帰直線 y= − 0.359x+6.368 が得られた。この回帰直線は，酸味強度からおいしさの評価を予測する際，有益であるといえる（p< 0.05）。

キーワード：果実類　甘味　酸味　官能評価　単回帰分析

Summary

We measured the composition of fruit using instruments and evaluated sweetness, acidity intensity and palatability using sensory evaluation methods. We also investigated the relationship between instrumental measurements and human sensory evaluation ratings in order to propose formulae describing the relationships between the two. Sugar content and sweetness intensity had a correlation coefficient of r = 0.540, with a regression equation y = 0.169x + 1.950, suggesting that sugar content was a significant predictor of sweetness intensity (p < 0.05). The pH and acidity intensity had a correlation coefficient of r = - 0.812, with regression equation y = - 1.490x + 10.039. This equation was shown to be helpful in predicting acidity intensity based on pH measurements (p < 0.001). Sweetness intensity and palatability ratings had a correlation coefficient of r = 0.815, with a regression equation y = 0.567x + 2.422 and was used in predicting palatability ratings based on sweetness intensity ratings (p < 0.001). Acidity intensity and palatability ratings had a correlation coefficient of r = - 0.611, with regression equation y = - 0.359x + 6.368. This equation predicted palatability ratings based on acidity intensity ratings (p < 0.05).

Key words : fruits　sweetness　acidity　sensory evaluation　simple regression analyses

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Introduction

The health benefits of the functional components of fruits has attracted much attention and previous studies have reported that the consumption of fruits may reduce the risk of certain diseases [1) 2) 3)]. It is suggested that a balance between sweetness and acidity contributes to greater palatability of fruits [4)]. Several studies have performed component analyses and sensory evaluations of fruits [5) 6) 7)], however, these studies used only a single type of fruit.

In the current study, we selected 14 different types of fruit and evaluated the components of each fruit, investigated the balance between sweetness and acidity and used sensory evaluation methods to determine palatability in humans. We also examined the relationship between the human sensory experience and instrumental measurements of taste components. We aimed to seek a predictive relationship between taste components and sensory evaluation ratings.

Materials and Methods

1. Samples

The samples used in the experiment are shown in Table 1. Food item numbers are based on the Standard Tables of Food Composition in Japan, 2015 [8)].

Table 1 Sample

Food	Food number	Production areas	Participants (person)
Tomato	6182	Mini tomato ; Hiroshima	29
Strawberry	7012	Toyonoka ; Saga	16
Valencia Orange	7041	America	30
Kiwifruit	7054	New Zealand	16
Grapefruit	7062	White ; America	18
Cherry	7070	Yamagata	30
Watermelon	7077	Tottori	29
Summer Oranges	7093	Hiroshima	14
Pineapple	7097	Philippines	18
Loquat	7114	Hiroshima	30
Grape	7116	Delaware ; Hiroshima	30
Lime	7145	Hiroshima	18
Apple	7148	Sun fuji ; Aomori	30
Lemon	7155	Hiroshima	30

Food item numbers are based on the Standard Tables of Food Composition in Japan, 2015 [8)].

2. Instrumental measurements of fruit components

pH (pH meter; KS701 Shin Denko Kogyo) and sugar content (saccharimeter; Atago handheld refractometer) were measured 3 to 6 times for each fruit.

3. Sensory evaluation

The participants were 14-30 healthy female students aged between 18 and 20 years who attended our junior college. The participants underwent a preliminary experiment and a training session before participating in the experiments. In the experiment, sensory evaluations were conducted in an air-conditioned, quiet room according to the method described below. The room contained a desk for testing, as well as a water supply and a sink for gargling. Sensory evaluations were conducted around 4 pm when the participants were neither hungry nor full. Fruits were presented at room temperature (20 ± 2°C) on white paper square trays.

Fruits were individually administered to the participants and sensory evaluation was performed using a 7-point scale (1 to 7 points). Participants evaluated sweetness intensity, acidity intensity, and palatability. The rating scale had verbal descriptors, with +1 = perceive the sweetness very weakly, +2 = perceive the sweetness weakly, +3 = perceive the sweetness moderately clearly, +4 = perceive the sweetness clearly, +5 = perceive the sweetness moderately strongly, +6 = perceive the sweetness strongly, +7 = perceive the sweetness very strongly. These measures of evaluation scores were set at regular intervals.

Before conducting this study, informed consent was obtained from all participants.

4. Data Analysis

The evaluation score for each sample was expressed as the mean (mean score) ± standard deviation. The instrumental measurements of fruit components was correlated with the average sensory evaluation ratings, and the different sensory evaluation items using Pearson's product-moment correlation coefficients [9] and simple regression analyses [10].

IBM SPSS Statistics 19.0 for Windows (IBM Company, Tokyo, Japan) was used for statistical analysis.

Results

1. Instrumental measurements of fruit components and sensory evaluation

Figure 1 shows the sugar content and sweetness intensity (average rating). Figure 2 shows the pH measurements and acidity intensity (average rating from sensory evaluations).

Participants gave higher sweetness intensity ratings to fruit with the highest sugar content (e.g., grape, pineapple), although watermelon was perceived as sweet despite its moderate sugar content. This may be due to its low acidity level (Figure 1). Participants reported stronger acidity in fruits with a low pH (e.g., lemon, lime), however, tomatoes were also perceived to be acidic, even though their average pH level was higher than the lemon and lime. (Figure 2).

2. Correlation between instrumental measurements of fruit components and sensory evaluation ratings

Figure 3 presents a scatterplot showing the correlation between sugar content measurements and sweetness intensity ratings for the 14 types of fruit. Figure 4 presents a scatterplot showing the correlation between pH measurements and acidity intensity ratings.

Sugar content measurements and sweetness intensity ratings had a moderately strong positive association ($r = 0.540$) (Figure 3).

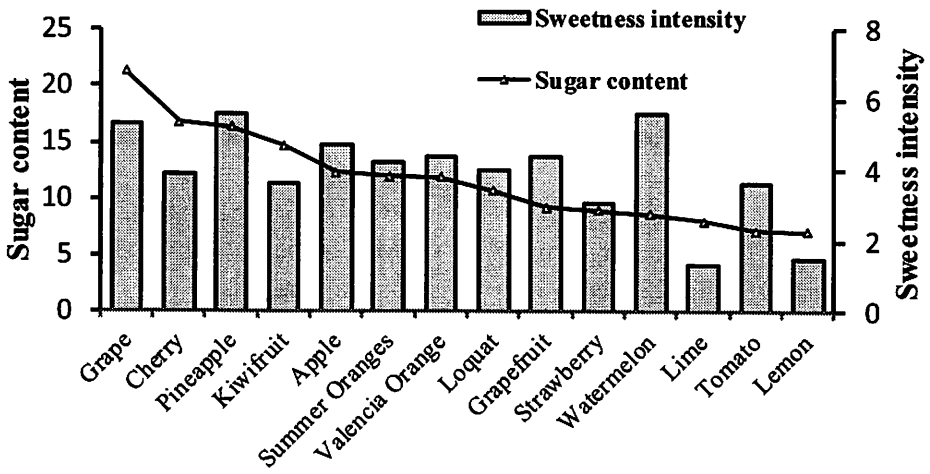

Figure 1 Sugar content and sweetness intensity (average rating). A hand-held refractometer (Atago, Tokyo, Japan) was used to measure the sugar content. Sweetness intensity is an average of ratings obtained by sensory evaluations.

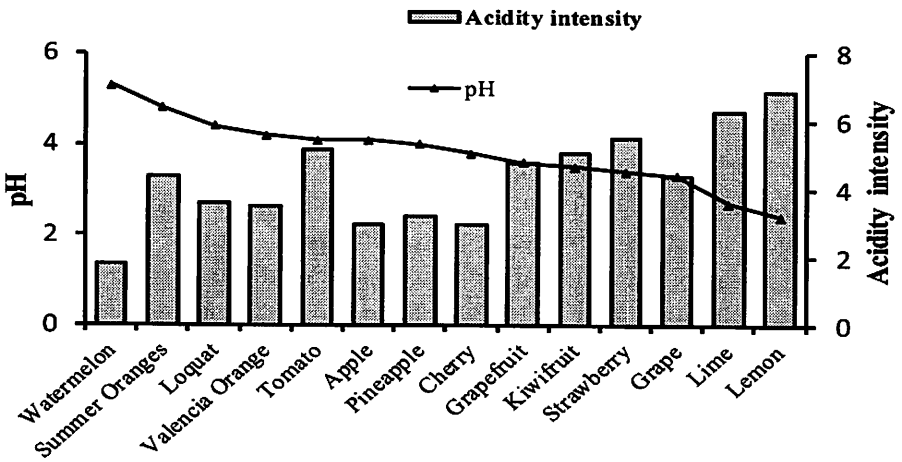

Figure 2 pH measurements and acidity. Acidity intensity is an average of ratings obtained by sensory evaluations.

Regression analysis demonstrated that a predictive relationship using sugar content as a predictor and sweetness intensity ratings as a criterion variable was significant ($p < 0.05$) using the following equation, $y = 0.169x + 1.950$. The correlation coefficient between pH measurement and acidity intensity ratings was $r = - 0.812$, indicating that the two variables had a strong negative correlation (Figure 4). The regression equation obtained using the regression analysis ($y = - 1.490x + 10.039$) indicated that the equation was significantly predictive of acidity ratings based on pH measurements ($p < 0.001$).

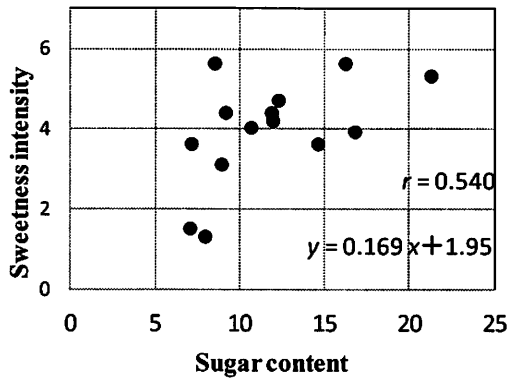

Figure3 Correlation between sugar content measurements and sweetness intensity ratings.

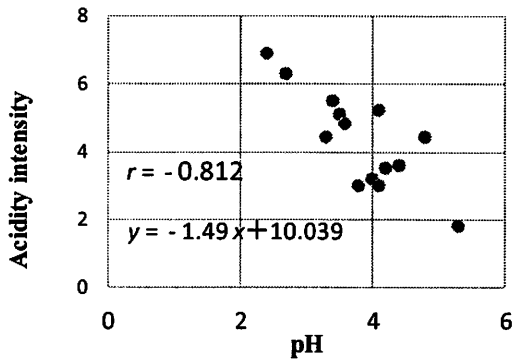

Figure4 Correlation between pH measurements and acidity intensity ratings.

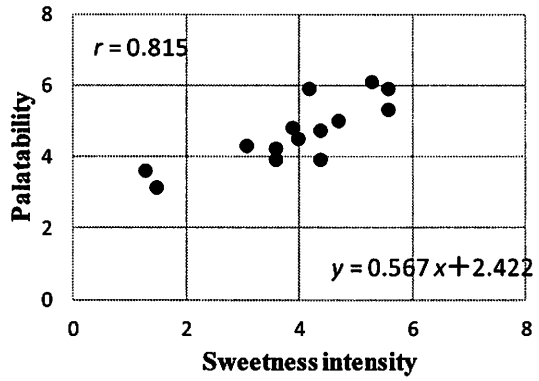

Figure 5 Correlation between sweetness intensity ratings and palatability ratings.

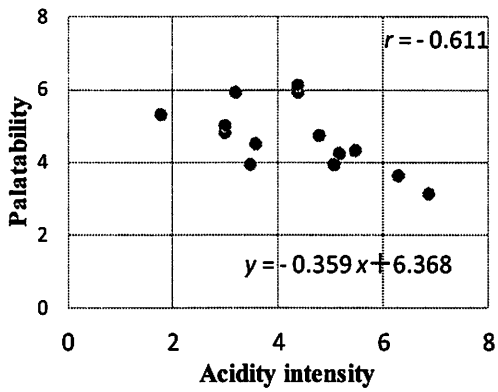

Figure 6 Correlation between acidity intensity ratings and palatability ratings.

3. Correlation between sensory evaluation items

Figure 5 presents a scatterplot showing the correlation between sweetness intensity ratings and palatability ratings. Figure 6 presents a scatterplot showing the correlation between acidity intensity ratings and palatability ratings.

The correlation coefficient between sweetness intensity ratings and palatability ratings was r = 0.815, indicating a strong positive correlation (Figure 5). Participants rated the fruit that they perceived as sweet to be palatable. The regression coefficient was significant (p < 0.001), indicating that the equation y = 0.567x + 2.422 is predictive of palatability based on sweetness intensity ratings. The acidity intensity and palatability ratings showed a moderately strong negative correlation, with an r = - 0.611 (Figure 6). Regression analysis indicated that the regression equation y = - 0.359x + 6.368 was

significantly predictive of palatability ratings based on acidity intensity ratings ($p < 0.05$).

Discussion

Our results demonstrated a moderately strong positive relationship between sugar content and sweetness intensity ratings of fruit, and a very strong negative relationship between pH measurement and acidity intensity ratings. Significant associations between instrumental measurements of sugar content and pH and human sensory perception of sweetness and acidity were observed. The association between pH and acidity was stronger than the association between sugar content and sweetness intensity. It is possible that the saccharimeter used in this study did not measure all the sugars contained in the fruit. Future studies should include analyses of sugar compositions and quantitative measurements of organic acid. It was previously found that instrumental measurements were considered helpful in assisting human sensory judgment and evaluation when analyzing the relationship between taste components of food and sensory evaluation ratings [11].

We found that participants had a tendency to report high palatability when they perceived a fruit to be sweet (with moderately high correlation between instrumental measurements and sensory evaluation ratings). Low palatability was reported when participants perceived a fruit to be acidic (with moderately high negative correlation between the instrumental measurements and sensory evaluation ratings). The sense of taste has a physiological role in that sweetness signifies the presence of sugars while acidity signals materials that should be avoided [12]. It is likely that humans tend to perceive high palatability when they strongly perceive a sweet taste, while they perceive low palatability when they sense acidity.

Conclusion

We measured the composition of fruit using instruments and evaluated sweetness, acidity intensity and palatability using sensory evaluation methods. We also investigated the relationship between instrumental measurements and human sensory evaluation ratings in order to propose formulae describing the relationships between the two. Sugar content and sweetness intensity had a correlation coefficient of $r = 0.540$, with a regression equation $y = 0.169x + 1.950$, suggesting that sugar content was a significant predictor of sweetness intensity ($p < 0.05$). The pH and acidity intensity had a correlation coefficient of $r = -0.812$, with regression equation $y = -1.490x + 10.039$. This equation was shown to be helpful in predicting acidity intensity based on pH measurements ($p < 0.001$).

Sweetness intensity and palatability ratings had a correlation coefficient of $r = 0.815$, with a regression equation $y = 0.567x + 2.422$ and was used in predicting palatability ratings based on sweetness intensity ratings ($p < 0.001$). Acidity intensity and palatability ratings had a correlation coefficient of $r = -0.611$, with regression equation $y = -0.359x + 6.368$. This equation predicted palatability ratings based on acidity intensity ratings ($p < 0.05$).

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