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The relationship between the color value and pungent compound contents of ginger subjected to heating, soaking in hot water, or steaming

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Abstract

Medicinal ginger is produced by various processes in Japan and China, e.g., ginger that has been soaked in hot water or steamed is called *kankyo* in Japan, and roasted ginger is called *hokyo* (*paojiang* in Chinese) in China. However, the heating method differs between the two countries, and the quality of processed ginger might be affected by differences in the heating period and strength. The color of ginger changes markedly during heating. Therefore, in this study, we analyzed the color value and pungent compound contents of our processed ginger samples and elucidated the differences in the quality of these samples. In addition, we investigated the relationship between the color values and pungent compound contents of processed ginger samples.

As a result, we found that the *a** value (indicating redness) of steamed (St) ginger was positively correlated with its 6-shogaol to 6-gingerol ratio ([S/G]), the *a** value of ginger soaked in hot water (Soh) remained constant regardless of the [S/G], and the *a** value of ginger heated at 180℃ (H180) was correlated on a logarithmic curve with [S/G]. In addition, the *b** values (indicating yellowness) of the Soh, St, and H180 ginger samples were negatively correlated with their 6-shogaol concentrations. Therefore, we confirmed that color values are suitable indices for evaluating the quality of processed ginger because they can be used to evaluate its [S/G] ratio and the processing method by this value.

Key words ginger, processing, color, gingerol, shogaol.

Abbreviations H100, heated at 100℃; H180, heated at 180℃; [S/G], 6-shogaol to 6-gingerol ratio; Soh, soaked in hot water; St, steamed; St-AC, steamed by autoclaving; St-P, steamed in a pot.

Introduction

Ginger is a crude drug that is processed for specific medicinal purposes in Japan. In the 16th Japanese Pharmacopoeia,[1)] dried ginger is called *shokyo*, and ginger that has been soaked in hot water or steamed before being dried is called *kankyo*. In the Chinese Pharmacopoeia,[2)] fresh ginger is called *shokyo* (*shengjiang* in Chinese), dried ginger is called *kankyo* (*ganjiang* in Chinese), and roasted ginger is called *hokyo* (*paojiang* in Chinese). Although heated ginger is used in both countries, the heating methods used differ between the two countries. In addition, the quality of processed ginger can differ due to differences in the heating period and strength.

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Color is an important criterion for evaluating the quality of crude drugs. As for ginger, Japanese *kankyo* is redder than *shokyo*. However, there might be significant interindividual variation in the ability to detect such color changes with the naked eye. Mikage *et al*.[3] previously developed a method for objectively evaluating the quality of crude drugs using a colorimeter and reported that strength of processing given to ginseng could be estimated by measuring its color value. Therefore, in this study, we prepared five samples of ginger that were heated in an oven at 100 or 180℃, soaked in hot water, or steamed in a pot or by autoclaving and analyzed their color values using an objective method.

During the heating process, it has been reported that dehydration occurs and leads to the transformation of gingerol to shogaol, and a longer heating time results in an increased amount of shogaol.[4,5] These pungent compounds have antipyretic, antioxidant, anti-inflammatory, and anti-allergic[6-8] effects and also suppress gastric contraction and reduce blood pressure.[6] Meanwhile, previous reports showed that gingerol strongly inhibited the growth of *Helicobacter pylori*,[9] while 6-shogaol had strong antioxidant, anti-inflammatory,[7,10] and anti-allergic[8] effects. In addition, Govindarajan *et al*.[11] reported that the pungency (measured in Scoville units) of 6-shogaol was twice as high as that of 6-gingerol. Therefore, the ratio of 6-shogaol to 6-gingerol ([S/G]) is an important factor affecting the quality of processed ginger because medicinal effects of those compounds differs slightly each other. So, in this study, we also analyzed the 6-gingerol and 6-shogaol contents of processed ginger and elucidated the relationships between the color values and pungent compound contents of processed ginger samples.

Materials and Methods

Ginger material: Fresh ginger (breed name: *Sanshu*) was purchased from Sakata Nobuo Store Co., Kochi, Japan (2011).

Reagents: The 6-gingerol (purity: 98%) was purchased from Nakalai Tesque, Ltd., and the 6-shogaol (purity: more than 98%) was from Wako Pure Chemical Industries, Ltd. All chemicals were of analytical grade, and the chromatographic solvents were of HPLC grade.

Preparation method: Fresh ginger was cleaned, peeled, sliced into 5 mm thick sections, and mixed well. Eighty to 90 grams of fresh ginger were used in all examinations. Then, we processed the ginger using one of the following five methods:

(1) Soaking in hot water (Soh)

Fresh ginger pieces were heated by putting them in a beaker of water and then placing the beaker in boiling water.

(2) Steaming in a pot (St-P)

Fresh ginger pieces were wrapped with gauze and steamed in a pot for 15 to 180 minutes.

(3) Steaming by autoclaving (St-AC)

Fresh ginger pieces were placed into a culture bottle, and the top was covered with gauze. Then, the ginger pieces were steamed by autoclaving (SD-30N, Tomy Seiko Co., Ltd., Tokyo, Japan) in the following conditions: 120℃ and 2 atm for 5 to 20 minutes.

(4) Heating at 100℃ (H100)

Fresh ginger pieces were heated in an oven set to 100 ℃ for 15 to 180 minutes.

(5) Heating at 180℃ (H180)

Fresh ginger pieces were heated in an oven set to 180 ℃ for 15 to 180 minutes.

After the above treatment, the processed ginger pieces were dried for two nights in an oven set to 40 ℃. Fresh unprocessed ginger that had been dried for two nights in an oven was used as a control.

Color analysis: Each powdered sample (less than 300 μm) was placed into a minimal Petri dish (1.2cm×1cm, i.d.), and the light reflected when the dish was exposed to a D65 standard illuminant was analyzed using a spectral photometer (CM-3500d, Konica Minolta Holdings, Inc.). We evaluated the reflected light using the parameters L^* (brightness), a^* (redness), and b^* (yellowness).

HPLC method: HPLC was performed according to the methods described by Smith *et al*.[12] and Kano *et al*.[13]

(1) Preparation of samples

Each powdered sample (100 mg) was extracted with 10 ml of methanol under ultrasonication for 20 minutes. After centrifugation of the samples at 3000 rpm for 10 minutes, the supernatants were filtered through a 0.45

μm membrane filter. The resultant solutions were injected into the HPLC system.

(2) HPLC conditions

The apparatus comprised an L-2400 detector, an L-2130 pump, a D-2500 chromatograph, an L-2200 autosampler (Hitachi, Tokyo, Japan), a CTO-6A column oven (Shimadzu, Kyoto, Japan), and a COSMOSIL 5C18-MS-2 column (150 mm × 4.6 mm i.d.; Nacalai tesque, Kyoto, Japan)

The HPLC conditions were as follows: mobile phase: CH_3CN-CH_3OH-0.5% CH_3COOH (42:3:55 v/v); flow rate: 1.0 ml/min; detection wavelength: 280 nm; column temperature: 35℃, injected sample volume: 10 μl.

Under the above conditions, the recovery rates of gingerol and shogaol, which were calculated using the standard addition method, were 103.9 and 94.4%, respectively (mean of three experiments).

Results

1. Changes in the samples' color values

We analyzed the color values of powdered ginger samples that had been heated with different methods and for various durations. Under all conditions, the *a** values of the samples were negatively correlated with their *L** values. Except for in the H100 ginger, the *b** values of the samples were positively correlated with their *L** values and negatively correlated with their *a** values. The *b** value of H100 ginger varied from 35 to 41 although its *a** and *L** values showed little variation **(Fig. 1)**.

As the heating period increased, the *L** and *b** values of H180 ginger decreased markedly, and its *a** value increased markedly. Meanwhile, the *L** and *a** values of H100 ginger were hardly changed compared with those of unheated ginger, even in the samples processed for 180 minutes.

The ginger samples processed using the Soh or St method displayed decreased and increased *L** and *a** values, respectively. However, the *L** and *a** values of Soh ginger became stable after 30 minutes. As for the St-P ginger, its *L** and *a** values were slightly decreased and increased, respectively. In the case of St-AC ginger, its *L** and *b** values were decreased and its *a** value was increased compared with those of the St-P ginger samples processed for 180 minutes **(Fig. 2)**.

The *b** values of the samples tended to decrease in all conditions.

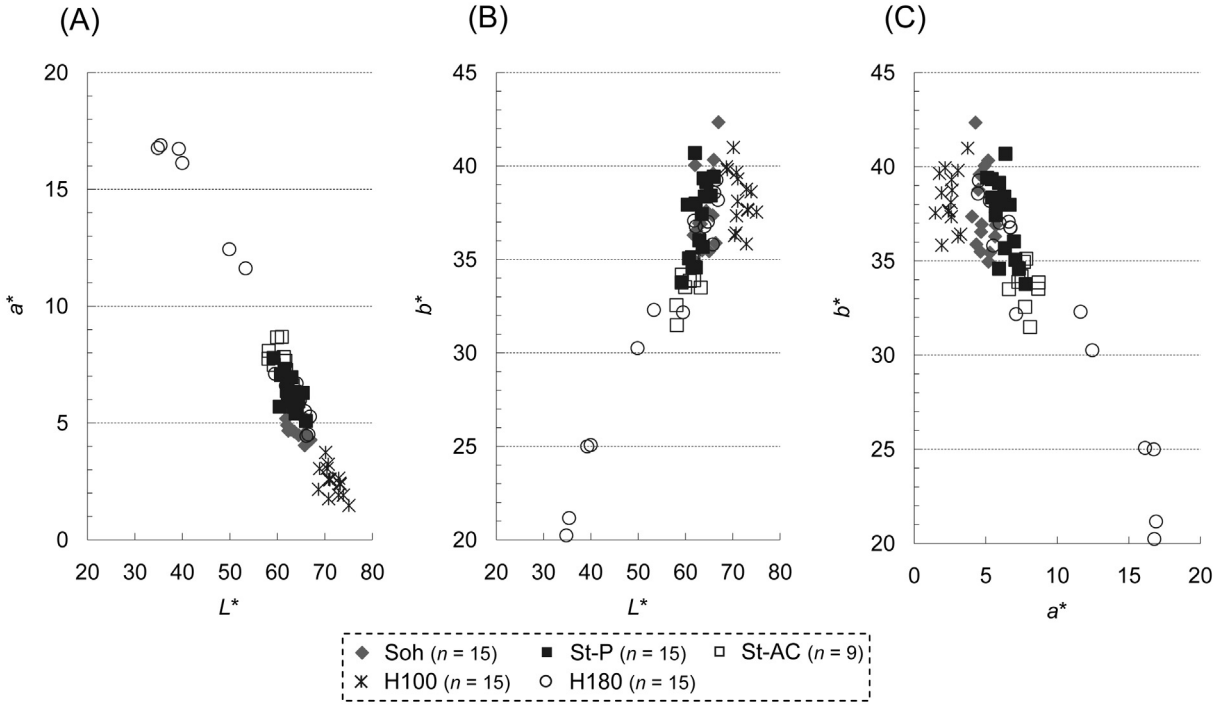

Fig. 1 The color values of powdered ginger samples heated with different methods and for various durations
The relationships between *L** and *a** values (A), *L** and *b** values (B), and *a** and *b** values (C).

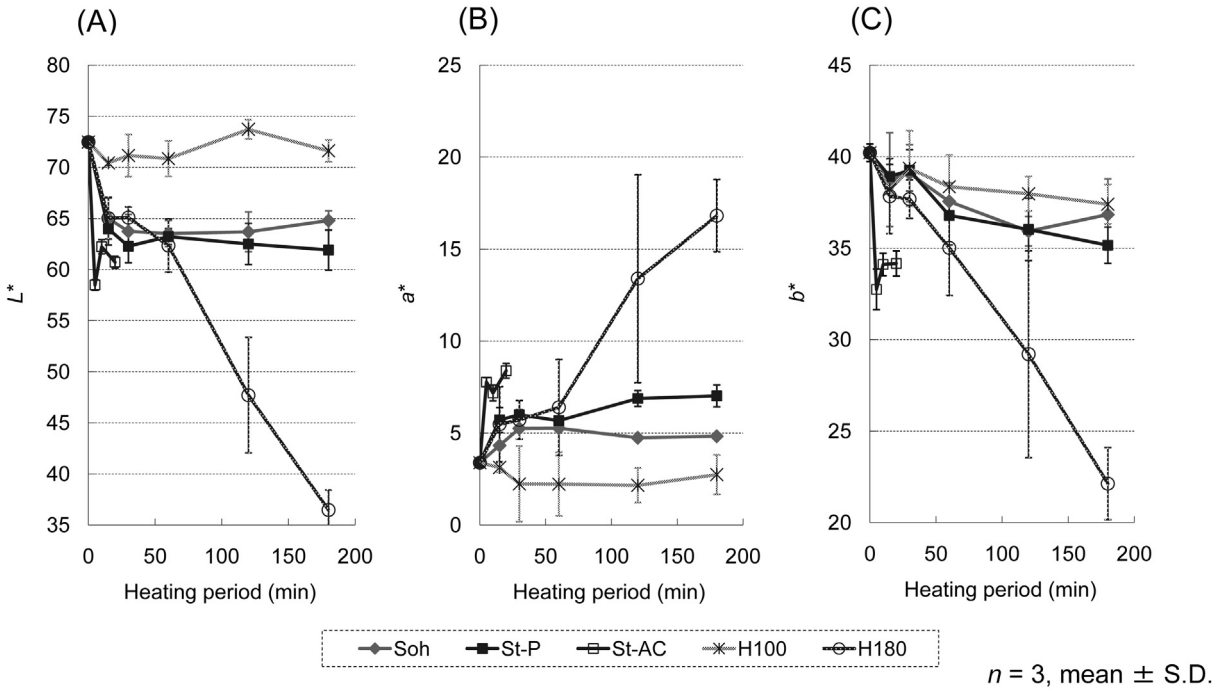

Fig. 2 The changes in the color values of the processed ginger powder samples depended on the heating period
(A) *L**, (B) *a**, (C) *b**

2. Changes in 6-gingerol and 6-shogaol content (Fig. 3)

We compared the changes in the levels of pungent compounds (6-gingerol and 6-shogaol) in ginger heated with various methods. As the heating period increased, the 6-gingerol content decreased and the 6-shogaol content increased, except in the H180 and H100 ginger. As for the H180 ginger, its 6-gingerol and 6-shogaol contents were approximately equal at 60 minutes, and its

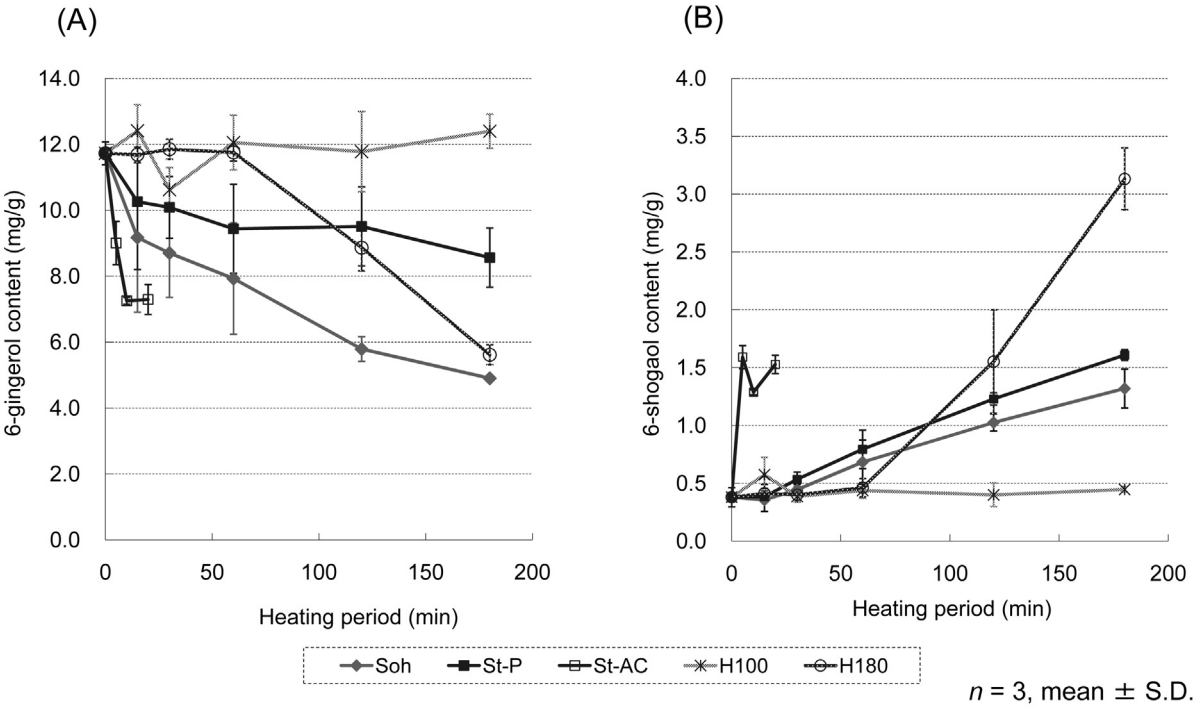

Fig. 3 The changes in the pungent compound levels of the processed ginger depended on the heating period
(A) 6-gingerol, (B) 6-shogaol

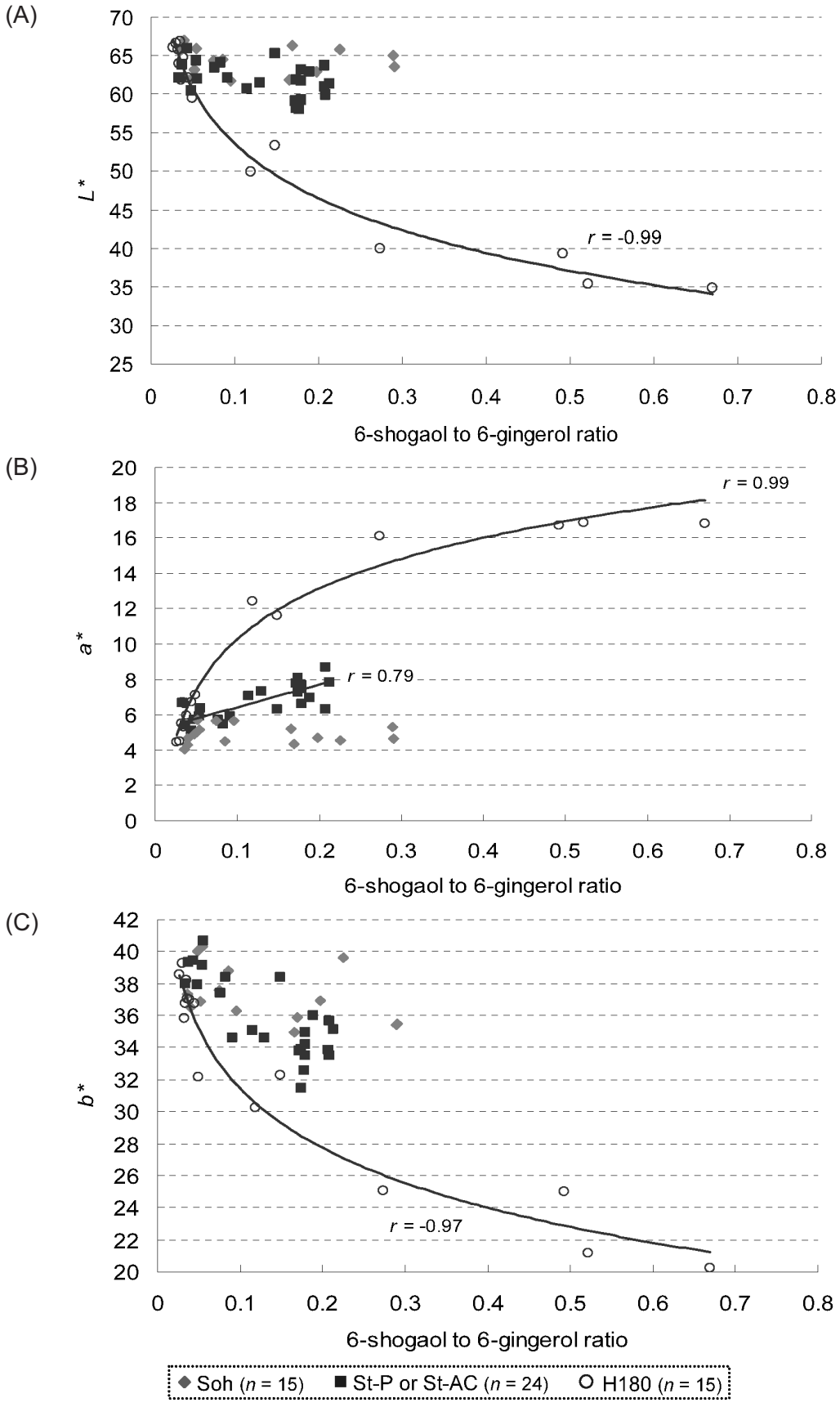

Fig. 4 The relationship between L^* (A), a^* (B), or b^* (C) value and the 6-shogaol to 6-gingerol ratio of processed ginger

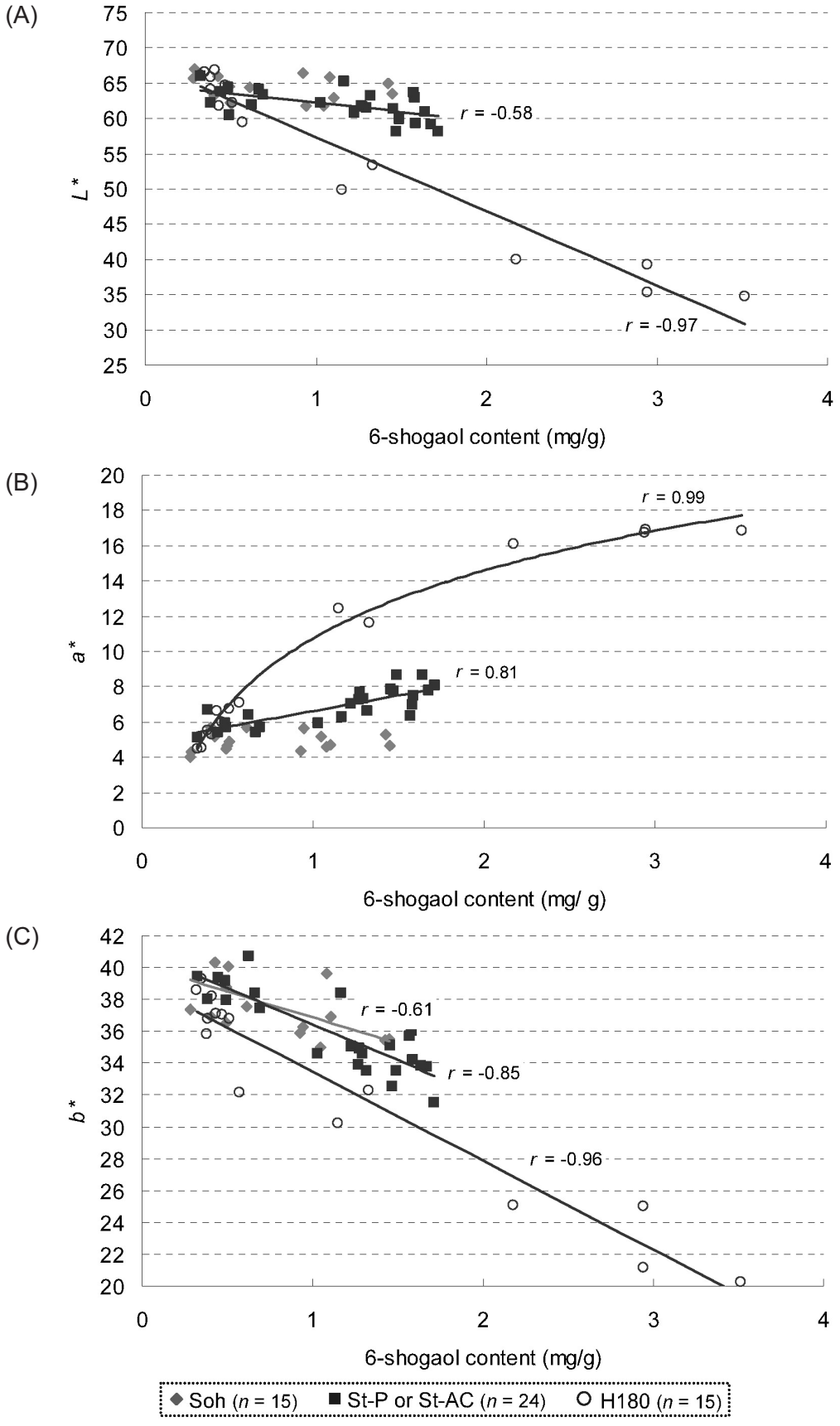

Fig. 5 The relationship between L^* (A), a^* (B), or b^* (C) value and 6-shogaol content of processed ginger

6-gingerol and 6-shogaol contents were markedly decreased and increased, respectively, after 60 minutes. As for the H100 ginger, its levels of 6-gingerol and 6-shogaol were hardly changed after heating for 180 minutes, although its 6-gingerol content was lower at 30 minutes and its 6-shogaol content was higher at 15 minutes than those of the other samples.

Then, we determined the differences between Soh ginger and St ginger, both of which are named *kankyo* in the Japanese Pharmacopoeia.[1] The 6-gingerol and 6-shogaol contents of Soh ginger were lower than those of the St ginger processed for the same period of time. In addition, the 6-gingerol and 6-shogaol contents of St-AC ginger were equivalent to those of the St-P ginger processed for about 150 minutes.

3. The relationships between color values and pungent compound levels

We found that the color values of H180, Soh, and St (St-P and St-AC) ginger were correlated with their pungent compound levels. First, the *a** value was positively correlated with [S/G] (r = 0.79) in St ginger, remained constant regardless of the [S/G] in Soh ginger, and correlated on a logarithmic curve with [S/G] (r = 0.99) in H180 ginger **(Fig. 4-B)**. In addition, the *L** and *b** value was negatively correlated on a logarithmic curve with [S/G] (r = -0.99 and -0.97, respectively), while those values of Soh and St (St-P or St-AC) was not correlated with [S/G] **(Fig. 4-A, C)**.

We also found that the *b** values of Soh, St, and H180 ginger were negatively correlated with their 6-shogaol levels (r = -0.61, -0.85, and -0.96, respectively) **(Fig. 5-C)**. In addition, the *L** values of St and H180 ginger were negatively correlated with their 6-shogaol levels (r = -0.58 and -0.97, respectively) **(Fig. 5-A)**. While, the relationship between *a** value and 6-shogaol content of processed ginger was similar to that between *a** value and [S/G] **(Fig. 5-B)**.

Discussion

We elucidated the relationships between the changes in the color values and pungent compound contents of ginger samples subjected to heating, soaking in hot water, or steaming, as follows:

1. The color values (*L**, *a**, and *b**) of ginger displayed changes that were correlated with each other after heating at 180℃ (H180), soaking in hot water (Soh), or steaming (St-P and St-AC). After heating at 100℃ (H100), the *L** and *a** values of the samples remained almost unchanged. Therefore, we found that the color of ginger was changed in a similar way by various heating processes, except for heating at 100℃.

2. Soh ginger and St ginger are referred to by the same name, *kankyo*, in the Japanese Pharmacopoeia.[1] However, in this study, we found that the color values and pungent compound levels of these processed ginger samples differ from each other. The *a** value of Soh ginger remained approximately constant after 30 to 180 minutes heating while that of St-P ginger increased. In addition, the decrease in the 6-gingerol content of Soh ginger was greater than that of St-P ginger, while the increase in the 6-shogaol content of St-P ginger was greater than that of Soh ginger. During the process used to produce the Soh ginger, the main compounds; i.e., 6-gingerol and 6-shogaol, might have dissolved in the hot water, and thus, been eluted from the samples, which would have lowered their concentrations. Thus, we concluded that the process used to produce St ginger is the best way to produce ginger with a high 6-shogaol content and a small decrease in 6-gingerol, and such ginger can be identified according to its *a** value.

3. Mikage *et al*.[3] previously reported that the *a** value of steamed ginseng was higher than that of unprocessed ginseng. In this study, we obtained the same result for ginger, and Soh ginger can be distinguished from St ginger according to its *a** value, as indicated above. In addition, the *a** value of the H180 ginger was markedly increased compared with those of the Soh and St ginger after 60 minutes. Therefore, we found that the *a** value is a useful factor for evaluating the heating method used to produce a ginger sample. As for ginseng, a previous study found that the *b** value of steamed ginseng was higher than that of unprocessed ginseng;[3] however, we obtained the opposite result for ginger.

4. Although the change in the color of a ginger sample is not directly related to changes in its pungent compound contents, they are both induced by the heating process. In this study, we elucidated that the color and pungent compound contents of ginger are related to each other and found that the [S/G] value of ginger that

has been steamed or strongly heated can be estimated by analyzing its *a** value. Furthermore, *L** and *b** value of strongly heated ginger were also important factor to evaluate its [S/G] ratio.

In addition, we found that the *b** value of processed ginger was negatively correlated with its 6-shogaol content. Thus, the 6-shogaol content of processed ginger can be estimated by analyzing its *b** value, and the 6-gingerol and 6-shogaol contents of processed ginger can be obtained from the above two parameters (*a** and *b**). In addition, we found that *L** value also can indicate 6-shogaol content of the ginger subjected to steaming or strongly heating.

5. As for H100, its 6-gingerol and 6-shogaol contents hardly changed except for in the samples heated for 15 or 30 minutes. The 6-gingerol content of the ginger samples was lower heated for 30 minutes and its 6-shogaol content was higher heated for 15 minutes than those of the other samples. Although it was reported that 6-gingerol is converted to 6-shogaol during heating,[4,5] our results do not seem to agree with this finding. Yoshikawa *et al*.[14] reported that the levels of 6-gingerol and 6-shogaol do not only depend on the conversion of gingerol to shogaol, but are also influenced by other chemical reactions. Therefore, we consider that the levels of 6-gingerol and 6-shogaol will not be changed when fresh ginger is heated at 100℃ for 3 hours in normal conditions, but other reactions might occur, which requires further examination.

6. As for H180, the 6-gingerol and 6-shogaol contents of the ginger samples processed for 60 minutes, which were rich in water, were approximately equal to those of the unheated ginger, while the levels of these compounds changed markedly after 60 minutes. However, the color value of the H180 ginger began to change from the beginning of the heating process. Therefore, we consider that the large amount of water contained in fresh ginger might inhibit the dehydration reaction of 6-gingerol, although carbonizing occurs from the beginning of the heating process at 180℃.

7. We examined samples of Japanese ginger whereas commercial ginger products are mainly derived from Chinese ginger. However, the changes in the color values of Chinese ginger induced by the abovementioned processing techniques will be similar to those induced in Japanese ginger; therefore, we suggest that the color value is a suitable index for estimating the quality of processed ginger. While, there are two types of *kankyo* products sold in Japanese market, i.e., the peel is stripped off or not, thus that may affect the color value and we need further examination.

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