Ingestion of Coffee Polyphenols Improves a Scaly Skin Surface and the Recovery Rate of Skin Temperature after Cold Stress: A Randomized, Controlled Trial

Sachie UEDA1, Masanori TANAHASHI1, Yuko HIGAKI2, Kayoko IWATA1 and Yoshinori SUGIYAMA1

1Skin Care Products Research, Kao Corporation, 2–1–3 Bunka, Sumida-ku, Tokyo 131–8501, Japan
2Institute of Women’s Health, Tokyo Women’s Medical University, Tokyo 131–8501, Japan

(Received November 25, 2016)

Summary Coffee polyphenols (CPPs) derived from coffee beans have beneficial effects on blood pressure and vascular endothelial function. In addition, CPPs suppress ultraviolet light induced erythema. However, the effects of CPPs on dry skin and cutaneous vascular function have not been clarified. We investigated the effects of CPPs on dry skin and the recovery rate (RR) of skin temperature after a cold-stress test as a measure of vascular function in subjects with visible scaliness in a double-blind, placebo-controlled, randomized study. The subjects were divided into two groups, the CPP group and the Placebo group. In the CPP group, the subjects ingested a beverage containing 297.8 mg CPPs every day for 4 wk. The degree of skin dryness was assessed quantitatively using a Visioscan to evaluate skin scaliness and smoothness. A subjective evaluation using a visual analog scale (VAS) of skin smoothness was also used. As a result, the scaliness and smoothness of cheek skin was significantly improved after 4 wk in the CPP group compared to the Placebo group. The improvements of the VAS score on ‘skin smoothness’ and the RR were also observed in the CPP group but the difference was not statistically significant. However, when the CPP group was divided into subgroups of high RR and low RR, the improvement of the RR was significant in the low RR subgroup. In conclusion, our results suggest that CPPs improve skin scaliness and play a role in cutaneous blood flow regulation after cold stress.

Key Words coffee polyphenols, chlorogenic acids, recovery rate (RR), dry skin, scaliness

Polyphenols are found in a wide variety of plants. Fruits, vegetables and beverages, such as tea, wine and coffee, are considered to be important dietary sources of polyphenols (1). The effects of polyphenols on the body have been reported to include the inhibition of carcinogenesis (2), the relief of allergy symptoms (3) and antioxidant effects (4). The reported allergy relief effect of polyphenols involves the direct binding of polyphenols to allergens, the suppression of T-cell proliferation and the suppressed production of interleukins (ILs)-4, -5 and -13. Moreover, polyphenols, represented by catechin contained in green tea and cocoa and resveratrol in red wine, have been reported to have beneficial effects on the skin, particularly effects on ultraviolet (UV) light exposure (5) and on dry skin (6–8). The epigallocatechin-3-gallate (EGCG) contained in green tea suppressed erythema induced by UVB and the infiltration of white blood cells (5). Ingesting cocoa powder containing epigallocatechin was reported to improve skin scaliness and skin blood flow (6, 7). Ingesting green tea containing catechins improved various skin properties, including skin elasticity, hydration of the stratum corneum, transepidermal water loss and skin blood flow (8). Among those reports, Heinrich et al. (8) suggested that the effects of ingesting green tea containing catechins on skin properties results from the improved supply of nutrients and oxygen to the skin through enhanced circulation.

Coffee beans also contain polyphenols, comprising caffeic acid or ferulic acid linked by an ester bond to quinic acid (9), and these chlorogenic acids are known to have similar physiological activities. The daily ingestion of coffee containing approximately 300 mg coffee polyphenols (CPPs) continuously for 12 wk has been reported to improve blood pressure and vascular endothelial function and to reduce visceral fat (10–13). In addition, CPPs have been reported to decrease the hyperpigmentation of pigmented spots on the skin (14). The intake of CPPs is thus thought to have pleiotropic functions, but the effects of CPPs on dry skin remain unclear.

As mentioned above, some polyphenols have been reported to improve vascular function and skin properties. Furthermore, our recent studies showed that the recovery rate (RR) after cold stress, but not blood flow at a resting state, is associated with dry skin. The RR has also been shown to play a role in the deterioration of skin dryness from summer to winter (15). Similar effects can therefore be expected from CPPs, which have been shown to improve blood pressure and vascular endo-
The effects of CPPs on dry skin and blood flow regulation characterized by the RR of skin temperature after a cold-stress test in subjects who had visible scaly skin in a double-blind, placebo-controlled, randomized study. Reducing the scaliness of facial skin, which is always visible, is important in terms of esthetics. In a clinical setting, the cheek and perioral areas are important skin areas where scaliness is common, and reducing skin scaliness in those areas is recognized to be a clinically effective change. Thus, in this study, we examined the effects of CPPs on skin scaliness on the cheek and perioral areas of the face.

MATERIALS AND METHODS

Subjects and study design. The subjects of this study included healthy Japanese women between 25 and 35 y of age. This study was approved by the Ethics Committee of the Kao Corporation in accordance with the principles of the Declaration of Helsinki (Approval number: 13-24). In addition, subjects only participated after receiving a sufficient explanation of the purpose and content of the study and providing informed consent. This study used a double-blind, placebo-controlled, randomized design, and was carried out from October to December 2013. Healthy women who indicated they were concerned about skin dryness of their face in a self-evaluation, and who did not meet any of the exclusion criteria (Table 1), were recruited for this study. A total of 100 subjects were evaluated for scaly skin. The 40 subjects with the highest dryness scores were then chosen as subjects for this study, and were divided into two groups to ensure equal distributions of ages and skin scaliness scores, and underwent double-blinding. Subjects ingested either a beverage containing CPPs (297.8 mg/100 mL/d; the CPP group) or a beverage with no CPPs (the Placebo group) continuously for 4 wk. Subjects also started to ingest their beverage in the follicular phase as judged by the question, “How many days have passed since your last menstrual period started?,” to avoid any effects of the menstrual cycle. In addition, all subjects were instructed to maintain a normal lifestyle and were told to refrain from ingesting coffee, excessively exposing themselves to the sun, changing their cosmetics, changing exercise habits, or eating or drinking too much during the entire study period. Subjects were also asked to avoid ingesting alcohol the day prior to each measurement day and from shaving hair at the test areas from 1 wk before each measurement day until completion of the measurement.

Test beverage. CPPs were extracted from ground green coffee beans with boiling water. Caffeine was removed by activated carbon from the CPP extract. The composition analysis of CPPs was determined by high-performance liquid chromatography and showed that they included: CQAs (5-caffeoylquinic acid, 3-caffeoylquinic acid and 4-caffeoylquinic acid), FQAs (3-feruloylquinic acid, 4-feruloylquinic acid and 5-feruloylquinic acid) and di-CQAs (3,4-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid and 4,5-dicaffeoylquinic acid). The CPP beverage was prepared in such a way as to include 297.8 mg of the main components of CPPs (CQAs and FQAs), sweetener, sour seasoning and flavor in 100 mL water. The Placebo beverage was prepared using the same amounts of sweetener, sour seasoning and flavor but contained no CPPs. No difference in taste existed between the CPP beverage and the Placebo beverage. No caffeine was detected in either beverage.

Experimental conditions. Evaluations of scaly skin surface after washing with a cleanser were made after 15 min of acclimatization in a room with a temperature of 20±1˚C and a relative humidity (RH) of 40±5%. Measurements of skin temperature following cold water stress were done after 20–30 min of acclimatization in a room with a temperature of 24±1˚C and a RH of 50±5%.

Evaluation of scaly skin. Skin surface profiles were measured using a Visioscan VC98 (Courage + Khazaka Electronic GmbH, Koln, Germany), which is commonly used to evaluate scaly skin (16). Two different variables, skin evaluation of scaliness (SESC) and skin evaluation...
of smoothness (SESM), were calculated to characterize the skin surface using acquired images of a 15×17 mm area. To determine target areas beforehand, a separate test using a CPPs-containing beverage was performed. That test revealed that a remarkable improvement of scaliness was observed in the cheek and perioral areas (data not shown). Measurements of the conditions of the skin surface in this study were therefore made at the cheek (intersection of the outer corner of the eye and the nostril) and perioral (intersection of the outer corner of the eye and the corner of the mouth) areas.

**Visual analog scale (VAS) meter.** Subjective effects on the skin were analyzed using the VAS. The evaluation item was set as ‘skin smoothness.’ The evaluation method involved having each subject mark the current condition of their skin on a 100-mm VAS, where the right end indicated the best possible experience and the left end indicated the worst possible experience. The two groups were compared after analyzing changes from the baseline.

**Cold stress test (CST).** The CST was performed by a modified method as previously described (17). Thermal images were acquired using a Thermo Tracer TH9260 (Nippon Avionics, Tokyo, Japan). After capturing the dorsal aspect of the right hand immediately before the cold-water stress, the right hand was immersed for 1 min up to the wrist in cold water at 15˚C. The skin temperature on the dorsal aspect of the right hand was then captured immediately after and 10 min after the cold-water stress. The RR of the skin temperature following the cold-water stress was calculated using the following formula after analysis of the skin temperature below the nail at the fingertip on recorded thermal images:

\[
RR = \frac{(T_{10} - T_0) / (T_{bl} - T_0)}{100} \%
\]

where \(T_{bl}\) is the skin temperature immediately before the cold-water stress, \(T_0\) is the skin temperature immediately after the cold-water stress, and \(T_{10}\) is the skin temperature 10 min after the cold-water stress.

**Statistical analysis.** All measured values are shown as means ± standard deviation (SD). All statistical analyses were performed using SPSS Statistics version 23 software (IBM, Armonk, NY) after calculating the varia-

<table>
<thead>
<tr>
<th>Item</th>
<th>CPP (n=16)</th>
<th>Placebo (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>31.1±3.7</td>
<td>29.9±3.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>157.3±5.4</td>
<td>160.6±5.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.8±4.8</td>
<td>54.8±5.1</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>20.7±2.1</td>
<td>21.3±1.7</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>106.1±11.9</td>
<td>111.5±10.6</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>65.7±8.0</td>
<td>71.9±13.0</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>71.4±11.7</td>
<td>70.1±10.3</td>
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</table>

Values are reported as means ± SD.
tion from week 0. In addition, all statistical tests were two-tailed, with the level of significance set at 5%. All variables were compared using unpaired \( t \)-tests, and \( p \)-values for time effect and interaction (group-by-time) in repeated-measures analysis of variance were adjusted by the Bonferroni method. Fixing and statistical analyses of analysis sets were performed prior to releasing the double-blinding, in accordance with the analysis protocol approved by the Ethics Committee.

RESULTS

Thirty-one out of the 40 subjects completed the protocol and were included in the final analysis set (Fig. 1). No significant differences were seen in age, occupation, height, weight, body mass index or blood pressure between these 31 subjects divided into the CPP group and the Placebo group (Table 2).

Effects of CPPs on scaly skin

The effects of CPPs on scaly skin were evaluated using a Visioscan. This evaluation revealed that the SESC, an indicator of skin scaliness, of the cheek and perioral areas decreased significantly at 1 wk only in the CPP group: week 0, 0.36 ± 0.13; week 1, 0.26 ± 0.12 (\( p = 0.015 \), paired \( t \)-test) at the cheek; week 0, 0.47 ± 0.20; week 1, 0.33 ± 0.12 (\( p = 0.006 \), paired \( t \)-test) at the perioral area. A significant difference between the CPP group and the Placebo group was detected after 1 wk of ingestion, and this difference persisted until week 4 (cheek \( F_{1,29} = 8.80, p < 0.01 \); perioral area \( F_{1,29} = 7.0, p < 0.05 \); Fig. 2A). In addition, the SESM, an indicator of skin surface smoothness, of the cheek and perioral areas decreased significantly at week 4 only in the CPP group: week 0, 22.6 ± 2.9; week 4, 13.5 ± 2.4 (\( p = 0.006 \), paired \( t \)-test) at the cheek; week 0, 21.2 ± 2.6; week 4, 16.5 ± 2.1 (\( p = 0.002 \), paired \( t \)-test) at the perioral area.

Fig. 3. Changes in ‘skin smoothness’ following the ingestion of CPPs. ‘Skin smoothness’ was measured using VAS at weeks 0, 1, 2 and 4 during the ingestion period. Changes in these measurements relative to the baseline level (\( \Delta \)) are shown: ● indicates the CPP group (\( n = 16 \)); ○ indicates the Placebo group (\( n = 15 \)). Error bars=SD.

Table 3. Changes in fingertip skin temperature during 10 min in 15˚C water.

<table>
<thead>
<tr>
<th></th>
<th>CPP (( n = 16 ))</th>
<th>Placebo (( n = 14 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>week 0</td>
<td>week 1</td>
</tr>
<tr>
<td>( T_{bl} ) (˚C)</td>
<td>32.0±1.1</td>
<td>30.4±2.3</td>
</tr>
<tr>
<td>( T_{0} ) (˚C)</td>
<td>19.7±0.5</td>
<td>19.7±0.6</td>
</tr>
<tr>
<td>( T_{10} ) (˚C)</td>
<td>29.4±4.4</td>
<td>29.4±3.7</td>
</tr>
<tr>
<td>( T_{0}−T_{bl} ) (˚C)</td>
<td>-12.3±0.9</td>
<td>-10.7±2.0</td>
</tr>
<tr>
<td>( T_{10}−T_{bl} ) (˚C)</td>
<td>-2.5±3.8</td>
<td>-1.1±2.7</td>
</tr>
<tr>
<td>RR (%)</td>
<td>78.2±33.6</td>
<td>89.2±30.4</td>
</tr>
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Values represent means±SD.
CPPs Improve Skin Scaliness and the RR of Skin Temperature after Cold Stress

20.2 ± 2.0 (p = 0.006, paired t-test) at the cheek; week 0, 25.7 ± 3.6; week 4, 23.1 ± 2.8 (p = 0.003, paired t-test) at the perioral area. A significant difference between the CPP group and the Placebo group was detected after 4 wk of beverage ingestion, in the cheek area (p < 0.05; Fig. 2B). In the perioral area, the difference between the two groups was not significant. These findings indicated that scaly skin is improved by the ingestion of CPPs.

Subjective effects of CPPs on dry skin using VAS

The subjective effects of CPPs on skin with regard to ‘skin smoothness’ as evaluated using the VAS revealed that the CPP group tended to have a stronger perception of improved ‘skin smoothness’ than the Placebo group, but it was not significant (F(1,29) = 3.3, p > 0.1; Fig. 3).

Effects of CPPs on the RR after the CST

The CST was performed to investigate the effects of CPPs on cutaneous vascular function. The RR before beverage ingestion (week 0) and at 1 and 4 wk after beverage ingestion was calculated according to changes in skin temperature (Table 3; RR analysis was not possible in 1 subject due to equipment problems). Although significant differences between the two groups were not detected, a decrease from the initial value was seen in the Placebo group at week 4 (20.2 ± 2.0%), whereas the initial state was maintained at week 4 in the CPP group (Fig. 4A; p = 0.08).

Scaly skin in the low RR group

Analysis of subjects with a lower RR after the CST was undertaken to clarify the potential effects of CPPs on cutaneous vascular function. For this analysis, subjects with poor cutaneous vascular function were defined as those lower than the median RR of the final analysis set (90.5%) before beverage ingestion (week 0). Subjects with an initially low RR included 7 individuals in the CPP group and 8 individuals in the Placebo group (a total of 15 subjects). The results of RR analysis of those two subgroups revealed that the RR-increasing effects of CPPs were more pronounced than in the comparison of the final analysis set, and the difference between these two subgroups was significant (F(1,14) = 11.6, p < 0.01) at 4 wk (Fig. 4B). These two subgroups were also compared regarding the effects of CPPs on scaly skin. That comparison revealed that improvements were more pronounced than during comparison of the final analysis set in all parameters, including SESC, SESM and ‘skin smoothness’ (Fig. 5).

DISCUSSION

In this study we examined the effects of CPPs on scaly skin and the RR of skin temperature after a cold stress which represented its vascular function. Changes in temperature and RH during the period of this study associated with seasonal fluctuations were: week 0, 13.9 ± 1.9°C and 56.5 ± 13.2% RH; week 1, 11.6 ± 1.7°C and 51.3 ± 10.7% RH; and week 4, 8.9 ± 2.5°C and 61.6 ± 15.3% RH (http://www.jma.go.jp/jma/menu/ menureport.html). Decreases in temperature and humidity have already been reported as potential causes of dry skin (18). The effects of CPPs on SESC and SESM were observed at 1 and 4 wk after ingestion, and the CPPs ingestion was counter to any seasonal fluctuation-related change in skin scaliness. To elucidate the mecha-
nisms underlying these early effects of CPPs, especially those observed at 1 wk, further studies about the effects of CPPs on various components secreted to the skin surface and on cutaneous oxygen saturation of hemoglobin are necessary.

A decrease in the outside temperature has been reported to lower the RR (19). The RR in the Placebo group was also slightly decreased after 4 wk of ingestion in this study. The improvement in RR was particularly pronounced in subjects with an initially low RR (Fig. 4B). This finding suggests that the RR was improved in the CPP group to counter any seasonal fluctuation. CPPs are already known to enhance the production of nitric oxide, which is a vasodilator (13). This suggests that the improvement in RR noted in this study may have resulted from the vasodilatory effects of CPPs. Moreover, sympathetic vasoconstrictor nerves are densely distributed in the hand (20), and changes arising from local cooling of the hand have been reported to show effects on efferent sympathetic nerves (21–23). CPPs may improve the RR by inhibiting sympathetic nervous activity.

A recent study by our group revealed that the RR after CST correlates with dry skin (15). Similar relationships between the RR and dry skin parameters, SESC and SESM, were revealed at both the cheek and the perioral areas in this study (ex.: The RR correlated with SESC of the periorial area at 0 wk; r = −0.33, p = 0.08, n = 30 of all subjects.). Our results of comparing the low-RR CPP subgroup with the low-RR Placebo subgroup revealed that significant improvements were observed in the low-RR CPP subgroup in all parameters, including SESC and SESM, in both the cheek and the perioral areas, and in ‘skin smoothness,’ compared with the final analysis set (Fig. 5). Thus, our results suggest that the effects of CPPs on skin scaliness occur concomitant with the improvement of the RR. It is well known that blood plays an important role in supplying the nutrients and oxygen necessary to maintain skin tissue homeostasis. In addition, catechin and α-glucosylhesperidin are known to improve the condition of the skin by improving blood flow and the RR (8, 24). The CPP-mediated improvement of the RR suggests that vascular reactivity after cold stress may be involved in its efficacy on dry skin conditions. Further studies to explore how the RR as an index of vascular reactivity affects skin physiology and functions would help clarify the mechanisms underlying the effects of CPPs on dry skin. In particular, analyses of the microvascular reactivity of facial skin after short- and long-term ingestion of CPPs will help to clarify the connection of vascular reactivity with skin properties.

REFERENCES


