

Improvement of Skin Moisture Capacity through Dietary Beauty Supplement Containing Ceramides Derived from Rice

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Abstract A placebo-controlled double-blind ingestion study of a beauty supplement containing rice-derived ceramide was performed. Thirty three subjects who always tended to have rough skin due to dryness participated in the study. Dermatological diagnosis by physicians showed that the supplement significantly improved dryness and itching of the skin. On measurement of water content in the skin, the supplement was shown to significantly increase water content in the skin. On microscopic three-dimensional analysis of the epidermis, the supplement was shown to improve smoothness, exfoliation, and short-term ingestion of the supplement containing rice derived ceramide, which is very effective as skin beautifying food.

Keywords: rice derived ceramide, skin, sphingolipid, beauty supplement, skin beautifying food

Introduction

The epidermis, which is the outermost layer of the skin, protects the human body from the external environment, and the stratum corneum, which is the uppermost part of the epidermis, is an epidermal barrier and inhibits moisture evaporation and loss to prevent skin dryness (1, 2). Intercellular lipids play an important role in the skin barrier, and of these lipids, ceramide (50%), cholesterol (25%) and fatty acid (10%) collectively make up 85% of the epidermal barrier, thus making up its majority (3). Ceramide, which is the major component of keratinocyte lipid, is a type of sphingolipid linked to fatty acids in sphingosine, which also serves an important role in the skin barrier (4,5).

Recent findings show that sphingolipids contained in the stratum corneum of the skin block moisture infiltration, bacteria and ultraviolet ray infiltration from the outside, and thus prevents skin diseases such as senile psoriasis and atopic dermatitis (6-8). Due to this knowledge, sphingolipids such as ceramide have entered the market as a skin-care factor for hand cream, and demand for sphingolipid-related products is also increasing in the field of food manufacturing. As a result, sphingolipids are a major focus of functional foods (9).

Rice is one of the major crops in Southeast Asian countries as well as of South Korea, and is one of the grains that has been a staple food since ancient times. Recently, many studies have been conducted on the physiologically active substances contained in rice and rice bran, and such substances have been extensively used in pharmaceuticals, health foods, food additives, and cosmetic raw materials after extraction of the effective ingredients (6, 9).

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Conventional ceramides extracted from rice, rice bran, or edible plants have been widely used as a skin moisturizing agent. However, the dry skin conditions observed in atopic dermatitis is accompanied by loss of natural moisturizing factors and keratinocytes. Due to the change in the arrangement of interstitial lipids, when ceramide is administered orally, it is absorbed by the digestive tract and enters the bloodstream, which is then directly transferred to the stratum corneum through capillary blood vessels. The effect from oral administration has been found to be more significant (10).

Many moisturizers using synthetic ceramides have already been released, but there is a growing interest in natural ceramides that are more similar to the ceramides that are naturally produced in human skin. Among them are animal and synthetic ceramides. Due to the possibility of infection with PRION (proteinaceous infectious particle) viruses, natural ceramides of plant origin such as rice, soybean, and corn are attracting attention and are being used widely (10). Rice extract ceramide, a new food material with skin moisturizing and whitening effects, which has proven its safety and efficacy through various studies, helps modern people who are exposed to harmful environmental conditions maintain healthy skin, and contribute to good health.

Deterioration of proper skin function is affected by both internal and external factors such as ultraviolet rays, environmental pollution, mental stress, and the process of ageing. One factor in particular, ultraviolet rays, cause wrinkles, a reduction in skin elasticity, hyperpigmentation, and damage to the skin barrier causing moisture loss, and rough or dry outer skin layers. (11-13). Therefore, in order to maintain healthy skin, retaining moisture content is imperative, meaning that maintaining moisture levels in the skin is key. In addition, acne, psoriasis, and especially atopic dermatitis (one of the three major skin diseases) have become a major target for health and beauty products, and interest in controlling the skin barrier function of skin care products has been gradually increasing (14). However, existing clinical research evaluations of laboratory products that are expected to provide a skin-toning effect, including topical agents and cosmetics, relies on classic dermatological diagnoses. Therefore, the research evaluation was heavily dependent on diagnoses by physicians, making it difficult to completely eliminate difference of opinion by several physicians working together in a large-scale research environment.

The purpose of this study was to evaluate the skin condition after oral ingestion of skin cosmetic supplements containing rice-derived ceramides for subjects who suffered from chronic dry skin, but who have not received prior oral or topical treatments. The epidermis was evaluated on the basis of a dermatologist's diagnosis, skin moisture content, acidity, oil content, and a computer image analysis system.

Materials and Methods

Selection of Research Subjects

This study selected 46 subjects between the ages of 19 to 55 with skin that had become rough and uncomfortable due to chronic dry skin, but have been untreated either orally or topically prior to this study. Of the selected subjects, those with skin moisture levels at 50% or higher were excluded, thus a total of 37 subjects participated in the study. Four subjects dropped out after the study began for personal reasons (i.e., forgot to bring supplements and did not return to the experiment). A total of 33 subjects (6 males, 27 females) completed the final evaluation. Before the study was conducted, the subjects were provided a thorough explanation of the study's purpose, duration, method, compliance, and expected effect. Subjects then signed a written consent form. This study was approved by the Institutional Review Board (IRB, Tokyo, Japan) of Miyagawa Clinic.

Rice Extract Ceramide: Raw Material Extraction and Preparation Method

The rice extract ceramide raw material is a ceramide concentrate (40%) made by 1) extracting rice bran or rice embryo using 99% ethanol, 2) concentrating, refining, sterilizing and filtering the raw ceramide concentrate (40%), 3) adding a food additive, cyclodextrin (60%), 4) then spray-drying for use. The formulation used was Oryza emulsifier, a soft capsule (1.2 mg/day of ceramide containing rice-derived sphingoglycolipids) and the test preparation used 20 mg of ceramide per capsule. The placebo formulation had the same shape and flavor (odorless) as the experimental adjuvant, and the supplement containing rice ceramide contained 3.35% glucosylceramide.

Research Design

This study used a randomized, double-blind, placebo-controlled research design study of oral supplementation with rice-derived ceramide over the course of 6 weeks. The average age of the participants was 25.1 ± 7.8 . Among the 33 subjects who

completed the study, 17 participants were placed in the ceramide group, and 16 participants were placed in the placebo group. The subjects were divided into two groups: the test group and the control group, where the test group was administered the test pill, and the control group was administered a placebo. Each group was instructed to administer their respective pills twice daily (40 mg total daily intake) with water for 6 weeks. Skin tests were performed before administration, 3 weeks into administration, and 6 weeks into administration.

Dermatological Diagnosis

General skin conditions such as itching, dryness, redness, corrosion, flaking, puffiness, blistering, and swelling, along with conditions specific to facial skin such as cosmetic rash, dryness, redness, and cosmetic product longevity, were rated on a 4-point scale, ranging from 0 (no symptoms) to 3 (severe). The mean value of the four levels was arbitrarily indicated, and a lower score indicated a lowered severity of symptoms. All symptoms, both general skin conditions and those specific to the face, were evaluated and categorized as general skin conditions. In each evaluation, anchor points were prepared and evaluated by a physician certified by the Japanese Society for Dermatology.

Skin Analysis and Methods

Skin conditions were measured using a non-invasive method in order to check effectiveness on the skin when supplemented with rice-derived ceramide. To control for environmental bias, measurement was performed under specific conditions (Temp: 18-22 °C, Humidity: 44-45%) for 30 minutes, then water content, oil content, pH, and skin surface analysis were measured.

Measurement Site

Moisture content, oil content, pH, and transdermal water loss were measured 1 cm below the left eye, on the inner left arm (3 cm above the elbow), and on the back of the neck (3 cm below the spinous process).

Skin Moisture Content

The moisture content of the skin was measured using a Corneometer CM825 (Courage & Khazaka, Köln, Germany), which measures the moisture content of the skin by measuring capacitance through the stratum corneum. A probe of 16 mm in diameter was applied to the skin at the

measurement site with a constant pressure, then the capacitance at the contact point was measured. An average was recorded from the three measurements taken from under the left eye, inside of the left arm, and back of neck.

Skin Oil Content (Sebum Amount)

The Sebumeter SM810 (Courage & Khazaka) was used to measure skin oil content (sebum amount). This measuring instrument uses a special tape that absorbs only oil, and the oil content is measured from the change of optical transparency. This study attached a lipid-absorbent tape under the left eye, inside of the left arm, and back of the neck, let the tape absorb for 30 seconds each, then the amount of sebum ($\mu\text{g}/\text{cm}^2$) was measured.

Skin pH

The Skin-pH-meter pH900 (Courage & Khazaka) was used to measure skin pH. This device connects an electrode to the skin's surface through an ion-permeable membrane adjacent to the glass membrane and the acidity is measured electrochemically (noninvasive). The pH was measured by dividing the cylindrical hyaline bar filled with the buffer into the skin under the left eye, inside of the left arm, and back of the neck. To maintain the same environmental conditions, the measurements were made under specific conditions (temperature: 18-22 °C, humidity: 45-55%). Before taking measurements, subjects waited for 30 minutes or more while in a rested state. Subjects were not allowed to apply cosmetics for 60 minutes prior to their measurements. Subjects who arrived with cosmetics applied were required to remove all cosmetic products from the skin during the wait time, and waited 60 minutes before taking measurements.

3D Microscopic Skin Epidermal Analysis

Skin epidermal analytical measurements were performed with the Skin Visiometer SV600 software (Courage & Khazaka), a computer-based image analysis system. Measurements were made under the left eye, inside the left arm, and back of the neck. When the surface of the skin is irradiated by a special ultraviolet light source, the image is captured and digitized by a high performance CCD (charge couple device) camera for evaluation. Multivariable analysis was performed for many of the clinical findings, and the following factors were used as variables.

Skin Elasticity Index (SEsm)

The skin elasticity index is calculated by the average value of the

width and depth of observed wrinkles. A lower value indicates that the skin is more elastic.

$$SE_{sm} = (Co - Cu) \times (F_{mx} - F_{my}) \times K$$

F_{mx}: average width of furrows for the row analysis

F_{my}: average width of furrows for the column analysis

Co: right frontier of the histogram whose calculation is based on a set-up values

Cu: left frontier of the histogram whose calculation is based on a set-up values

K: factor

Skin Roughness Index (SEr)

The skin roughness index was calculated by the ratio of the dark parts to the whole. A higher value indicates rougher skin.

$$SEr = I / (N_x - N_y) \times 100$$

I: counter whose start value is 0 and which is incremented each time the gray value of the current point is smaller than the threshold issued from the set-up programs

N_x: amount of points per row

N_y: amount of points per column

Skin Exfoliation Index (SEsc)

The skin exfoliation index indicates the degree of dryness of the stratum corneum. An exfoliated area of the skin shows brighter on the image than regular skin, and the ratio of bright areas to the whole is calculated to find the index value. A decrease in value indicates more moisture in the skin and a lower rate of exfoliation.

$$SEsc = I / (N_x - N_y) \times 100$$

I: counter whose start value is 0 and which is incremented each time the gray value of the current point is bigger than the threshold issued from the set-up programs

N_x: amount of points per row

N_y: amount of points per column

Skin Wrinkle Index (SEw)

The skin wrinkle index shows the number and width of the horizontal and vertical textures or wrinkles of the skin. The larger the number, the more wrinkles are present.

$$SEw = F_{mx} \times F_{my} / (F_{ax} \times F_{ay}) \times F_{ay} / F_{ax} \times K$$

F_{ax}: amount of furrows for the row analysis

F_{mx}: average width of furrows for the row analysis

F_{ay}: amount of furrows for the column analysis

F_{my}: average width of furrows for the column analysis

K: factor

Kurtosis (Correction K)

The kurtosis constant is an index value indicating the flexibility of the skin and gives a quality value for skin color distribution. As the numerical value moves closer to 0, the frequency distribution of the color represents a gentler curve and thus ideal skin tone.

The equation for obtaining the kurtosis of the sample is as follows:

$$K = (\sum (X - \mu)^4 / (n - 1) \sigma^4) - 3$$

μ: Average

σ: Standard deviation

n-1: Use n instead to obtain the unbiased value because it uses the mean and standard deviation of the sample.

Statistical Analysis

All measurements were statistically processed using SPSS package 12 for Windows (Statistical Package for the Social Science, SPSS Inc., IL, USA). All measurements were expressed as mean ± S.E.. The Wilcoxon signed ranks test was used before and after oral administration to each group, and the Mann-Whitney test was used to compare the initial value of each group and the changes before and after administration. P < 0.01 and p < 0.05 for all tests were statistically significant.

Results and Discussion

General Characteristics of the Subjects

Participants in this study did not differ significantly in background history, including skin problems, sleep time and regularity, exposure to direct sunlight (hours per day), menstrual irregularities, occupation, or drinking habits (Table 1).

General Symptom Diagnosis

The dermatological skin diagnosis results before and after administration are shown in Table 2. Each number randomly represented the mean value of four levels, from 0 (asymptomatic) to 3 (severe). In the ceramide group, there was a significant improvement in facial symptoms after 3 and 6 weeks of administration compared with their initial symptoms, before administration in terms of facial skin dryness, redness, and cosmetic product longevity. In contrast, in the placebo group, dryness and redness significantly improved compared with before administration, but cosmetic product longevity did not significantly improve. Regarding general symptoms, significant improvements were observed in itchiness, dryness, and redness in both groups. Also for general symptoms, there was no improvement in the placebo group but significant improvement in the ceramide group. Symptom improvements are shown in Table 3. The improvement rate (%) for skin-related diagnosis was calculated by the following method:

Improvement rate (%) = (number of subjects improved or markedly improved) / number of subjects in each group × 100

Table 1. Subject backgrounds

	Ceramide group	Placebo group
Number of subjects	17	16
Age ¹⁾	24.9±5.82 ²⁾	25.3±9.81
Height (cm)	162.5±7.45	162.2±8.41
Body weight (kg)	53.9±7.61	56.3±10.0
BMI	20.3±1.60	21.3±2.32
Number of smokers	3	3

¹⁾No significant differences were observed in any of the background items including other factors of skin trouble, time and regularity of sleep, time of exposure to direct sunlight (h/day), irregular menstruation, occupation, or alcohol drinking habit.

²⁾Mann-Whitney test: not significant

Comparing before administration, after 6 weeks of administration, “markedly improved” is when the symptom has improved 2 levels or disappeared entirely, “improved” is when the symptom has improved 1 level, “aggravated” when the symptom has worsened 1 level, and “markedly aggravated” when the symptom has worsened 2 levels. As a result, both experimental adjuvants were effective for skin dryness, redness, and cosmetic product longevity, but all of these symptomatic improvements were more effective in the ceramide group than in the placebo group. Although improvement in general symptoms was observed in both groups, improvement was greater among all symptoms in the ceramide group. The results of the diagnostic criteria for 11 skin-related factors were converted into percentages, resulting in 43.8% in the placebo group and 64.7% in the ceramide group. The ceramide group showed results 20% higher than the placebo group.

Skin Moisture Content

The moisture content of the stratum corneum is a factor that indicates the character of the skin barrier.

It is well known that increasing the moisture content of the stratum corneum through the skin barrier increases percutaneous absorption (15). The minimum moisture content of the stratum corneum to maintain normal skin is about 10%, and the moisture content of the stratum corneum in normal skin is 15-40% (16). The stratum corneum itself contains about 30% water, of which 10% is found in lipids and the remaining 20% in keratin (17). Table 4 shows changes in skin moisture content after the administration of rice-derived ceramide supplements. In the placebo group, there was no significant change in the moisture content and acidity (pH) compared to before administration. Whereas in the ceramide group, 3 weeks on the back of neck, and after 6 weeks under

the left eye, on the left forearm, and back of neck, moisture content significantly increased when compared to before administration. Similar results to this study were shown in Asai and Miyachi (10), in which that corn-derived ceramides were orally administered for 3 weeks and then moisture content of the stratum corneum of the leg was measured. In the placebo group (141%), and in the ceramide 20 mg group and ceramide 40 mg group, moisture content significantly increased (290% and 394%, respectively) when compared with the placebo group ($p < 0.05$). As the result of 3 weeks of transdermal application of rice-derived ceramide, the placebo group (before administration at 111%), the resulting 141% ($p < 0.05$) shows that in both studies there was a significant increases (10). These results suggest that these two plant-based ceramides show some promise as orally administered as well as transdermal skin moisturizers.

Skin Oil Content and pH

There is a dynamic relationship between the moisture entering through the stratum corneum and the moisture content within the stratum corneum, where moisture binding capacity and water retention are important (18). The pH of the skin surface is acidic and the acidic pH is very important for the homeostasis of the skin barrier (19-21). In the recovery period after skin barrier damage, an acidic pH of the skin shows normal skin barrier recovery, whereas at neutral or alkaline pH, recovery of the skin barrier is delayed (22). Table 4 shows changes in oil content and pH after supplementation with rice-derived ceramide. With exception for under left eye skin, the oil content for most subjects was 0, so from the second test and onward the left forearm and back of neck skin measurements were excluded. In both groups, oil content changes under the left eye were not significant. There was no significant change in pH in both groups.

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Table 2. Results of dermatological diagnosis before and after ingestion of the test food

		Ceramide group				Placebo group			
		Number of subjects with symptoms	0 week	3 weeks	6 weeks	Number of subjects with symptoms	0 week	3 weeks	6 weeks
Face	Cosmetic rash	4	1.25±0.001 ¹⁾	1.00±0.021	1.00±0.001	3	1.00±0.001	1.00±0.031	1.00±0.021
	Dryness	17	2.00±0.011	1.29±0.001 ^{**2)}	1.18±0.008 ^{**}	16	2.13±0.002	0.69±0.021*	1.63±0.001 ^{**}
	Flush	14	1.86±0.018	1.29±0.008 ^{**}	1.21±0.021 ^{**}	15	1.93±0.009	1.53±0.025*	1.47±0.008*
	Holding of cosmetic	8	1.88±0.007	1.13±0.011*	1.00±0.011*	5	1.40±0.007	1.20±0.008	1.20±0.001
General	Itching	17	1.65±0.018	1.24±0.005*	0.94±0.009 ^{**}	12	1.92±0.001	1.50±0.002	1.17±0.011 ^{**}
	Dryness	17	2.18±0.002	1.47±0.007 ^{**}	1.18±0.021 ^{**}	16	2.00±0.011	1.44±0.004	1.38±0.021*
	Flush	7	1.71±0.005	1.29±0.001	0.86±0.011*	10	1.80±0.021	1.30±0.011*	1.20±0.009*
	Erosion	2	2.00±0.001	1.00±0.021	0.00±0.001	3	2.33±0.009	2.00±0.051	2.00±0.011
	Squamation	4	1.50±0.021	1.25±0.021	0.75±0.001	5	1.80±0.001	1.60±0.031	1.60±0.001
	Papules	3	1.33±0.021	1.33±0.009	1.33±0.002	4	1.75±0.005	1.50±0.011	1.75±0.009
	Blebs	2	1.50±0.011	1.50±0.015	1.50±0.011	2	1.50±0.005	1.50±0.001	2.00±0.011
The value represents the mean in each group. (non-parametric analysis was employed for statistical analysis) 0 (no symptoms) -1 (mild); -2									
Overall		17	1.71±0.001	1.24±0.008*	1.00±0.021 ^{**}	16	1.69±0.021	1.25±0.012	1.31±0.001
¹⁾	Swelling	0	-	-	-	3	2.01±0.001	1.67±0.008	1.67±0.021

(moderate); -3 (severe)

²⁾Significant difference from that of baseline Wilcoxon test: * $p < 0.05$, ** $p < 0.01$

Table 3. Improvement rate of each symptom

Symptoms	Test food	Total number of subjects with symptoms	Improvement rating					Improvement rate (% Improved or better)
			Markedly improved	Improved	Unchanged	Aggravated	Markedly aggravated	
Facial symptoms								
Cosmetic rash	Ceramide	4	0	1	3	0	0	25.0
	Placebo	3	0	0	3	0	0	0.0
Facial dryness	Ceramide	17	3	8	6	0	0	64.7
	Placebo	16	0	8	8	0	0	50.0
Facial flush	Ceramide	14	2	8	2	2	0	71.4
	Placebo	15	2	3	10	0	0	33.3
Holding of cosmetic	Ceramide	8	2	3	3	0	0	62.5
	Placebo	11	0	1	4	0	0	9.1
Somatic symptoms								
Itching	Ceramide	17	5	4	8	0	0	52.9
	Placebo	12	4	1	7	0	0	41.7
Dryness	Ceramide	17	6	5	6	0	0	64.7
	Placebo	16	1	8	7	0	0	56.3
Flush	Ceramide	6	2	2	2	0	0	66.7
	Placebo	10	2	3	5	0	0	50.0
Erosion	Ceramide	2	2	0	0	0	0	100.0
	Placebo	3	0	1	2	0	0	33.3
Squamation	Ceramide	4	2	1	0	1	0	75.0
	Placebo	5	0	1	4	0	0	20.0
Papules	Ceramide	3	0	0	3	0	0	0.0
	Placebo	4	0	1	2	1	0	25.0
Blebs	Ceramide	2	0	1	0	1	0	50.0
	Placebo	2	0	0	1	1	0	0.0
Overall	Ceramide	17	3	8	5	1	0	64.7
	Placebo	16	0	7	8	1	0	43.8

Skin Epidermal Analysis

The relationship between the water loss of the epidermis and the moisture content of the stratum corneum is not a simple one. In normal skin, the moisture content of the stratum corneum is high, and the amount of water loss is also high (23). Table 5 shows the change of each variable in image analysis using the Skin Visiometer. A significant improvement was observed in the neck area, in terms of general skin flexibility of kurtosis, of the ceramide group, and no significant change was observed in the placebo group. The skin elasticity index, SE_{sm}, calculated by the depth, width, and number of wrinkles, was significantly improved in the neck area of the ceramide group, which indicates recovery of skin flexibility. In contrast, no significant changes were observed in the placebo group. The skin roughness index (SE_r) for the ceramide group showed significant improvement in the area under the left eye and neck after 6 weeks of administration compared with before administration. Similarly, the keratodermal drying index (SE_{sc}) showed significant improvement in all measured

areas. In contrast, no significant improvement was observed in the placebo group. The skin wrinkle index (SE_w) showed significantly improvement in the under left eye area after 3 weeks of administration in the ceramide group, but significant changes were not observed in other measured areas.

Corn-derived ceramides were administered orally for 3 weeks, and transdermal water loss of the stratum corneum was measured by Skicon-200 and Tewameter. Compared to the placebo group (69%), when 20 mg of ceramides were administered to the test group, water loss was contained to 33%, and when 40 mg were administered to the test group, water loss was contained to (14%, $p < 0.05$). Transdermal administration of rice-derived ceramide for 3 weeks showed transdermal water loss up to 23% of the baseline value compared to the placebo group (39%, $p < 0.01$) (10). These results suggest that plant-derived ceramide is promising as a skin moisturizer in both oral and topical administrations. Other reports observed that percutaneous water loss upon oral administration of

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glucosylceramide in atopic eczema patients was significantly reduced ($p < 0.05$) compared to the baseline at 2, 4, and 8 weeks after administration. In addition, percutaneous water loss in the inner left elbow decreased significantly ($p < 0.05$) after 4 and 8 weeks of glucosylceramide administration (24). The decrease in the amount of percutaneous water loss is due to the fact that the packing density of each layer during the administration period was increased. The results of this study show that food supplements containing rice-derived ceramides not only increased skin moisture content, but also reduced skin dryness, and improved the condition of dry skin.

Summary

A placebo-controlled, double-blind study on the intake of cosmetic supplements containing rice-derived ceramide was conducted on 33 subjects with pre-existing rough skin caused by dryness. After 6 weeks of administration, the dermatologic diagnosis showed improvements in both the placebo and ceramide groups in terms of dryness, redness, cosmetic product longevity, and itchiness. The placebo group showed a 43.8% improvement rate, whereas the ceramide group showed 64.7% improvement. The results of

moisture content, oil content and pH measurements showed no significant changes for oil content and pH in both placebo and ceramide groups. However, no significant changes in moisture content were observed in the placebo group, but a significant increase in moisture content was observed in the ceramide group after 6 weeks. According to the results of analysis by 3-D microspheres, the ceramide group showed significant improvement in kurtosis, flexibility index (SEsm), roughness index (SEr), keratin and exfoliation index (SEsc) and wrinkle index (SEw). No significant changes were observed in the placebo group. This is in contrast to dermatologic diagnosis showing a clear placebo effect in this double-blind study. In addition to observations by physicians, these objective scientific measurements have demonstrated that ceramide is effective in improving skin dryness and roughness, and oral administration has shown to be effective. These results show that long-term intake of rice-derived ceramide adjuvant is effective in maintaining moisture and flexibility in the skin, and is an effective skincare supplement.

Table 4. Water content, pH, and oil content before and after ingestion of the test food

		Ceramide group (n=17)		
		0 week	3 weeks	6 weeks
Water content (%)	Below the left eye	43.2±5.51 ¹⁾	48.0±14.32	52.2±12.12** ²⁾
	Left forearm	37.0±5.63	41.1±11.00	43.2±35.71**
	Dorsal neck	43.5±10.82	51.2±11.76**	55.9±11.12**
Acidity (pH)	Below the left eye	5.8±0.71	5.6±0.61	5.8±0.54
	Left forearm	5.5±0.50	5.5±0.62	5.8±0.52
	Dorsal neck	2.9±1.16	5.5±0.51	5.4±0.41
Oil content (%)	Below the left eye	42.3±34.87	49.9±35.12	38.1±25.91
		Placebo group (n=16)		
		0 week	3 weeks	6 weeks
Water content (%)	Below the left eye	43.4±5.43	43.2±9.22	41.7±9.42
	Left forearm	35.7±5.61	37.7±7.00	35.7±9.01
	Dorsal neck	49.1±8.82	51.0±10.48	56.1±20.51
Acidity (pH)	Below the left eye	5.9±0.89	5.8±0.61	5.9±0.73
	Left forearm	5.5±1.00	5.8±0.61	5.9±0.72
	Dorsal neck	5.5±1.00	5.6±0.82	5.9±0.52
Oil content (%)	Below the left eye	58.4±55.81	29.5±22.03	40.8±33.35

¹⁾Each value represents the mean±S.E. (non-parametric analysis was employed for statistical analysis)²⁾Significant difference from that of baseline Wilcoxon test: ***p*<0.01**Table 5. Parameter values measured by Skin Visiometer before and after ingestion of the test food**

		Ceramide group			Placebo group		
		0 week	3 weeks	6 weeks	0 week	3 weeks	6 weeks
Kurtosis ³⁾	Below the left eye	0.38±0.011 ¹⁾	0.37±0.001	0.35±0.009	0.39±0.021	0.38±0.021	0.38±0.009
	Left forearm	0.35±0.021	0.39±0.011	0.40±0.011	0.43±0.009	0.43±0.001	0.40±0.001
	Dorsal neck	0.40±0.009	0.40±0.001	0.30±0.011* ²⁾	0.40±0.021	0.40±0.004	0.40±0.021
SE sm ⁴⁾	Below the left eye	377.4±55.27	364.4±49.87	342.1±36.14	368.0±40.75	354.1±62.34	347.7±29.98
	Left forearm	339.4±62.35	304.8±59.62	308.5±56.25	326.1±49.24	317.3±72.69	334.2±87.91
	Dorsal neck	386.8±95.58	327.8±58.68*	333.1±35.97*	355.2±75.36	349.2±56.27	354.5±45.27
SE r	Below the left eye	0.29±0.021	0.26±0.009	0.25±0.009*	0.30±0.021	0.31±0.011	0.30±0.001
	Left forearm	0.26±0.011	0.20±0.001	0.16±0.001	0.31±0.011	0.26±0.011	0.25±0.008
	Dorsal neck	0.18±0.001	0.15±0.002	0.14±0.009*	0.31±0.001	0.30±0.011	0.30±0.008
SE sc	Below the left eye	49.6±10.25	47.6±5.61*	46.8±12.3*	46.6±8.34	46.8±10.68	46.6±10.38
	Left forearm	48.9±9.61	47.9±11.21*	47.6±10.51*	48.3±9.28	48.9±8.99	48.4±10.04
	Dorsal neck	46.1±8.92	44.5±9.91*	42.9±8.79*	46.4±10.01	46.9±10.15	46.4±9.91
SE w	Below the left eye	36.1±9.91	32.3±10.01*	33.9±9.02	36.0±8.64	33.0±9.31	35.5±10.02
	Left forearm	26.7±5.25	24.7±9.98	27.1±8.59	27.5±7.91	24.5±8.48	27.7±8.99
	Dorsal neck	28.4±4.31	24.7±9.87	26.1±7.92	28.2±10.00	25.9±9.00	30.6±9.72

¹⁾The value represent the mean in each group.²⁾Significant difference from that of baseline Wilcoxon test: **p*<0.05³⁾Ideal value: 0⁴⁾Ideal value: low value

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