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Effects of Olfactory Stimulation from the Fragrance of the Japanese Citrus Fruit Yuzu (*Citrus junos* Sieb. ex Tanaka) on Mood States and Salivary Chromogranin A as an Endocrinologic Stress Marker

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Abstract

Objective: This study investigated the soothing effects of fragrance from yuzu, a Japanese citrus fruit (*Citrus junos* Sieb. ex Tanaka), with salivary chromogranin A (CgA) used as an endocrinologic stress marker reflecting sympathetic nervous system activity.
Methods: Twenty healthy women (mean age, 20.5 ± 0.1 years) participated in a randomized, controlled, crossover study. Participants were examined on two separate occasions—once using the yuzu scent and once using unscented water as a control—in the follicular phase. This experiment measured salivary CgA and the Profile of Mood States (POMS) as a psychological index before and after the aromatic stimulation.
Results: Ten-minute inhalation of the yuzu scent significantly decreased salivary CgA. At 30 minutes after the inhalation period, the salivary CgA level further decreased. In addition, POMS revealed that inhalation of the aromatic yuzu oil significantly decreased total mood disturbance, a global measure of affective state, as well as four subscores of emotional symptoms (tension–anxiety, depression–dejection, anger–hostility, and confusion), as long as 30 minutes after the olfactory stimulation.
Conclusions: Yuzu's aromatic effects may alleviate negative emotional stress, which, at least in part, would contribute to the suppression of sympathetic nervous system activity.

Introduction

YUZU (*CITRUS JUNOS* SIEB. EX TANAKA), a yellow-golden citrus fruit resembling a small orange or tangerine, is believed to have originated in the upper reaches of the Yangtze River in China and arrived in Japan during the Sui Dynasty or Tang Dynasty over 1000 years ago.[1] Yuzu fruit and its juice have been traditionally used for making vinegar and seasoning. The peel of the yuzu fruit is valued by chefs, who use it to enhance flavor and garnish dishes. The Japanese also use yuzu to make various sweets, including marmalade, jellies, and cakes. According to food and nutritional science studies, yuzu also possesses antioxidant,[2] anticarcinogenic,[3] anti-inflammatory,[4] and antidiabetic properties[5] and exhibits preventive effects on cognitive dysfunction.[6] The pale yellow essential oil extracted from yuzu rind by the cold expression method emits an exquisite citrus aroma. While producing a very appealing, almost floral note, the essence of this fragrance falls somewhere between grapefruit and mandarin orange, with subtle overtones of bergamot and lime. Because of its distinctive pleasing fragrance, producers of cosmetics and perfumes use yuzu essential oil in the manufacture of their products. Studies published in Japanese scientific journals suggest the soothing effects of the yuzu fragrance and its potential application to aromatherapy.[7,8] An extensive literature search for the present study that used the PubMed database, a service of the U.S. National Library of Medicine and the National Institutes of Health, however, identified no available empirical human-subject research regarding the efficacy of yuzu fragrance for psychosomatic health.

Chromogranin A (CgA)—an acidic glycoprotein initially isolated as the major soluble protein of adrenal medullary chromaffin granules—localizes in secretory granules of a wide variety of endocrine cells and neurons.[9] Circulating levels of CgA co-released exocytotically with catecholamines correlate to the noradrenaline release rate.[10] In addition, CgA is produced

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by human submandibular glands and, in response to activation of the autonomic nervous system innervating the submandibular gland, is released directly from the exocrine cells of the granular convoluted tubules into the saliva.[11] Salivary CgA, thus, has been proposed as a surrogate marker of sympathetic nervous system activity.[12] A series of studies has shown that compared with salivary cortisol, salivary CgA increases more rapidly and more sensitively to psychological stressors induced by activities such as public speaking,[12] word-processing and arithmetic tasks,[13,14] academic examinations,[15] and venipuncture in hospitalized children.[16] A recent finding from the author's laboratory further demonstrated that salivary CgA levels in the late-luteal phase significantly increased among women with severe premenstrual emotional symptoms, while salivary cortisol showed no menstrual-cyclic changes.[17] In contrast, stress-reduction interventions, such as aromatherapy with lavender essential oil,[14] exposure to negative air ions,[13] and laughter while watching a comedy video,[18] have decreased salivary CgA levels. Saliva testing is a novel device with the advantage of quick, painless, noninvasive, and relatively nonstressful sampling. Taken together, salivary CgA could serve as a potential index for evaluating the efficacy of the yuzu fragrance as a new modality for alleviating psychoemotional stress in women.

Accordingly, the present research involved a randomized crossover study to investigate the efficacy of olfactory stimulation with fragrance from commercially available yuzu essential oil on emotional mood states and salivary CgA as an endocrinologic stress marker reflecting sympathetic nervous system activity.

Materials and Methods

Participants

Twenty women in their twenties volunteered to participate in this study. The women, all college students, responded to a campus advertisement. The study protocol was approved in advance by the Institutional Review Board of Shitennoji University and was performed in accordance with the Declaration of Helsinki of the World Medical Association. All participants received an explanation of the nature and purpose of the study: to investigate the possible soothing effects of plant fragrance on emotional symptoms. However, the participants were not told which fragrance would be used for the experiments. Before receiving any data about the experiments, all participants gave their written informed consent to participate in the study.

The participants underwent medical examinations and interviews and completed a standardized health questionnaire regarding medical history, medications, current health condition, regularity of menstrual cycle, and lifestyle. The participants were not obese and did not smoke. None of the participants had been clinically diagnosed with diabetes mellitus, hypertension, hyperlipidemia, or cardiovascular or any other endocrine or systemic disorders that could affect the autonomic nervous system. Menstrual cycle–related discomfort, such as premenstrual syndrome and premenstrual dysphoric disorder, influences the autonomic nervous system.[17,19–21] However, scores from the menstrual distress questionnaire[22] the participants had answered in the follicular (the fifth to the 11th day from the first day of menstruation) and the late-luteal phase (within 7 days before the next menstruation) revealed that none of the participants had premenstrual disorders. The medical examination and interview further clarified that no participants had any other gynecologic or psychiatric disorders. None of the participants had periodontal or salivary gland disorders. Some medications, including dimenhydrinate, alter the response of salivary CgA secretion, although the literature reveals scarce information on this.[23] None of the participants in this study, however, were taking antihistaminic drugs, tranquilizers, sleeping pills, or any other medication influencing the salivary gland or autonomic nervous system. Further, none of the women reported taking oral contraceptives to control the menstrual cycle.

To minimize the effects of food and drink on levels of salivary CgA, participants were asked to abstain from food and drink, other than mineral water, for 2 hours before the saliva sampling.[24] The participants were also instructed to abstain from alcohol use and excessive physical activity for 24 hours before testing.[25,26]

Referring to a study by Kiecolt-Glaser and colleagues[27] and the authors' own recent research on aromatherapy,[26] the olfactory function test was performed on all participants to confirm that none had anosmia. Briefly, participants were given two sets of three bottles—two held distilled water, and the third contained essential oils (yuzu or lavender)—and were asked to choose the one that differed from the other two. To be eligible for the study, participants had to choose the correct response in both trials.

Experimental procedure

All participants were examined on two separate occasions (during aroma and control trials) in the nonsymptomatic follicular phase (the fifth to the 11th day from the first day of menstruation). The order of testing was randomized. The cycle phase was determined by the onset of menstruation and oral temperature and verified by concentrations of ovarian hormones, estrone (E1), and pregnanediol-3-glucuronide (PdG), in a urine sample taken early in the morning. Both E1 and PdG were indexed to creatinine (Cr) excretion.[17,19,25,28]

All measurements were taken between 11:00 and 15:00, in consideration of the circadian rhythm of salivary stress markers.[29] We carried this out in a temperature-controlled (25°C), quiet, comfortable room, with minimization of arousal stimuli. Height and body weight of each subject were measured to calculate body mass index (BMI) as body weight divided by height squared.

This experiment used two kinds of aroma stimulation: yuzu (*C. junos* Sieb. ex Tanaka, Lot No. 20, Tree of Life Co. Ltd., Tokyo, Japan) and water as a control. Table 1 shows major components of the yuzu oil used in this study. Following recent research on aromatherapy with lavender essential oil,[26] 10 μL of yuzu essential oil or water was pipetted onto a small cotton pad designed for a diffuser (Aroma Breeze NOVA T, ALTA Corp., Nagoya, Japan). Airflow from the diffuser was set at 1.3 m/min and placed near the participants' nostrils using the diffuser's 30-cm-long circular cylinder fitted with a perforated funnel (diameter, 5 cm).

Before measurements were taken, the participants were instructed to relax quietly and comfortably for at least 10 minutes in a seated position. They then filled out the Profile of Mood States (POMS), explained in detail below. To collect a sufficient quantity of saliva, the Salivette sampling device was used; this special sampling tube includes a small

Table 1. Major Components of Yuzu Essential Oil

Component	*Content (%)*
Limonene	78.02
γ-Terpinene	9.32
β-Myrcene	1.77
α-Pinene	1.34
δ-Elemene	0.79
β-Pinene	0.69
β-Caryophyllene	0.60
α-Phellandrene	0.43
Terpinolene	0.41
p-Cymene	0.38
α-Terpinenol	0.07
Linalool	0.03
Total	93.85

cotton swab (Sarstedt Co. Ltd., Rommelsdorf, Germany). After the POMS test, participants rolled the cotton swab in the oral cavity, as they would hard candy, for 2 minutes while seated in a comfortable chair. Each participant then inhaled the scent for 10 minutes. Immediately following the aroma stimulation, saliva was again collected and participants were asked to rate five items (likes and dislikes, pleasantness, familiarity, refreshed feeling, and calmness) by using a visual analogue scale (VAS) with a 10-cm horizontal line[27] to determine any acute psychological effects of the fragrance. According to Herz,[30] it takes at least 20 minutes for the chemically active substance of a fragrance to be circulated through blood and then cross the blood–brain barrier. To investigate any pharmacologic effects of fragrance, therefore, we further collected saliva from participants 30 minutes after the aroma inhalation period. After the saliva collection, the participants then repeated the POMS test.

Assessment of emotional symptoms

The Japanese version of the POMS test (Kaneko Shobo Co., Tokyo, Japan) was administered. This globally standardized, self-administered, 65-item questionnaire (including 7 dummy items) assessed mood states before and after inhalation of the yuzu scent and water. Each item was rated on a 5-point Likert-type scale of 0–4, ranging from "not at all" to "extremely." These raw scores were added to generate six subscales of emotional state: tension–anxiety, depression–dejection, anger–hostility, vigor, fatigue, and confusion. These added raw scores were then converted into T-scores according to the POMS manual.[31] As a global measure of affective state, a total mood disturbance (TMD) score was also calculated, with higher scores indicating more mood disturbance, by adding the T-scores on the six subscales; vigor was negatively weighted.[17,32] Referring to a study by Kuroda and colleagues[33] and the authors' recent aroma research,[26] to investigate the effect of yuzu aroma on mood states, changes in the POMS scores of the yuzu and control trials were compared before and 30 minutes after the aroma stimulation.

Determination of salivary CgA

After saliva collection, the sampling tubes were labeled and stored at −20°C until the completion of the determination assay. Salivary CgA levels were later determined using an enzyme-linked immunosorbent assay kit (YK070 Human Chromogranin A EIA, Yanaihara Institute, Inc., Shizuoka, Japan), according to a previously described method.[34] The CgA concentration was corrected by the total protein concentration of saliva.[12,16,17]

Basal CgA concentration differs from individual to individual, and the values were not normally distributed as in previous studies.[17,29] Referring to earlier investigations,[18,35,36] therefore, the values for CgA concentration before the aroma inhalation were standardized to 100%. The rate of change after the inhalation was compared between aroma and control trials.

Statistical analysis

To investigate the influence of inhalation of the yuzu aroma on salivary CgA, the effects of aroma and time and the interaction (aroma × time) were evaluated using two-way analysis of variance (ANOVA) with repeated measures. When significant interactions were found, a paired t test was conducted between the yuzu and control trials and one-way ANOVA with repeated measures during each trial. For acute psychological effects, a paired t test was performed to compare the values on VAS between yuzu and control trials immediately following the aroma inhalation. A paired t test was also performed to compare changes in POMS scores before and 30 minutes after the aroma inhalation period between yuzu and control trials. Values are reported as mean ± standard errors (SEM); p values $<.05$ were considered to represent statistically significant differences. All statistical analysis was performed by using a commercial software package (SPSS Statistics, version 20, IBM, Chicago, Illinois).

Results

Clinical characteristics of participants

Mean values of physical features of all participants were as follows: age, 20.5 ± 0.1 years; height, 159.6 ± 1.6 cm; weight, 54.8 ± 1.1 kg; and body–mass index, 21.6 ± 0.6 kg/m^2. Length of menstrual cycle and duration of menstrual flow of the participants during the study were 31.9 ± 1.3 days and 6.4 ± 0.2 days, respectively. The yuzu and control experiments took place on day 7.8 ± 0.4 and day 7.6 ± 0.5 in the follicular phase from the first day of menstruation, respectively. The interval between the two trials was 2.6 ± 0.9 days.

To confirm regular ovulatory menstrual cycles among participants, oral temperatures and urinary ovarian hormone concentrations were measured in the follicular phase (day 7.6 ± 0.3) and in the late-luteal phase (day 28.2 ± 0.9). The basal body temperature in the late-luteal phase significantly increased from that of the follicular phase (36.61 ± 0.08°C vs. 36.35 ± 0.05 °C; $p = .013$). A significant late-luteal increase in urinary ovarian hormones compared with the follicular phase was also found (E1: 17.2 ± 2.2 vs. 7.5 ± 1.5 ng/mL Cr, $p < .001$; PdG: 1.49 ± 0.14 vs. 0.30 ± 0.04 μg/mL Cr, $p < .001$).

Comparisons of acute psychological effects between yuzu and control trials

Table 2 shows acute psychological effects evaluated with VAS right after the 10-minute aroma stimulation with yuzu and water. Scores were significantly higher for all five items—likes and dislikes, pleasantness, familiarity, refreshed

Table 2. Comparison of Acute Psychological Effects Between Yuzu Fragrance and Water

Variable	*Yuzu*	*Water*	p-*Value*
Likes and dislikes	8.1±0.4	4.7±0.4	<.001
Pleasantness	8.0±0.3	6.4±0.4	.001
Familiarity	8.1±0.3	5.0±0.5	<.001
Refreshed feeling	7.8±0.4	5.0±0.3	<.001
Calmness	8.0±0.3	6.6±0.4	.001

The values are given as mean±standard error.

feeling, and calmness—after the yuzu trial compared with the control trial with water.

Changes of salivary CgA concentration immediately and 30 minutes after 10-minute aroma inhalation

Figure 1 shows the changes in salivary CgA immediately and 30 minutes after the 10-minute aroma stimulations. Salivary CgA significantly decreased after the inhalation of yuzu scent in comparison with water (aroma effect: $F[1,19]=10.8$, $p=.004$; time effect: $F[2,38]=2.9$, $p=.069$; aroma×time effect: $F[2,38]=5.3$, $p=.009$). One-way ANOVA showed that salivary CgA in the yuzu trial had a significant time effect ($F[2,38]=10.3$, $p<.001$). The Bonferroni multiple comparison test further revealed that salivary CgA decreased to a greater extent immediately ($p=.005$) and 30 minutes ($p=.002$) after the inhalation with yuzu fragrance compared with baseline. In contrast, no significant time effect on the salivary CgA was found during the control trail. A paired t test further clarified that the rate of decrease in salivary CgA was significantly greater immediately ($p=.006$) and 30 minutes ($p=.019$) after aroma inhalation in the yuzu trial compared with the control trial with water.

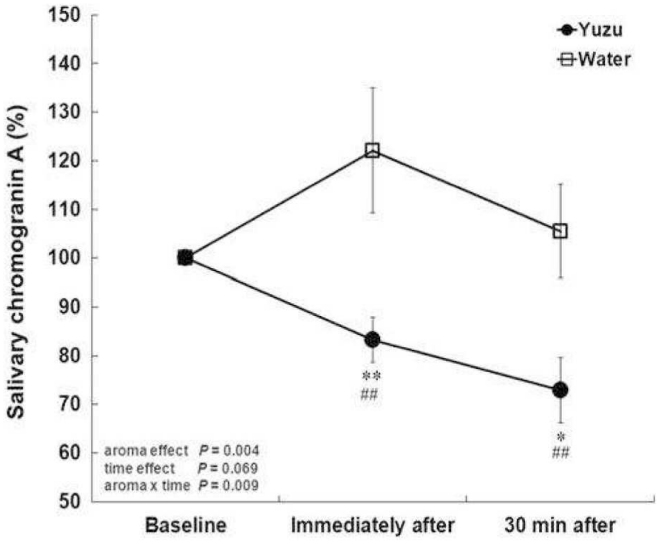

FIG. 1. Changes of salivary chromogranin A before (baseline), immediately after, and 30 minutes after 10-min inhalation of yuzu fragrance and water during the non-symptomatic follicular phase. One-way analysis of variance with Bonferroni multiple comparison showed a significant decrease immediately and 30 minutes after the yuzu aroma inhalation compared with baseline ($^{\#\#}p<.01$). A significant difference by paired t test was apparent between yuzu and control (water) trials ($^{*}p<.05$, $^{**}p<.01$).

Changes of mood states 30 minutes after aroma inhalation

The TMD scores significantly decreased in the yuzu trial (change, −12.8±2.6) compared with the control trial with water (0.5±2.2) ($p<.001$). Figure 2 illustrates the changes of the POMS subscales 30 minutes after the 10-minute aroma inhalation period. The subscores of tension–anxiety ($p=0.018$), depression–dejection ($p=0.041$), anger–hostility ($p=0.002$), and confusion ($p=0.019$) significantly decreased after the inhalation of yuzu compared with those of the control trial with water. Another negative symptom, fatigue, also decreased more in the yuzu trial compared with the control trial, but the difference in the changes of the subscore between the yuzu and control trials did not reach statistical significance.

Discussion

Beyond its role as an essential ingredient in food products and various cuisines, yuzu, a popular Japanese citrus fruit, has traditionally been used to promote mind and body health in Japan. For instance, taking a yuzu-yu (yuzu bath), a hot bath in which whole yuzu fruits are floated, is a winter solstice custom that dates back to at least the early 18th century. The yuzu bath is said to warm the body; guard against colds; and treat arthritis, rheumatism, and rough skin. As in aromatherapy, a long, relaxing soak relieves stress and creates feelings of well-being.[1] In modern days, yuzu has attracted worldwide attention; a 2003 article in the *New York Times* introduced yuzu as the darling of chefs and as having an amazing floral citrus fragrance.[37] While Yuzu is now commercially available as a healthcare modality, the psychophysiologic effects of its essential oil remain unclear.

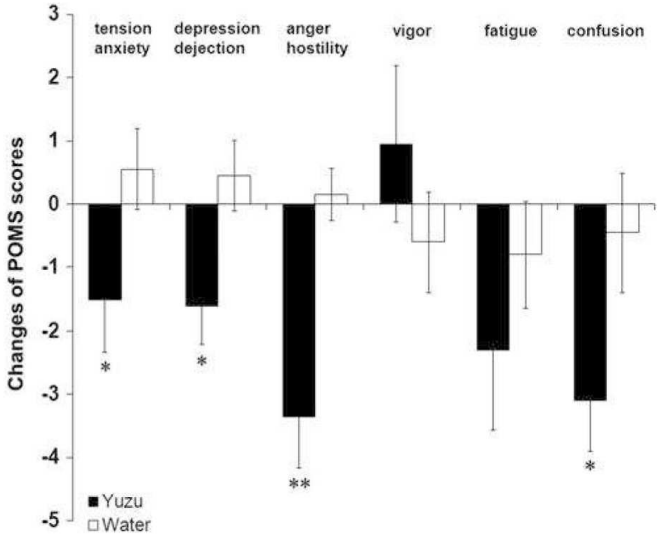

FIG. 2. Subscore changes in Profile of Mood States (POMS) test performed before and 30 minutes after the 10-minute inhalation of yuzu fragrance and water. A significant difference by paired t test was apparent between yuzu and control (water) trials ($^{*}p<.05$, $^{**}p<.01$).

The present study appears to be the first to provide novel information on the soothing effects of the fragrance from yuzu by using salivary CgA as an endocrinologic stress marker. The main findings reveal that salivary CgA, reflecting sympathetic nervous system activity, significantly decreased directly after 10-minute inhalation of aromatic yuzu oil. The CgA level further decreased at 30 minutes after the short-term aroma inhalation. Along with these physiologic stress reductions, psychological effects of the yuzu fragrance were seen: As the higher VAS scores on likes and dislikes, pleasantness, and familiarity indicate, the participants in the present study responded positively to the yuzu fragrance. The inhalation of the yuzu scent significantly decreased TMD on the POMS test, as well as four subscores of emotional symptoms (tension–anxiety, depression–dejection, anger–hostility, and confusion), as long as 30 minutes after the olfactory stimulation.

Although little information has been published on the effects of yuzu inhalation, an animal study by Kumagai and colleagues[38] published in a Japanese aroma research journal reported that olfactory stimulation with the yuzu scent decreased activities of sympathetic nerves innervating brown adipose tissue and white adipose tissue in urethane-anesthetized rats. The study further revealed that olfactory stimulation with the yuzu scent lowered body temperature and plasma-free fatty acid levels. Two other articles investigated the efficacy of yuzu aroma on humans published in Japanese scientific journals. A clinical study by Sawamura and colleagues[7] demonstrated that an inpatient group who inhaled the yuzu aroma fell asleep more easily on the night before an operation and woke up feeling better compared with the control group. According to Konno,[8] who examined patients with subclinical depression (4 men and 4 women; mean age, 22.3 ± 2.8 years), 7-minute inhalation of yuzu fragrance significantly decreased two subscores of POMS—anger–hostility and fatigue—and increased the subscore of vigor. With regard to physiologic measurements using acceleration plethysmography, the ratio of low-frequency to high-frequency power (indicating sympathetic nervous system activity) decreased, and the coefficient of the variation of the a-a intervals, an index of parasympathetic nervous system activity, increased; however, the changes did not reach statistical significance.

Olfaction is mediated by chemoreceptors of olfactory cells located in the nasal mucosae and olfactory neurons in the olfactory bulb. Olfactory information is further transmitted to the primary olfactory regions in the brain, and most of the brain regions strongly relate to or make up part of the limbic system, the center of autonomic function and emotion.[39] Although experimental designs and conditions and clinical features of the participants, as well as an index of the autonomic nervous system activity, were not always consistent, these earlier investigations[7,8,38] support the current findings, indicating that even a short-term inhalation of the yuzu fragrance could alleviate negative emotional mood states. At the moment, the detailed mechanism of the efficacy of yuzu cannot be fully elucidated. However, the significant decrease in salivary CgA immediately and 30 minutes after inhalation with the yuzu fragrance found in the present study additionally suggests that yuzu interacts, at least in part, with the autonomic nervous system to decrease the sympathetic nerve activity, which consequently modulates the cluster of negative psychoemotional symptoms.

To further explore the potential efficacy of the yuzu fragrance, the literature on the scientific analysis of citrus fruit essential oils influencing physiology, mood, and behavior was extensively reviewed. Both animal and human studies demonstrated that fragrance inhalation from grapefruit (*C. paradisi*) essential oil increased sympathetic nervous system activity.[30,40,41] Limonene, accounting for approximately 95% of volatile components of grapefruit, contributes to sympathetic stimulatory effects and subjective alertness.[30,40] In contrast, other citrus fruits consisting of less limonene than grapefruit have the opposite effect on autonomic function. Women (but not men) who were exposed to ambient fragrance from sweet orange (*C. sinensis*) peel oil, made up of limonene (88%), myrcene (4%), and α-pinene (1%), showed a lower level of anxiety and a more positive mood in a dental office setting.[42] Two studies[43,44] evaluated the efficacies of bergamot essential oil (*C. bergamia*) by using heart rate variability power spectral analysis and demonstrated that short-term inhalation of the fragrance generated from a diffuser significantly decreased low-frequency power and the ratio of low-frequency to high-frequency power, indicating sympathetic nervous system activity and increased high-frequency power as an index of parasympathetic nervous system activity. The study[44] further clarified that participants with moderate and high degrees of anxiety benefited from aromatherapy with bergamot fragrance more than those with light anxiety. Commercial bergamot oil is made up of limonene (26%–53%) together with linalool (2%–22%) and linalyl acetate (16%–40%), two major components of lavender, a representative of relaxing essential oils.[45] As Table 1 shows, limonene is a major component (78.02%) of the yuzu essential oil used in the present study, but the amount is less than that of the grapefruit oil. The second major component of yuzu, γ-terpinene (9.32%), promotes dopamine release, resulting in stress reduction.[7] Yuzu also shares other common components with lavender, such as β-caryophyllene and linalool, which also have sedative effects.[26] A combination of limonene with these volatile components might suppress sympathetic nervous system activity to modulate psychoemotional status. However, revealing the psychological, neurophysiologic, and pharmacologic functions of yuzu essential oil will require further interdisciplinary scrutiny and research.

Several limitations of the present study deserve mention. First, this study used two kinds of aroma, yuzu and water as a control. As Table 2 shows, participants in this study evaluated the yuzu fragrance as pleasant. This result, however, prompts uncertainty as to whether the yuzu fragrance itself improved the participants' psychophysiological states or whether a pleasant fragrance regardless of its source would have contributed to the improvements. To better explore the net psychological and pharmacologic effects of yuzu fragrance, a study could investigate experimental conditions with at least three olfactory stimuli—unscented water, yuzu scent, and another scent considered pleasant by a participant among the popular, scientifically evidenced antistress fragrances (such as lavender, rose, orange, sandalwood, and clary sage).[45] Significant psychophysiologic improvements after smelling yuzu fragrance compared with the other two conditions could support the current study and strengthen the results on soothing effects of yuzu essential oils. Second, 16 of 20 participants in the present study rated

a VAS response greater than 7 when asked to what extent they liked the yuzu fragrance. Personal like or dislike of a fragrance is directly related to the mood change that occurs.[30] Contrary to expectations, however, salivary CgA apparently decreased after the yuzu aroma stimulation among four participants, showing less than 7 on the VAS of likability; the reduction did not significantly differ when compared with the responses in the remaining 16 participants. Given the study's small sample size, caution should be used in interpreting the results. Does this imply that, regardless of likability, yuzu fragrance might exert the psychological and pharmacologic effects of alleviating negative emotional stress via the autonomic nervous system? A future study should include a larger sampling of women with different degrees of preference for yuzu and should further scrutinize how and to what extent the likability of the fragrance influences the soothing effects of yuzu oil. Investigating whether cultural and ethnic differences contribute to the efficacy of yuzu would also hold some interest.

Third, a series of the authors' previous research studies has shown that autonomic function altered among women with premenstrual syndrome, premenstrual dysphoric disorder, or menopausal symptoms.[17,19,25,26,28,46] Thus, it would be beneficial to compare the efficacy of yuzu fragrance as a potential healthcare modality between women with and without disorders related to psychosomatic obstetrics and gynecology.

Finally, some studies have indicated that women have greater sensitivity than men to fragrance at certain times during the menstrual cycle, and this varying sensitivity may modulate the effectiveness of plant essential oils on physical and emotional states.[30,42] At the time of this writing, however, research has yet to elucidate the mechanisms of sex differences and the effects of aromatherapy. To scrutinize the efficacy of yuzu aroma, further studies should investigate whether yuzu fragrance has sex-dependent effects on improving mind and body health. In addition to sex differences, other factors, such as age, may influence olfactory and psychoneuroendocrinologic systems in humans.

In conclusion, the present study demonstrated that short-term inhalation of fragrance from yuzu essential oil significantly decreased salivary CgA levels. Although the underlying mechanisms of the soothing effects of yuzu remain unclear, this study indicates that yuzu's aromatic effects could alleviate negative emotional stress, which, at least in part, would help suppress sympathetic nervous system activity. The study also implies that salivary CgA can be used as a reliable noninvasive biomarker to evaluate psychophysiologic changes or improvement resulting from healthcare modalities, including aromatherapy.

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Disclosure Statement

No competing financial interests exist.

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