Title	Synergistic effect of fragrant herbs in Japanese scent sachets.
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Citation	Planta medica (2015), 81(3): 193-199
Issue Date	2015-02-11
URL	http://hdl.handle.net/2433/198450
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Type	Journal Article
Textversion	author

The synergistic effect of fragrant herbs in Japanese scent sachets

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Abstract

The sedative activity of 8 aromatic natural medicines that are traditionally used in Japanese scent sachets was examined using an open field test with mice. Galangal (*Kaempferia galanga*), patchouli (*Pogostemon cablin*), sandalwood (*Santalum album*), spikenard (*Nardostachys chinensis*), cinnamon (*Cinnamomum cassia*), clove (*Syzygium aromaticum*), star anise (*Illicium verum*), and borneol (*Dryobalanops aromatica*) distilled oils were used. These natural medicines have various pharmacological effects. For example, galangal has insecticidal activity and clove extracts possess strong total antioxidant activity. Aromatherapy, a well-known complementary medicine system that uses inhalation, has recently attracted much attention. The sedative activity of inhaled aromatic compounds or essential oils has been examined by measuring the spontaneous motor activity of mice in an open field test. The galangal, patchouli, sandalwood, spikenard, and borneol oils showed significant sedative effects. The effect was stronger for a mixture of the 5 oils than for any of the single oils. This suggests that the oil mixture may have synergistic activity. Sedative activity was not observed when inactive oils (cinnamon, clove, and star anise) were added to the mixture of the 5 active oils.

Keywords

sedative effect, inhalation, fragrant herbs, synergestic effect

Abbreviations

AUC : area under the curve
FID : flame ionization detector
GABA : γ-aminobutyric acid
NREM : non-rapid eye movement
PAH : perillaldehyde
SEM : standard error of the mean

Introduction

In Japan it is a traditional custom to enjoy the fragrance of natural medicines using scent bags or sachets known as *koubukuro*. Aromatic natural medicines that emit fragrances at room temperature, such as galangal (*Kaempferia galanga*, Zingiberaceae), patchouli (*Pogostemon cablin*, Lamiaceae), sandalwood (*Santalum album*, Santalaceae), spikenard (*Nardostachys chinensis*, Santalaceae), cinnamon (*Cinnamomum cassia*, Laureaceae), clove (*Syzygium aromaticum*, Myrtaceae), star anise (*Illicium verum*, Illiciaceae), and borneol (*Dryobalanops aromatica*, Dipterocarpaceae), are commonly

used for this purpose. The sachets can be carried in pockets and are also stored with clothes and paper as insect repellents. Similar scent sachets are used in Europe and China, although the fragrance materials vary.

These natural medicines have various pharmacological effects. For example, galangal has insecticidal activity [1] and clove extracts possess strong total antioxidant activity [2]. However, the majority of studies use extracts and there are very few that use essential oils. In animal experiments, the pharmacological effects of essential oils are usually administered orally, and by abdominal or percutaneous injection, rather than by inhalation. Aromatherapy, a well-known complementary medicine system that uses inhalation, has recently attracted much attention, and some interesting effects have been reported. Lavender essential oil shows antianxiety and antidepressant effects [3] and olfactory stimulation with black pepper oil significantly improves the sensory and reflexive motor movement of swallowing [4]. Further studies and trials for the clinical use of essential oils are needed to improve their effective use and increase the evidential background for therapies. The sedative activity of inhaled aromatic compounds or essential oils has been examined by measuring the spontaneous motor activity of mice in an open field test [5].

Sedative effects have been also been reported for some of the aromatic natural medicines found in Japanese scent sachets administered by inhalation. For example, the sedative activity of spikenard extract was examined using a spontaneous vapor administration system [6] and the main component of sandalwood, santalol, significantly decreased the total waking time and increased total non-rapid eye movement sleep time in rats [7]. In the present study, the chemical compositions of the distilled oil of natural medicines commonly used in Japanese sachets were analyzed, and their possible effects on spontaneous motor activity in mice were examined. Mixtures of oils were also investigated and we discuss the contribution of the results to the scientific background for traditional Japanese scent sachets.

Results

The analysis results for the 8 essential oils are shown in Tables 1S-8S, Supporting Information. The structures of the 2 main components of each essential oil are shown in Fig. 1S, Supporting Information. The yield of the essential oils for each natural medicine was calculated as 0.26% (w/w) for galangal, 0.24% (w/w) for patchouli, 0.20% (w/w) for sandalwood, 0.23% (w/w) for spikenard, 0.47% (w/w) for cinnamon, 3.33% (w/w) for clove, and 1.88% (w/w) for star anise, per dry weight. The essential oils of galangal, sandalwood, clove, and star anise were colorless, and those of patchouli,

spikenard, and cinnamon were pale yellow. Each oil had a characteristic odor.

Essential oils isolated by hydrodistillation were administered to mice by vapor inhalation, and their sedative activity examined. The doses of 4×10^{-4} to 4×10^{-2} mg were calculated according to the range of doses that have been reported as effective for the same experimental system [8]. Perillaldehyde (PAH) is a major component in the essential oil of *Perilla frutescens* (Labiatae), and that was previously reported to have sedative and antidepressant-like effects on mice [9.10]. The results of administration of the essential oils are shown in Fig. 1. An activity of sedative effects of fragrant compound administered by inhalation often draws U-curve. This is in common with other sedative volatile compounds [6]. Sedative activity was observed for galangal, patchouli, sandalwood, spikenard, and borneol crystals. The strongest activities were observed at doses of 4×10^{-4} mg (galangal), 4×10^{-3} mg (patchouli), 4×10^{-4} mg (sandalwood), 4×10^{-3} mg (spikenard), and 4×10^{-3} mg (borneol crystals), respectively, and they were statistically significant (Fig. 1a-d and h, $p < 0.05$). During the first 10 min of administration, the locomotor activity of the mice decreased to approximately to two-thirds that of the control (Fig. 2). In contrast, none of the cinnamon, clove, and star anise oils showed sedative activity. Administration of these non-sedative oils caused a continuous increase of locomotor activity from 30 min onward, or abnormal behavior such as jumping, rapid movement, and frequent excretion. The control mice became calm and their locomotor activity was reduced to nearly zero after 30 min.

There are a vast number of possibilities for generating combinations of 8 essential oils and doses. We initially investigated a sedative effect for a mixture of the 8 oils, although sedative activity was not observed at every concentration (data not shown). Therefore, mixtures of the 5 oils that showed a sedative effect were examined for synergistic effects. Furthermore, each of the inactive oils was added to the mixture of active oils and the sedative activity of these mixtures was also examined. The doses of the oil mixtures were the most effective doses for single administration. The composition of the mixtures of 5 active oils is shown in Table 1. The results of the administration of oils are shown in Figures 3 and 4. When the mixture of the 5 active oils was administered to mice, the locomotor activity decreased more than when the oils were administered individually. Although neither was significant, this result shows that the mixture of effective oils produced synergistic effects. When 3 inactive oils, namely, cinnamon, clove, and star anise, were added separately to the mixture of the 5 active oils, the activity of the mixtures was decreased.

Table 10S, Supporting Information shows the boiling point temperatures under atmospheric pressure, vapor pressure at 25 °C, and lipophilicity indicated by logP of the

main components of each oil. Generally, the volatility of compounds increases as the boiling point decreases and the vapor pressure is higher. Higher lipophilicity increases the penetration rate through membranes and should increase the amount of compound absorbed. Three of the inactive oils have lower boiling points and higher vapor pressures compared with those of the 5 active oils. The activities of the oil mixtures containing an inactive oil were strongly affected by the main components of the inactive oils, probably because the inactive oils had high volatility and were thus dominant in the vapor. Some of the active oils have a lower vapor pressure; however, patchouli alcohol (patchouli), α-santalol (sandalwood), and calarene (spikenard) have high lipophilicity and showed a fast effect because they are absorbed faster. These results suggest that the potency, volatility, and lipophilicity of the oil components may affect sedative activity.

Discussion

The sedative effect of galangal hexane extract administered by inhalation has been examined. Huang [11] reported that inhaling the hexane extract at a dose of 1.5 and 10 mg produced a significant reduction in locomotor activity. The 2 main aromatic compounds, ethyl *p*-methoxycinnamate and ethyl cinnamate, showed sedative effects at doses of 0.0014 and 0.0012 mg, respectively [11]. In the present report, the distilled galangal oil showed sedative activity at a dose of 4×10^{-4}. The distilled oil produced a sedative effect at a lower dose that the hexane extract. Organic solvents extract both the volatile and the nonvolatile compounds, whereas the distilled oil only contains the volatile compounds. For inhalation, where the volatile compounds are most important, the distilled oil is more effective than the hexane extract, and this produced a difference in effective dose. The distilled oil produced sedative activity at one-third of the dose of a single compound, suggesting that sedative activity observed in this report was caused by the whole oil.

The most abundant component in patchouli was patchouli alcohol (66.2%). Patchouli alcohol has been reported to be responsible for the sedative activity of *Microtoena patchouli* essential oil. The effective dose of patchouli alcohol is 75-750 μg [12]. This dose is about 25-fold greater than the effective dose of patchouli oil in this report, which was 4×10^{-3} mg. As was the case with galangal, patchouli essential oil has a higher sedative activity compared with its individual components.

The most abundant compounds in sandalwood—α-santalol and *trans*-β-santalol—contribute to the characteristic odor of sandalwood oil and have many pharmacological effects [13,14]. Santalol caused a significant increase in total non-rapid eye movement (NREM) sleep time [7], suggesting that santalol has sedative activity.

Twenty-six components were identified in spikenard essential oil, and most of them were sesquiterpene compounds. Cedarwood or sandalwood oils, which have high sesquiterpene contents, are often used for inhalation to produce relaxing effects. Calarene, α-gurjunene [6] and β-maaliene [8] have sedative activities at doses of 0.17%, 1.5%, and 0.014-0.14%, respectively. In contrast, the active dose observed in this paper was 4×10^{-3} mg. These results indicate that the sedative activity is caused by multiple sesquiterpene components rather than a single compound.

Fifteen compounds were identified in clove essential oil. It has been reported that eugenol may improve learning and memory, although the dose dependency was not investigated [15]. Tianpeng et al. reported that inhaling eugenol changed the amount of neurotransmitters in the hippocampus and cortex. Levels of glutamate and choline acetyltransferase, an excitatory neurotransmitter, were significantly increased, whereas that of γ-aminobutyric acid (GABA), an inhibitory neurotransmitter, was not. These results may indicate that elevating the levels of excitatory neurotransmitters was caused by inhaling eugenol. The excitatory motion of the mice in this study, such as rapid movement and jumping, was consistent with these results. Inhaling eugenol appeared to produce a central nervous stimulatory effect.

Aromatic natural medicines have characteristic scents. The most abundant components may contribute heavily to the scent; however, the sedative effects of the essential oils do not appear to arise from single compounds, because oils consist of small amounts of various different compounds. The pharmacological effects observed in this study could not be related to the individual main components of the essential oils, suggesting that sedative effect arose from the whole oil.

The mixture of the 5 active oils decreased the locomotor activity of the mice more than did the individual oils. This showed that the mixture of active oils produces synergistic effects. The decrease in locomotor activity was small compared with the increase in the number of components, and it did not reach 2-fold that for the individual oils. This applied to mixtures of active oils that did not contain a large amount of a single component or components with an excitatory effect. Patchouli alcohol, borneol, and isoborneol constituted more than 50% because they are lower effective compounds and bigger amount were required for their highest activity. However, combination of the species of compounds in the mixture oil is different from what it was in each oil, and it might be dangerous to conclude the activity be attributed to those large-amount constituents. However, it is certain that the mixture of active oils produces synergistic effects.

A possible biological mechanism behind the pharmacological activity may involve the

cerebral limbic system [16]. When a volatile component molecule reaches the nose, it binds to an olfactory receptor on an olfactory cell. The fragrance information is transmitted to the cerebral limbic system, and then to the hypothalamus, where it affects the autonomic nervous system and the endocrine system. Serizawa et al. reported that mice have more than 1000 olfactory receptor genes, and each olfactory cell expresses a single olfactory receptor gene for a receptor that detects a volatile component molecule with a specific structure. The axons of each olfactory cell in an olfactory bulb extend to one of 2000 glomeruli and form a neural circuit; thus, each glomerulus corresponds to 1 olfactory receptor [17]. Assuming that the sedative effect observed in this study only arises from this pathway, the results for the mixture of the 5 active oils can be explained as follows. The mixture of the 5 active oils showed a synergistic effect, although the spontaneous activity did not decrease in proportion to the increase in the number of compounds. If the proposed mechanism is accurate, when many volatile component molecules compete to bind to a limited number of olfactory receptors, not all the molecules will bind, and consequently the sedative activity should correspond to the number of receptors.

When the inactive cinnamon, clove, and star anise oils were added individually to the mixture of the 5 active oils, there was a significant decrease in sedative activity. Interestingly, none of the resultant mixtures exhibited sedative activity, despite the small ratio of the inactive oil to the active oil mixture of 1:5. The most abundant components of the cinnamon, clove, and star anise inactive oils are cinnamaldehyde, eugenol, and anethole, respectively. Iwasaki et al. reported that an intravenous injection of cinnamaldehyde increased adrenaline secretion in rats. The secretion of adrenaline occurs through the activation of the transient receptor potential ankyrin1 ion channel, which is involved with transmission of pain, by volatile irritants, such as allyl isothiocyanate or cinnamaldehyde [18]. The administration of GABA elicited a bimodal response in locomotion that was not dose-dependent; a lower dose elicited a small increase in locomotion, whereas a higher dose elicited a reduction. In addition, GABA attenuated locomotion, although it did not abolish locomotion in dopamine-stimulated locomotor activity [19]. Therefore, our results suggest that the 3 main compounds of the inactive oil produced adrenaline secretion and show an excitatory activity, whereas the inhibitory activity was mediated by GABA. The effect is not dose-dependent and does not completely suppress excitatory activity, meaning that it shows an overall excitatory effect.

We investigated the sedative effect of inhaling vapors from 8 aromatic natural medicines using the decrease in spontaneous motor activity of mice as a model for

relaxation. We also examined the effect of mixtures of the 5 active essential oils, and observed a synergistic effect. Our results suggest that fragrance materials that have experiential benefits may also have a pharmacological sedative effect. This evidence can be used as the basis for possible medical applications and product development. Inhalation is a simple, noninvasive administration method, and the use of several natural products with low activities should reduce the likelihood of adverse side effects. Therefore, the inhalation of essential oils is a promising alternative method for treating and preventing a wider range of diseases. We expect that future studies of the sedative effects of essential oils mixtures will provide further useful results.

Materials and Methods

Materials

Eight fragrant herbs, galangal (*K. galanga*), patchouli (*P. cablin*), sandalwood (*Sa. album*), spikenard (*N. chinensis*), cinnamon (*C. cassia*), clove (*Sy. aromaticum*), star anise (*I. verum*), and borneol (*D. aromatica*), were purchased from Mitsuboshi Pharmaceutical Co., Ltd., Nara, Japan. The batch numbers of there purchased products are as follows: 567A (*K. galanga*), 591A (*P. cablin*), 2687D (*Sa. album*), 591C (*N. chinensis*), 7015(*C. cassia*), 517A (*Sy. aromaticum*), 585B (*I. verum*), 09144206 (*D. aromatica*). Voucher specimens of 8 fragrant herbs were deposited in the herbarium of Experimental Station for Medicinal Plants, Graduate School of Pharmaceutical Sciences, Kyoto University (Specimen numbers: EST-5009 (*K. galanga*), EST-5010 (*P. cablin*), EST-5012 (*Sa. album*), EST-5011 (*N. chinensis*), EST-5013 (*C. cassia*), EST-5014 (*Sy. aromaticum*), EST-5015 (*I. verum*), EST-5016 (*D. aromatica*)). Triethyl citrate (Merck KGaA, Darmstadt, Germany), an odorless solvent, was used to dissolve the fragrance components. DL-perillaldehyde (Tokyo Kasei Co., Ltd., Tokyo, Japan.) was used as positive control. The authentic compounds decane, dodecane, tetradecane, hexadecane, octadecane (Wako Pure Chemical Industries Co., Ltd., Osaka, Japan.), docosane, tetracosane (Nacalai Tesque Co., Ltd., Kyoto, Japan.), eicosane, pentacosane, hexacosane (Tokyo Kasei Co., Ltd., Tokyo, Japan.), were prepared as the gas chromatography retention indices. All other chemicals and reagents used in this study were of the highest grade available.

Distillation of aromatic natural medicines

The aromatic natural medicines (100 g, each), except for borneol, were hydrodistilled for 2 h using the clevenger-type apparatus designated in the Japanese Pharmacopoeia 16th edition and the distilled oil was captured in hexane. The essential oil was dried

over anhydrous sodium sulfate and stored at -20 °C before analysis and animal experiments.

GC and GC/MS analysis

Qualitative analysis of the volatile components was performed by GC/MS (6850GC/5975MSD, Agilent Technologies) under the following operating conditions. Fused silica capillary column, DB-Wax (Agilent Technologies), 60 m × 0.25 mm, film thickness of 0.25 μm; column temperature program for galangal: 60-240 °C increasing at 3 °C/min, holding at 240 °C for 30 min; column temperature program for other materials: 60-210 °C increasing at 3 °C/min, holding at 210 °C for 30 min; injector, 100 °C; carrier gas, helium, 26 cm/min; split ratio, 100:1; injection volume, 1 μL; ionization energy, 70 eV.

Quantitative analysis of volatile components was performed by GC (G5000, Hitachi) with a flame ionization detector (FID) under the following operating conditions. Fused silica capillary column, InertCap-Wax (GL Sciences), 60 m × 0.25 mm, film thickness = 0.25 μm; column temperature program, same as for GC/MS; injector, 100 °C; detector for galangal, 250 °C; detector for other materials, 220 °C; carrier gas, helium, 0.8 cm/min; split ratio, 100:1; injection volume, 1 μL.

The retention indices of the components were calculated on the InertCap-Wax column using *n*-alkane standards. The compounds were identified by comparing the fragmentation pattern of the mass spectra with those available from the National Institute of Standards and Technology and flavors libraries. Quantitative analysis was achieved with an FID.

Animals

Animal experiments were designed following the recommendations of the Animal Research Committee of Kyoto University, Kyoto, Japan (the approval number was 2012-18). Experimental procedures involving the use and care of animals conformed to the institutional guidelines, which comply with the Fundamental Guidelines for the Proper Conduct of Animal Experiments and Related Activities in Academic Research Institutions under the jurisdiction of the Ministry of Education, Culture, Sports, Science, and Technology, Japan (2006).

Male 4-week-old ddY mice were purchased from Japan SLC (Shizuoka, Japan). The mice were housed in colony cages at an ambient temperature of 25 ± 2 °C and relative humidity of 50 ± 10% with a 12 h light-dark cycle before being used for experiments. They were fed standard pellet chow and water ad libitum. All behavioral observations

were conducted between 10:00 and 17:00 at the same temperature and humidity.

Evaluation of spontaneous motor activity

The sedative activities of the fragrant components were evaluated in mice by their spontaneous motor activity in an open field test described in a previous report [6]. The distilled oils and borneol crystals were dissolved in triethyl citrate (400 μL total), at concentrations ranging from 4×10^{-4} to 4×10^{-2} mg (v/v) in a glass cage (W 60 × L 30 × H 34 cm). The samples were dropped onto 4 filter paper disks (100 μL each), which were placed on the wall of the glass cage using adhesive tape. The solution vapor was allowed to fill the cage by natural diffusion for 60 min. A mouse was placed in the center of the cage and was monitored by a video camera for another 60 min. The frequency at which the mouse crossed lines drawn on the bottom of the cage at 10 cm intervals was counted every 5 min for 60 min. The area under the curve (AUC), indicating total locomotor activity over 60 min, was calculated by the trapezoidal rule [20]. All values are expressed as the mean ± the standard error of the mean (SEM). Statistical analyses were carried out using Dunnett's test using GraphPad Instat3 (GraphPad Software, San Diego, CA). A probability level of $P < 0.05$ was taken to be statistically significant in the analysis. The results were reproducible; therefore, 5 mice from each administration group were chosen at random for statistical analysis.

Conflict of interest

The authors declare no conflict of interest.

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Legends for Figures

Fig. 1 Total spontaneous motor activity of mice given (a) galagal, (b) patchouli, (c) sandalwood, (d) spikenard, (e) cinnamon, (f) clove, (g) star anise essential oils, and (h) borneol crystals. Data are shown as means ± SEM for 5 mice. Statistical differences vs. the control group were calculated using analysis of variance, followed by Dunnett's test. $*p < 0.05$ and $**p < 0.01$.

Fig. 2 Locomotor activity transition of mice given essential oils.

Fig. 3 Comparison of the effect of essential oils on locomotor activity of mice treated with galangal (4×10^{-4} mg), patchouli (4×10^{-3} mg), sandalwood (4×10^{-4} mg), spikenard (4×10^{-3} mg), crystal of borneol (4×10^{-3} mg) and a mixture of the 5 active oils. Data are shown as means ± SEM for 5 mice. Statistical differences vs. the mixture of the 5 active oils were calculated using Student's *t*-test. Neither was significant.

Fig. 4 Comparison of the effect of essential oils on locomotor activity of mice treated with 3 inactive oils, a mixture of the 5 active oils and the mixtures of oils composed of the 5 active oils with either of the 3 inactive oils. The doses of 3 inactive oils were cinnamon (4×10^{-3} mg), clove (4×10^{-4} mg), star anise (4×10^{-3} mg). Data are shown as means ± SEM for 5 mice. Statistical differences vs. the mixture of the 5 active oils were calculated using Student's *t*-test. $*p < 0.05$ and $**p < 0.01$.

Table

Table 1. Composition of a mixture of the 5 active oils

Compound[a]	RI[b]	Peak Area(%)[c]
β-patchoulene	1681	0.4
α-copaene	1688	0.3
aristolene	1784	0.7
calarene	1811	4.2
α-gurjunene	1839	1.2
seychellene	1865	2.0
calaradiene	1882	0.8
isoborneol	1885	6.8
borneol	1916	23.4
α-bulnesene	1929	0.3
anethole	2024	0.5
β-ionone	2100	1.1
caryophyllene oxide	2133	0.8
(-)-globulol	2181	0.6
spathulenol	2206	1.9
ethyl cinnamate	2213	0.8
patchouli alcohol	2242	18.8
α-santalol	2309	1.9
β-santalol	2343	2.3
ethyl *p* -methoxycinnamate	2431	2.5
Total identified		71.1
unknown		28.9

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Fig. 1

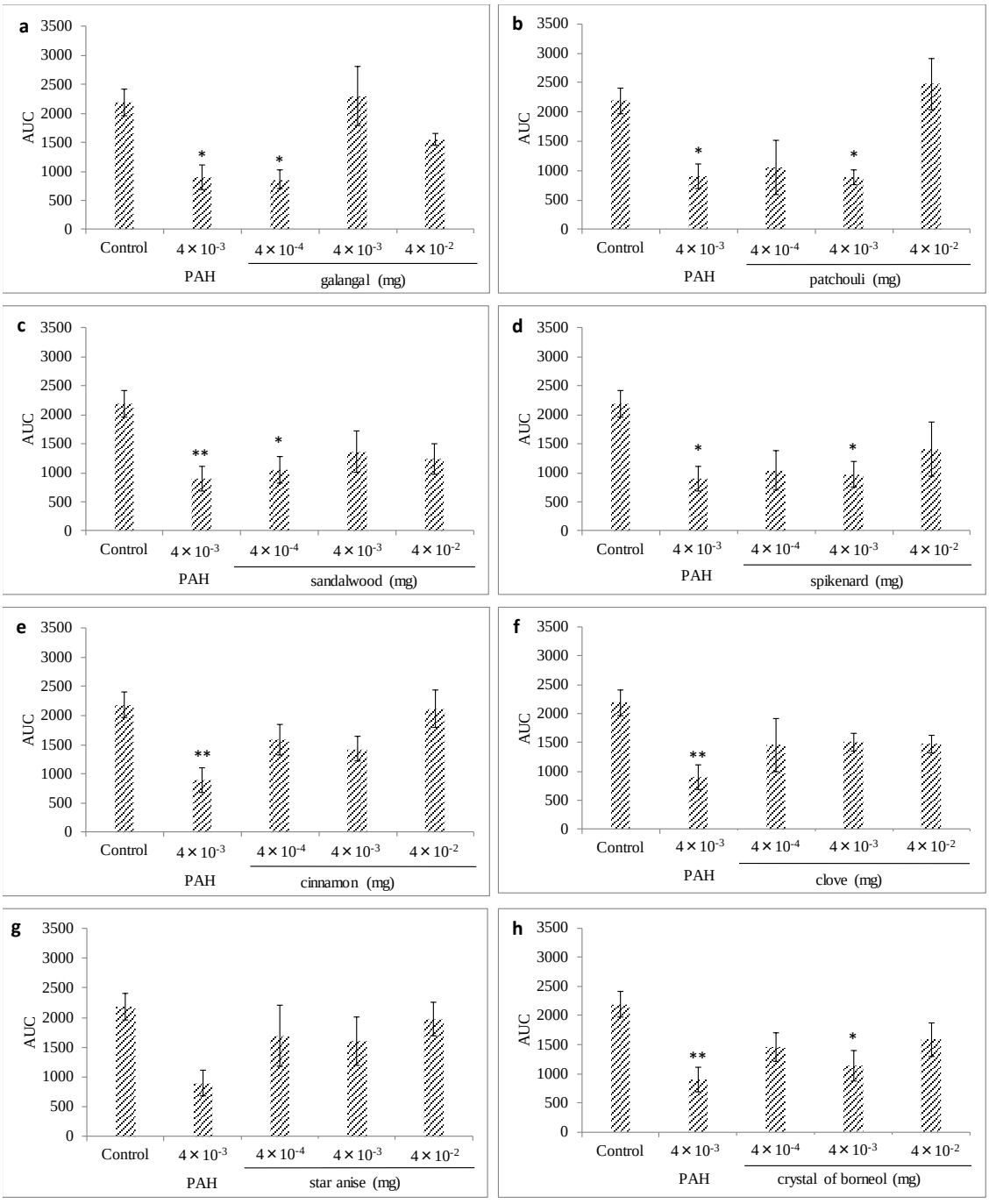

a
b
c
d
e
f
g
h
AUC
3500
3000
2500
2000
1500
1000
500
0
Control
4 × 10-3
4 × 10-4
4 × 10-3
4 × 10-2
PAH
galangal (mg)
patchouli (mg)
sandalwood (mg)
spikenard (mg)
cinnamon (mg)
clove (mg)
star anise (mg)
crystal of borneol (mg)

Fig. 2

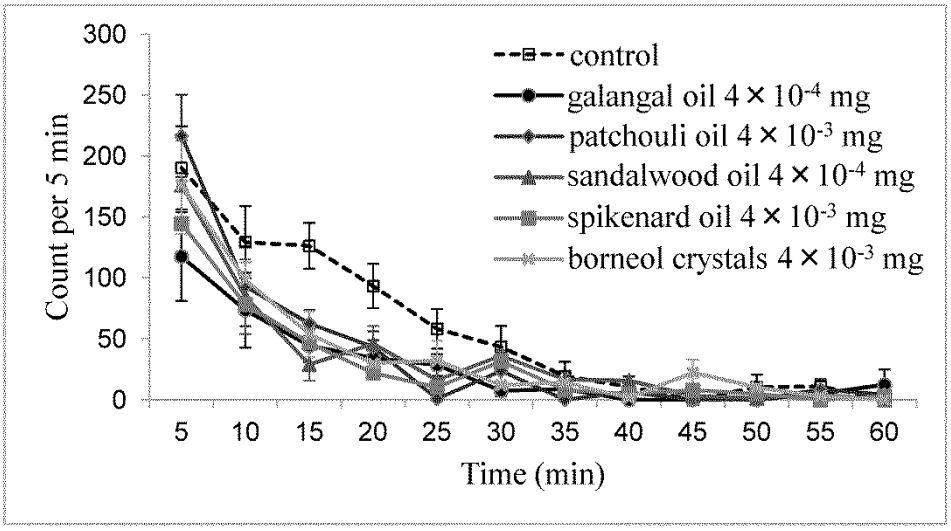

300
250
200
150
100
50
0
Count per 5 min
5
10
15
20
25
30
35
40
45
50
55
60
Time (min)
control
galangal oil 4 × 10-4 mg
patchouli oil 4 × 10-3 mg
sandalwood oil 4 × 10-4 mg
spikenard oil 4 × 10-3 mg
borneol crystals 4 × 10-3 mg

Fig. 3

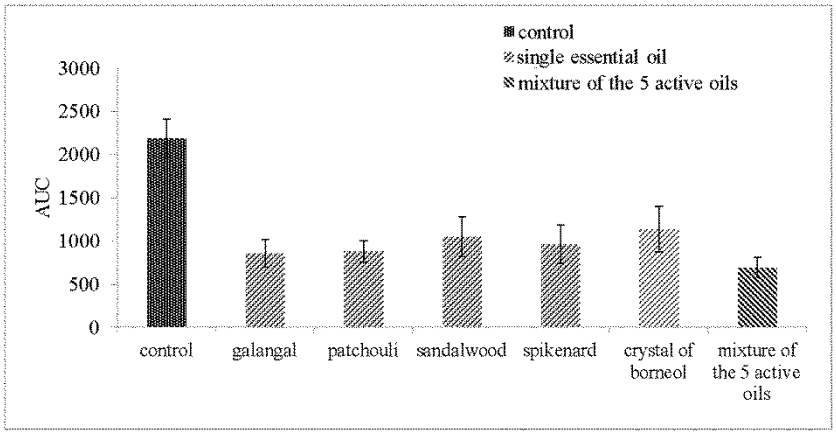
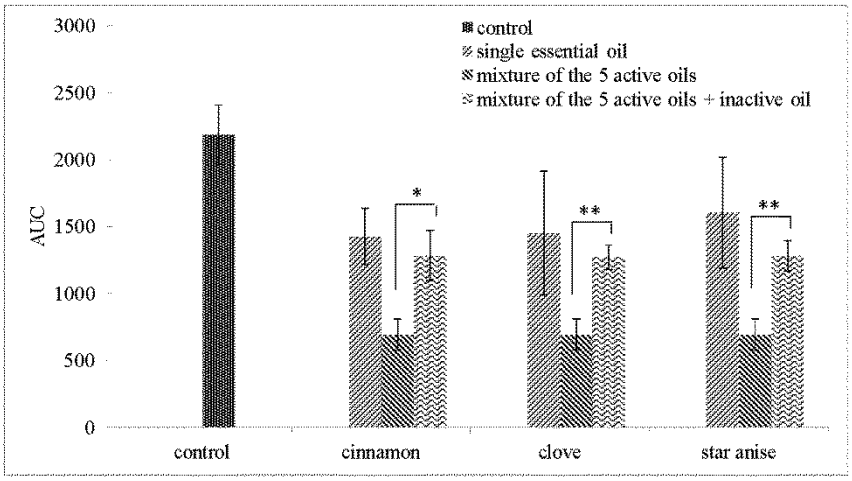

control
single essential oil
mixture of the 5 active oils
AUC
3000
2500
2000
1500
1000
500
0
control
galangal
patchouli
sandalwood
spikenard
crystal of borneol
mixture of the 5 active oils

Fig. 4


3000
2500
2000
1500
1000
500
0
AUC
control
single essential oil
mixture of the 5 active oils
mixture of the 5 active oils + inactive oil
*
**
**
control
cinnamon
clove
star anise

Supporting Information

The synergistic effect of fragrant herbs in Japanese scent sachets

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Legends for Figure
Fig. 1S Structures of the main components of essential oils of (a) galangal, (b) patchouli, (c) sandalwood, (d) spikenard, (e) cinnamon, (f) clove, (g) star anise, and (h) borneol crystals.

Legends for Tables

Tables

Table 1S. Composition of galangal oil

Compound[a]	RI[b]	Peak Area(%)[c]
3-carene	1062	1.3
pentadecane	1660	2.6
ethyl cinnamate	2199	30.6
ethyl *p* -methoxycinnamate	2417	62.5
Total identified		97.0
unknown		3.0

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 2S. Composition of patchouli oil

Compound[a]	RI[b]	Peak Area(%)[c]
β-patchoulene	1659	1.0
seychellene	1846	2.3
α-bulnesene	1911	0.8
anethol	2006	1.0
caryophyllene oxide	2117	2.8
cinnamyl aldehyde	2151	0.9
eugenol	2223	1.0
patchouli alcohol	2230	66.2
Total identified		76.2
unknown		23.8

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 3S. Composition of sandalwood oil

Compound[a]	RI[b]	Peak Area(%)[c]
epi -β-santalene	1832	1.1
camphenenol	2277	1.0
α-santalol	2318	49.5
(*Z*)-*trans* -α-bergamotol	2322	6.7
cis -β-santalol	2361	4.3
trans -β-santalol	2371	22.4
Total identified		85.0
unknown		15.0

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 4S. Composition of spikenard oil

Compound[a]	RI[b]	Peak Area(%)[c]
α-copaene	1665	0.9
δ-selinene	1733	2.7
aristolene	1764	1.8
calarene	1792	15.7
α-gurjunene	1821	3.0
calaradiene	1863	1.7
anethol	2006	0.7
β-ionone	2083	3.4
β-ionon-5,6-epoxide	2101	0.7
ledol	2141	0.8
cinnamaldehyde	2151	1.0
(-)-globulol	2166	2.3
spathulenol	2192	5.2
patchouli alcohol	2228	4.9
Total identified		44.9
unknown		55.1

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 5S. Composition of cinnamon oil

Compound[a]	RI[b]	Peak Area(%)[c]
α-copaene	1668	2.0
benzaldehyde	1718	0.4
α-muurolene	1920	0.5
δ-cadinene	1949	0.9
cinnamaldehyde	2155	93.9
α-cadinol	2251	0.5
2-methoxycinnamaldehyde	2385	1.9
Total identified		100.0

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 6S. Composition of clove oil

Compound[a]	RI[b]	Peak Area(%)[c]
α-copaene	1668	0.2
linalool	1726	0.1
trans -caryophyllene	1803	12.6
estragole	1868	0.1
humulene	1874	1.5
endo -borneol	1899	0.2
α-farnesene	1936	0.2
δ-cadinene	1949	0.2
methyl salicylate	1972	0.2
anethole	2009	2.7
caryophyllene oxide	2119	0.2
eugenol	2222	75.0
acetyleugenol	2267	5.2
allyl phenol	2315	0.1
Total identified		98.4
unknown		1.6

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 7S. Composition of star anise oil

Compound[a]	RI[b]	Peak Area(%)[c]
α-pinene	803	0.2
d -limonene	1167	0.3
linalool	1725	0.4
α-bergamotene	1777	0.2
caryophyllene	1797	0.8
β-farnesene	1866	0.2
estragole	1872	1.9
α-terpineol	1890	0.2
endo -borneol	1898	0.9
(*Z*)-anethole	1950	0.2
(*E*)-anethole	2013	91.1
anisaldehyde	2144	1.6
eugenol	2216	0.8
Total identified		98.8
unknown		1.2

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 8S. Composition of borneol crystals

Compound[a]	RI[b]	Peak Area(%)[c]
isoborneol	1867	21.6
borneol	1899	70.0
Total identified		91.7
unknown		8.3

[a]Order of elution is on an InertCap-Wax column.

[b]RI is the retention index, calculated against C10-C26 n-alkanes on an InertCap-Wax column.

[c]Peak area percentage is determined by calculating the peak area of the FID chromatogram.

Table 9S. Boiling point, vapor pressure, and lipophilicity of the main compounds in the essential oils.[21]

	Main compound	Boiling Point (at 760mmHg, °C)	Vapor Pressure (at 25 °C, mmHg)	Lipophilicity (logP(o/w))
galangal	ethyl *p* -methoxycinnamate	325-326	0.000235	2.650
patchouli	patchouli alcohol	287-288	0.000278	4.484
sandalwood	α-santalol	302	0.000002	4.647
spikenard	calarene	260	0.020000	6.252
borneol crystals	borneol	212	0.040000	3.240
cinnamon	cinnamaldehyde	249-252	0.026500	1.900
clove	eugenol	252-253	0.010000	2.270
star anise	anethole	234-237	0.069000	3.390

Figure 1S