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## Safety Assessment of Citrus-Derived Peel Oils as Used in Cosmetics

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Status: Tentative Report for Public Comment  
Release Date: June 25, 2014  
Panel Meeting Date: September 8-9, 2014

*All interested persons are provided 60 days from the above release date to comment on this safety assessment and to identify additional published data that should be included or provide unpublished data which can be made public and included. Information may be submitted without identifying the source or the trade name of the cosmetic product containing the ingredient. All unpublished data submitted to CIR will be discussed in open meetings, will be available at the CIR office for review by any interested party and may be cited in a peer-reviewed scientific journal. Please submit data, comments, or requests to the CIR Director, Dr. Lillian Gill.*

The 2014 Cosmetic Ingredient Review Expert Panel members are: Chairman, Wilma F. Bergfeld, M.D., F.A.C.P.; Donald V. Belsito, M.D.; Ronald A. Hill, Ph.D.; Curtis D. Klaassen, Ph.D.; Daniel C. Liebler, Ph.D.; James G. Marks, Jr., M.D., Ronald C. Shank, Ph.D.; Thomas J. Slaga, Ph.D.; and Paul W. Snyder, D.V.M., Ph.D. The CIR Director is Lillian J. Gill, D.P.A. This report was prepared by Christina Burnett, Senior Scientific Analyst/Writer and Monice Fiume, Assistant Director/Senior Scientific Analyst.

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### Cosmetic Ingredient Review

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## **ABSTRACT**

*The Cosmetic Ingredient Review Expert Panel assessed the safety of 14 Citrus-derived peel oil ingredients and concluded that these ingredients are safe for use in cosmetic products when finished products that are applied to the skin, excluding rinse-off products, do not contain more than 0.0015% (i.e., 15 ppm) 5-methoxysporalen (5-MOP), and when formulated to be non-sensitizing and non-irritating. The Citrus-derived peel oil ingredients are most frequently reported to function in cosmetics as skin conditioning agents or as fragrance ingredients. The Panel reviewed the available animal and clinical data to determine the safety of these ingredients. Because final product formulations may contain multiple botanicals, each containing similar constituents of concern, formulators are advised to be aware of these constituents and to avoid reaching levels that may be hazardous to consumers. Industry should use good manufacturing practices to limit impurities that could be present in botanical ingredients.*

## **INTRODUCTION**

Citrus-derived peel oils are widely used as cosmetic ingredients, and function primarily as skin conditioning agents-miscellaneous and fragrance. This report assesses the safety of 14 citrus-derived peel oils. The full list of ingredients in this report is found in Table 1.

The citrus ingredients in this assessment are found in foods, and daily exposure from food use would result in much larger systemic exposures than those from use in cosmetic products. Additionally, essential oils, oleoresins (solvent-free), and natural extracts (including distillates) derived from some citrus fruits are generally recognized as safe (GRAS) for their intended use in foods for human and animal consumption according to the Food and Drug Administration. Volatile oils of limes, lemons, grapefruits, bitter oranges, oranges, and tangerines are described as flavoring agents in the USP Food Chemicals Codex.<sup>1</sup> Thus, the systemic toxicity potential of citrus-derived peel oils via oral exposure is not addressed further in this report. The primary focus of the safety assessment of these citrus ingredients as used in cosmetics is on the potential for irritation and sensitization from dermal exposure.

The CIR does not review ingredients that function only as fragrance ingredients because, as fragrances, the safety of these ingredients is evaluated by the Research Institute for Fragrance Materials (RIFM). Three of the citrus-derived peel oils in this report function only as fragrance ingredients, according to the *International Cosmetic Ingredient Dictionary and Handbook* (see Table 2).<sup>2</sup> However, RIFM has not confirmed that these 3 ingredients function as fragrances and are within its purview, thus CIR is reviewing the safety of these ingredients.

Botanicals such as citrus contain hundreds of constituents, some of which have the potential to cause toxic effects. For example, bergapten (aka 5-methoxysporalen or 5-MOP) is a naturally-occurring phototoxic furanocoumarin (psoralen) in citrus peel oils. In this assessment, CIR is reviewing information available to evaluate the potential toxicity of each of the citrus-derived peel oils as a whole, complex substance. Except for specific constituents of concern, CIR is not reviewing information that may be available to assess the potential toxicity of the individual constituents of which the citrus-derived ingredients are composed. CIR requested information on the concentrations (including ranges, means, upper 95 percent confidence limits, detection limits, etc.) of individual constituents in citrus-derived peel oils used in cosmetics to facilitate the safety assessment of these ingredients. Such information on constituents that have been identified as constituents of concern by the Panel in previous safety assessments, or by other recognized scientific expert review bodies, is especially important.

Some toxicological data on lemon oil and sweet orange oil (synonyms: lemon, ext. and orange, sweet, ext., respectively) reviewed in this safety assessment were obtained from robust summaries of data submitted to the European Chemical Agency (ECHA) by companies as part of the REACH chemical registration process. These data are available on the ECHA website.<sup>3,4</sup>

**Note:** In many of the published studies, the information provided is not sufficient to determine how well the substance being tested represents the cosmetic ingredient. In this safety assessment report, if a substance tested in a study is not clearly a cosmetic ingredient, because of lack of information on the genus and species from which the substance was derived and/or the method of extraction used, the test substance will be referred to by a common name (e.g. lime oil). If the substance is clearly a cosmetic ingredient, the International Nomenclature of Cosmetic Ingredients (INCI) name will be used (e.g. "citrus aurantifolia (lime) peel oil"). In some instances, the part of the plant from which the oil was expressed is not known but, based on the method of manufacture; the oil could have

been expressed from the peels of the citrus fruit. Additionally, some inconsistencies were noted in both taxonomic and INCI naming conventions. For example, this report includes the sweet orange ingredient described as citrus aurantium dulcis (orange) peel oil in the *International Cosmetic Ingredient Dictionary and Handbook*.<sup>2</sup> In contrast, most of the published literature and FDA refer to this ingredient as citrus sinensis (sweet orange) peel oil.

## **CHEMISTRY**

### **Definition and General Characterization**

The definitions and functions of the citrus-derived peel oils included in this report are provided in Table 1. In some cases, the definition provides insight on the method(s) of manufacture. It should be noted that essential oils are hydrophobic, liquid, volatile aroma compounds from plants. These are typically small molecules, but their chemical structures can vary widely. Fixed oils, on the other hand, are hydrophobic, nonvolatile, fatty compounds from plants. These consist primarily of glycerides and, to some extent, free fatty acids. The volatile nature of essential oils makes them likely to be useful as fragrances, but does not preclude other functions for them in cosmetics.

There are numerous *Citrus* varieties distributed throughout the world; most citrus fruits are grown in the temperate and tropical zones in both the northern and southern hemispheres.<sup>5</sup> Citrus can be propagated and new varieties can be produced by cultivating asexual nuclear or chance seedlings or by crossing or mutation.

### **Physical and Chemical Properties**

Physical and chemical properties of the citrus-derived peel oils are provided in Table 3.

### **Method of Manufacturing**

#### **Bitter Orange Oil**

Bitter orange oil (cold-pressed) is obtained by expression, without the use of heat, from the fresh peel of the fruit of *Citrus aurantium*.<sup>1</sup>

#### **Lemon Oil**

Lemon oil, expressed, is produced by pressing the outer rind of the ripe fruit by hand or by machine.<sup>6</sup> More economical processes involve an integrated juice-oil procedure. Lemon oil can also be produced by distillation of expressed oils or direct distillation of fruit. Distilling (rectifying) removes terpenes. Steam distillation removes non-volatile furocoumarins.

#### **Lime Oil**

Lime oil is produced using the same methods previously described above for lemon oil.<sup>6</sup>

#### **Mandarin Oil – Expressed**

Mandarin peel oil expressed (identified in the literature as *Citrus reticulata*) is prepared by expression of the peels of the ripe fruit of the mandarin orange.<sup>7</sup>

#### **Orange Oil**

Orange oil (cold-pressed) is obtained by expression, without the use of heat, from the fresh peel of the ripe fruit of *Citrus sinensis*.<sup>1</sup> Distilled orange oil is obtained from the fresh peel or juice of the fruit of *Citrus sinensis*, with or without the previous separation of the juice, pulp, or peel.

#### **Tangerine Oil**

Tangerine oil (cold-pressed) is obtained from the peels of the ripe fruit of the Dancy tangerine, *Citrus nobilis* or *Citrus reticulata*, and from some other closely related varieties.<sup>1</sup>

### **Constituents/Composition**

The citrus-derived peel oils are complex botanicals composed of numerous constituents; there is great variation among citrus species and cultivars because of frequent bud mutations, interspecific and intergeneric hybridization,

and apoximis (i.e., one or more of several types of asexual reproduction).<sup>8</sup> The composition of citrus oils will vary based on the location where the plant is grown, the maturity of the plant, and storage conditions.<sup>5</sup> The method of extraction will also affect the composition.

Citrus oils contain large amounts of monoterpene hydrocarbons; limonene is present in the greatest amount, composing 38.1%-95.8% of the oils. Citrus oils also contain sesquiterpene hydrocarbons, which are responsible for the characteristic flavors of these oils.<sup>9</sup> Table 4 lists the chemical compositions of cold-pressed,<sup>8-12</sup> hydrodistilled,<sup>13-15</sup> and steam-distilled<sup>16</sup> peel oils sorted by citrus plant species, Table 5 presents the typical levels of 5-MOP found in some of the oils, and Table 6 provides the levels of major coumarins and furocoumarins in lemon and lime oil. Table 7 lists citrus constituents that are established contact allergens, according to the European Commission's Scientific Committee on Consumer Safety (SCCS).

## USE

### **Cosmetic**

Table 8 presents the current product-formulation use data for citrus-derived peel oils. These ingredients function primarily as skin conditioning agents-miscellaneous and fragrance.<sup>2</sup>

According to information supplied to the FDA by industry as part of the Voluntary Cosmetic Registration Program (VCRP), citrus limon (lemon) peel oil has the most reported uses in cosmetic and personal care products, with a total of 490; more than half of the uses are in leave-on skin care preparations.<sup>17</sup> Citrus aurantium dulcis (orange) peel oil (reported as citrus sinensis (sweet orange) peel oil by the VCRP) has the second greatest number of overall uses reported, with a total of 289; about half of those uses are in leave-on skin care preparations.

In the Personal Care Products Council's use concentration survey, citrus limon (lemon) peel oil had a maximum use concentration range of 0.0001% to 0.5% with 0.5% reported in "other" skin care preparations.<sup>18</sup> Citrus aurantium dulcis (orange) peel oil had a maximum use concentration range of 0.00002% to 29%, with 29% reported in non-coloring hair conditioners.

In some cases, reports of uses were received from the VCRP, but no concentration of use data were provided. For example, citrus junos peel oil is reported to be used in 6 formulations, but no use concentration data were available. In other cases, no reported uses were identified by the VCRP, but a maximum use concentration was provided in the industry survey. For example, citrus grandis (grapefruit) peel oil was not reported in the VCRP database to be in use, but the industry survey indicated that it is used at concentrations up to 0.05%. It should be presumed that citrus grandis (grapefruit) peel oil is used in at least one cosmetic formulation.

Table 9 lists all citrus-derived peel oils not indicated to be in use based on the VCRP data and the results of the Council concentration of use survey.

Under the rules governing cosmetic products in the European Union, citrus-derived ingredients must have furocoumarin content below 1 mg/kg in sun-protection products and in bronzing products.<sup>19</sup> The International Fragrance Association (IFRA) has issued standards for citrus oils and other furocoumarin-containing essential oils.<sup>20</sup> Thus, finished products that are applied to the skin, excluding rinse-off products like bath preparations and soaps, must not contain more than 0.0015%, or 15 ppm, 5-MOP. This equates to 0.0075%, or 75 ppm, in a fragrance compound used at 20% in a consumer product that is applied to the skin. If the level of 5-MOP has not been determined, limits specified for individual oils should be observed, and when such oils are used in combination with other phototoxic ingredients, the potential for an additive effect should be considered and use levels should be reduced accordingly. Restrictions for furocoumarin-containing essential oils have been recommended for bitter orange oil expressed, grapefruit oil expressed, lemon oil cold pressed, and lime oil expressed.

An IFRA standard also has been issued for 7-methoxycoumarin, which is prohibited for use in fragrance compounds.<sup>21</sup> Based on established maximum levels of this substance from commercially-available natural sources (like essential oils, extracts and absolutes), exposure to 7-methoxycoumarin from the use of these oils and extracts is regarded to be acceptable if the level of 7-methoxycoumarin in the finished product does not exceed 100 ppm. An example maximum concentration based on this standard is 0.1% for lime cold pressed oil.

The IFRA has also set limits on the amounts of some citrus-derived oils in finished products. For leave-on products applied to skin areas exposed to direct sunlight, these limits include: 1.25% bitter orange peel expressed;<sup>22</sup> 4% grapefruit oil expressed;<sup>23</sup> 2% lemon oil cold-pressed;<sup>24</sup> 0.7% lime oil expressed.<sup>25</sup> There are no restrictions for any of these oils in rinse-off products and products that are not applied to the skin. IFRA specified that if combinations

of phototoxic fragrance ingredients are used, the use levels must be reduced accordingly, so that the sum of the concentrations of all phototoxic fragrance ingredients, expressed as a percentage of their respective recommended maximum levels, shall not exceed 100% in the consumer product. Additionally, the IFRA general standard described above for 'Citrus oils and other furocoumarins-containing essential oils' must be considered.

### **Non-Cosmetic**

The essential oils, oleoresins (solvent-free), and natural extractives (including distillates) derived from the following citrus fruits are GRAS for their intended use in foods for human consumption: *Citrus aurantifolia* (lime); *Citrus aurantium* (bitter orange; the flowers and peel); *Citrus limon* (lemon); *Citrus paradisi* (grapefruit); *Citrus reticulata* (tangerine); *Citrus reticulata blanco* (mandarin); *Citrus sinensis* (orange; the leaf, flowers, and peel) and citrus peels (species not specified) (21CFR182.20). These essential oils, oleoresins (solvent-free), and natural extractives (including distillates) of these citrus fruits are GRAS for their intended use in animal drugs, feeds, and related products (21CFR582.20).

*Citrus aurantium amara* (bitter orange) and extracts of its dried fruit and peel have been used in traditional Western medicines and in Chinese and Japanese herbal medicines.<sup>26</sup>

### **TOXICOLOGICAL STUDIES**

As noted earlier, the citrus ingredients in this assessment are found in foods, and daily exposures from food use would result in a much larger systemic exposures than those from use in cosmetic products. Essential oils, oleoresins (solvent-free), and natural extracts (including distillates) derived from some citrus fruits are GRAS for their intended use in foods for human and animal consumption according to the FDA. Volatile oils of limes, lemons, grapefruits, bitter oranges, oranges, and tangerines are described as flavoring agents in the USP Food Chemicals Codex.<sup>1</sup> Therefore, the systemic toxicity potential of these ingredients is not addressed further in this report. The primary focus of this safety assessment is on the potential for irritation and sensitization from dermal exposure to these citrus ingredients as used in cosmetic products.

#### **Acute Toxicity**

##### ***Dermal – Non-Human***

###### **Lemon Oil**

The dermal LD<sub>50</sub> of lemon oil was greater than 10 g/kg in rabbits.<sup>3</sup> An occlusive patch of undiluted oil was applied to the skin of six animals for 24 h. One animal died during the observation period.

###### **Mandarin Oil – Expressed (*Citrus reticulata*)**

The dermal LD<sub>50</sub> of mandarin peel oil (*Citrus reticulata*) was greater than 5 g/kg in rabbits.<sup>7</sup> An occlusive patch of undiluted oil was applied to the skin of seven animals for 24 h.

###### **Orange Oil**

The dermal LD<sub>50</sub> of sweet orange oil was greater than 5 g/kg in female New Zealand White rabbits.<sup>4</sup> An occlusive patch of undiluted oil was applied to the skin of 10 animals for 24 h. Signs of skin irritation were observed, including moderate redness in 10/10 animals, slight edema in 3/10 animals, and moderate edema in 5/10 animals **was observed**.

### **REPRODUCTIVE AND DEVELOPMENTAL TOXICITY**

No published reproductive and developmental studies on citrus-derived peel oils were identified in a literature search for these ingredients and no unpublished data were submitted.

## GENOTOXICITY

Genotoxicity studies for in vitro assays are summarized in Table 10. No genotoxic effects were observed for lemon oil or sweet orange oil in bacterial reverse mutation assays, mouse lymphoma cell mutation assays, and Chinese hamster chromosome aberration assays.<sup>3,4</sup>

## CARCINOGENICITY

### Orange Oil, Lemon Oil, Grapefruit Oil and Lime Oil

Tumor-promoting activity was observed in mouse skin exposed to essential oils of orange (sweet), lemon, grapefruit, or lime.<sup>27</sup> Chemical constituents of these oils were not fully identified in this study, although the terpene and non-terpene fractions were separated. Groups of 10 male and 10 female strain 101 mice received a single application of 9,10-dimethyl-1,2-benzanthracene (DMBA) in acetone (300 µg in 0.2 ml in 4 groups, 225 µg in 0.15 ml in a fifth group). Group 1 was a control group that received no further treatments. Groups 2 through 5 received weekly applications of 0.25 ml of the test substances 3 weeks after the application of DMBA.

By the fifth week, papillomas were observed in Group 3 (lemon oil), Group 4 (grapefruit oil), and Group 5 (lime oil). Papillomas were observed in Group 2 (orange oil) by the 12<sup>th</sup> week. After 33 weeks, 10/20 mice in the lemon oil and lime oil treatment groups and 13/20 mice in the grapefruit oil and orange oil groups had papillomas. Only 1 mouse in the control group had papillomas after 33 weeks, and the affected site was not the treated skin. Additionally, 1 female mouse of the lemon oil group developed a sebaceous-gland tumor of the nipple. No malignant skin tumors were observed in the orange oil group: treatment for this group was stopped after 42 weeks. Squamous cell carcinomas of the skin were observed in 2 mice from the lemon oil group and 2 mice of the grapefruit oil group between weeks 36 and 55. One malignant skin tumor was observed in the lime oil group at week 34; however, the mouse was found dead and a proper histological examination was not possible. No malignant skin tumors were observed in the control group. Non-dermal tumors during the treatment period were observed in 1 mouse of the orange oil group (a hemangioma of the subcutaneous tissue starting at week 7) and in 1 mouse of the grapefruit oil group (a spindle cell sarcoma of the subcutaneous tissues). No tumors of the internal organs were observed. The survival of all the mice, including the controls, in this experiment was poor because of a very high incidence of renal disease.<sup>27</sup>

### Orange Oil

Tumor-promoting activity was observed in mouse skin exposed to orange (sweet) oil.<sup>27</sup> In the study, groups of 10 male and 10 female strain 101 mice received a single application of DMBA in acetone (300 µg in 0.15 ml). One group (15 mice of each sex) was a control group that received no further treatments. Two groups received weekly applications of 0.25 ml of 40% orange oil in acetone or 80% orange oil in acetone 3 weeks after the initial application of DMBA. The applications continued for 37 weeks.

Papillomas were observed in both groups treated with orange oil starting on the 12<sup>th</sup> week. After 33 weeks, 5/10 mice treated with 40% orange oil and 10/10 mice treated with 80% orange oil had papillomas, and at study end, only 1 tumor of each group was found outside of the treated area. Four mice in the control group had papillomas by week 33, but these tumors were outside of the treated area of the skin. Malignant tumors were observed in one mouse of each treatment group, arising from the pre-existing papilloma. Both tumors were squamous-cell carcinomas infiltrating the panniculus muscle. Additionally, tumors of the urethral orifice were observed in 4 female mice of the 40% orange oil group. The survival of all the mice in this experiment was poor due to a very high incidence of renal disease.

In the same study, tumor-promoting activity was observed in mice exposed to undiluted orange oil after pretreating the mice with either dermal or intraperitoneal injections of urethane. The effect was weak compared to the effects observed after DMBA induction.

A similar experiment performed in the same study tested the carcinogenic effects of orange oil without pretreatment with DMBA or urethane. The mice were treated once weekly with 0.25 ml of 40% or 80% orange oil in acetone or undiluted orange oil for 38 (diluted) or 46 (undiluted) weeks. This study found no evidence of direct tumorigenic effects on the treated mouse skin. Urethral orifice tumors were observed in one female mouse of the 40% orange oil group and in one female mouse of the 80% orange oil group. A papilloma was observed on the head of a mouse (outside of the treatment site) that was treated with 80% orange oil.<sup>27</sup>

## **IRRITATION AND SENSITIZATION**

### **Dermal Irritation**

Dermal irritation studies are summarized in Table 11. Irritation was observed in animals treated with unspecified concentrations of mandarin peel oil. In human subjects, no irritation was observed after topical exposure to lemon oil (up to 20%) or mandarin peel oil (8%).<sup>3,4,7,28</sup>

### **Ocular Irritation**

#### **Lemon Oil**

Lemon oil tested at 5% was not irritating to the eyes of 3 albino rabbits.<sup>3</sup> Each rabbit had 0.1 ml of the test material instilled into the right eye with no further treatment. The left eye served as the control. Eyes were examined every 24 h for 4 days and then again on the 7<sup>th</sup> day. No corneal opacity or iris congestion was observed. An intense conjunctival irritation occurred involving chemosis and discharge. Treated eyes were normal on the 7<sup>th</sup> day.

#### **Orange Oil**

Orange oil tested undiluted did not induce significant or irreversible damage to the eyes of 3 male New Zealand White rabbits.<sup>4</sup> The test was performed in accordance with OECD guideline 405. The test material (0.1 ml) was instilled into one eye of each rabbit. The mean scores calculated for the three animals across 3 scoring times were 0.0 for corneal opacity and iris lesions and 1.0 for reddening of the conjunctivae.

### **Sensitization**

Sensitization studies are presented in Table 12. Mandarin peel oil (8% in petrolatum) was not sensitizing in human maximization tests. In studies of 250 dermatitic patients, less than 2.5% had positive reactions to bitter orange oil, lemon oil, or sweet orange oil tested at 2% in paraffin.<sup>3,4,7,29</sup>

### **Phototoxicity and Photosensitization**

Phototoxicity and photosensitization studies are presented in Table 13. Phototoxic potential was observed for sweet orange oil and lemon oil in in vitro studies. No phototoxic responses were noted in some animal studies of lime oil, lemon oil, grapefruit oil, mandarin oil, or tangerine oil; however, signs of phototoxicity were observed in response to undiluted lime oil and lime oil diluted to concentrations of 15%; undiluted bitter orange oil, and undiluted lemon oil and lemon oil diluted to concentrations of 50%. In human studies, phototoxic reactions were observed in response to undiluted bitter orange oil, lemon oil (1%), sweet orange oil (1%), and undiluted and diluted expressed lime oil (30%). Many of the citrus-derived peel oils contain constituents that are photoactive agents, although those noted to be furocoumarin-free tended not to induce photosensitization.<sup>22,30-34</sup>

### **Occupational Exposure**

In a retrospective study (2001-2010) of professional food handlers in Denmark, 8.5% (16/188) of the patients had positive skin prick test reactions to orange peel and 7.9% (15/191) of the patients had positive skin prick test reactions to lemon peel.<sup>35</sup>

## **SUMMARY**

The 14 citrus-derived peel oils described in this report function primarily as skin conditioning agents-miscellaneous and fragrance. Botanicals such as citrus are composed of hundreds of constituents, some of which have the potential to cause toxic effects; for example, bergapten (aka 5-methoxysporalen or 5-MOP) is a naturally-occurring, phototoxic furanocoumarin (psoralen) in citrus peel oils. Presently, CIR is reviewing the information available on the potential toxicity of each of the citrus peel oil-derived ingredients as a whole, complex substance; CIR is not reviewing the potential toxicity information on the individual constituents of which the citrus-derived ingredients are comprised. CIR requested information on the concentrations (including ranges, means, upper 95 percent confidence limits, detection limits, etc.) of individual constituents in the citrus peel oil-derived ingredients used in cosmetics, to facilitate the safety assessment of these ingredients. Such information on constituents that have been identified as

constituents of concern by the CIR Expert Panel in previous safety assessments, or by other recognized scientific expert review bodies, is especially important.

Citrus oils contain large amounts of monoterpene hydrocarbons; limonene is present in the greatest amount, composing 38.1-95.8% of the oils. Citrus oils also contain sesquiterpene hydrocarbons, which are responsible for the characteristic flavor of these oils.

Citrus limon (lemon) peel oil has the most reported uses in cosmetics and personal care products, with a total of 490; more than half of the uses are in leave-on skin care preparations. The range of highest maximum use concentrations for citrus limon (lemon) peel oil is 0.0001% to 0.5%, with 0.5% reported in "other" skin care preparations. Citrus aurantium dulcis (orange) peel oil (reported as citrus sinensis (sweet orange) peel oil to the VCRP) has the second greatest number of overall uses reported, with a total of 289; about half of those uses are in leave-on skin care preparations. Citrus aurantium dulcis (orange) peel oil had a highest maximum use concentration range of 0.00002% to 29%, with 29% reported in non-coloring hair conditioners.

Under the rules governing cosmetic products in the European Union, citrus-derived ingredients must have furocoumarin content below 1 mg/kg in sun-protection and bronzing products. IFRA also has issued standards for citrus oils and other furocoumarin-containing essential oils. Finished products that are applied to the skin, excluding rinse-off products like bath preparations and soaps, must not contain more than 0.0015% or 15 ppm 5-MOP. If the level of 5-MOP has not been determined, limits specified for individual oils should be observed, and when such oils are used in combination with other phototoxic ingredients, the potential additive effect should be taken into consideration and use levels should be reduced accordingly. Restrictions for furocoumarin-containing essential oils and limits on the amounts of citrus-derived oils in finished products have been recommended for bitter orange oil expressed, grapefruit oil expressed, lemon oil cold pressed, and lime oil expressed.

The citrus ingredients in this assessment are found in foods, and the daily exposure from food use would result in a much larger systemic dose than that resulting from use in cosmetic products. Essential oils, oleoresins (solvent-free), and natural extractives (including distillates) derived from some citrus fruits are GRAS for their intended use in foods for human and animal consumption,

The dermal LD<sub>50</sub> of undiluted mandarin peel oil (*Citrus reticulata*) and undiluted sweet orange oil was greater than 5 g/kg in rabbits. In undiluted lemon oil, the dermal LD<sub>50</sub> was greater than 10 g/kg in rabbits.

No genotoxic effects were observed in lemon oil or sweet orange oil in bacterial reverse mutation assays, mouse lymphoma cell mutation assays, and Chinese hamster chromosome aberration assays.

Tumor-promoting activity was observed in mouse skin exposed to undiluted essential oils of orange (sweet), lemon, grapefruit, or lime after pretreatment with DMBA. Related studies of 40%, 80%, or 100% orange oil following pretreatment with DMBA or urethane also reported tumor-promoting activity, although the effect was weaker in the mice induced with urethane. No tumorigenic effects were observed in mice tested with orange oil without pretreatment with DMBA or urethane. Survival rates of the mice, including controls, in these experiments were poor because of a very high incidence of renal disease

Irritation was observed in animals treated with unspecified concentrations of mandarin peel oil. In human subjects, no irritation was observed after topical exposure to lemon oil (up to 20%) or mandarin peel oil (8%).

In rabbits, lemon oil tested at 5% was not irritating and orange oil tested undiluted did not induce significant or irreversible damage to the eyes.

Mandarin peel oil (8% in petrolatum) was not sensitizing in human maximization tests. In studies of 250 dermatitic patients, less than 2.5% had positive reactions to bitter orange oil, lemon oil, or sweet orange oil tested at 2% in paraffin.

Phototoxic potential was observed for sweet orange oil and lemon oil in in vitro studies. No phototoxic responses were noted in some animal studies of lime oil, lemon oil, grapefruit oil, mandarin oil, or tangerine oil; however, phototoxic reactions were observed in response to undiluted lime oil and lime oil diluted to concentrations of 15%; undiluted bitter orange oil, and undiluted lemon oil and lemon oil diluted to concentrations of 50%. In human studies, phototoxic reactions were observed in response to undiluted bitter orange oil, lemon oil (1%), sweet orange oil (1%), and undiluted and diluted expressed lime oil (30%). Many of the citrus-derived peel oils contain constituents that are photoactive agents, although those noted to be furocoumarin-free tended not to induce photosensitization.

A retrospective occupational study of food handlers noted positive reactions to orange and lemon peels.



No published studies on reproductive and development toxicity of citrus-derived peel oils were discovered and no unpublished data were submitted to address these topics.

### DISCUSSION

The citrus ingredients in this assessment are found in foods, and daily exposures from the consumption of foods can be expected to yield much larger systemic exposures to these ingredients than those from the use of cosmetic products. Essential oils, oleoresins (solvent-free), and natural extracts (including distillates) derived from some citrus fruits are GRAS in foods and animal feeds. Additionally, volatile oils of limes, lemons, grapefruits, bitter oranges, oranges, and tangerines are used as flavoring agents. Consequently, the primary focus of this safety assessment is on the potential for irritation and sensitization from dermal exposures to the citrus ingredients.

Most of the reports that the Panel reviewed were not sufficiently detailed to enable determining how well the substances tested represent the cosmetic ingredients included in this safety assessment. For example, the genus and species of the plants from which the test substances were derived, the cultivation methods used to grow the plants, and the methods of extraction are not specified in many of these studies. The Panel expressed concern about the potential for constituents in citrus-derived peel oils to cause phototoxicity, including the furocoumarin 5-MOP. They agreed that adherence to the IFRA standards for such constituents will prevent phototoxicity. Additionally, based on the findings of a rodent carcinogenicity study in which tumor promotion activity may have been caused by repeated skin irritation and resultant proliferation of DMBA-treated basal cells, the Panel concluded that citrus-derived peel oils could be irritants. Thus, these botanical ingredients must be formulated to be non-irritating.

The Panel noted that, because botanical ingredients are complex mixtures, there is concern that multiple botanical ingredients may each contribute to the final concentration of a single constituent. Therefore, when formulating products, manufacturers should avoid reaching levels in final formulation of plant constituents that may cause sensitization or other adverse effects. Specific examples of constituents that could induce sensitization are limonene, citral, and other monoterpenes, furocoumarins (such as 5-MOP and 7-methoxycoumarin), and those that could cause other adverse effects are terpenes (such as thujone and limonene).

The Panel expressed concern about pesticide residues and heavy metals that may be present in botanical ingredients. They stressed that the cosmetics industry should continue to use current good manufacturing practices (cGMPs) to limit impurities.

### CONCLUSION

The Panel issued a tentative safety assessment for public comment for the citrus-derived peel oils listed below with the conclusion that these ingredients are safe for use in cosmetic products when finished products that are applied to the skin, excluding rinse-off products, do not contain more than 0.0015% or 15 ppm 5-methoxysporalen (5-MOP), and when formulated to be non-sensitizing and non-irritating.

citrus aurantifolia (lime) peel oil\*  
citrus aurantium amara (bitter orange) peel oil  
citrus aurantium curassaviensis peel oil\*  
citrus aurantium dulcis (orange) peel oil  
citrus clementina peel oil\*  
citrus grandis (grapefruit) peel oil  
citrus iyo peel oil\*

citrus junos peel oil  
citrus limon (lemon) peel oil  
citrus medica vulgaris peel oil\*  
citrus nobilis (mandarin orange) peel oil  
citrus reticulata (tangerine) peel oil\*  
citrus tachibana/reticulata peel oil\*  
citrus tangerina (tangerine) peel oil

*\*Not reported to be in current use. Were ingredients in this group not in current use to be used in the future, the expectation is that they would be used in product categories and at concentrations comparable to others in this group.*

## TABLES

**Table 1. Definitions and functions of Citrus-derived ingredients.** <sup>2</sup>

<b>Ingredient</b>	<b>Definition</b>	<b>Function</b>
Citrus Aurantifolia (Lime) Peel Oil	Citrus Aurantifolia (Lime) Peel Oil is the volatile oil obtained from the peel of <i>Citrus aurantifolia</i> .	Fragrance Ingredients
Citrus Aurantium Amara (Bitter Orange) Peel Oil CAS No. 68916-04-1	Citrus Aurantium Amara (Bitter Orange) Peel Oil is the volatile oil obtained from the peel of <i>Citrus aurantium amara</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous
Citrus Aurantium Currassuviensis Peel Oil	Citrus Aurantium Currassuviensis Peel Oil is the volatile oil derived from the peel of the laraha orange, <i>Citrus aurantium currassuviensis</i> .	Fragrance Ingredients
Citrus Aurantium Dulcis (Orange) Peel Oil CAS No. 8008-57-9	Citrus Aurantium Dulcis (Orange) Peel Oil is the volatile oil obtained by expression from the peel of <i>Citrus sinensis</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous
Citrus Clementina Peel Oil	Citrus Clementina Peel Oil is the volatile oil obtained from the peel of <i>Citrus clementina</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous
Citrus Grandis (Grapefruit) Peel Oil CAS No. 8016-20-4	Citrus Grandis (Grapefruit) Peel Oil is the volatile oil obtained from the peel of the grapefruit, <i>Citrus grandis</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous
Citrus Iyo Peel Oil	Citrus Iyo Peel Oil is the volatile oil obtained from the peel of <i>Citrus iyo</i> .	Skin-Conditioning Agents - Emollient
Citrus Junos Peel Oil	Citrus Junos Peel Oil is the volatile oil obtained from the peel of <i>Citrus junos</i> .	Cosmetic Astringents
Citrus Limon (Lemon) Peel Oil CAS No. 8008-56-8; 8020-19-7; 84929-31-7; 85085-28-5	Citrus Limon (Lemon) Peel Oil is the volatile oil obtained from the peel of <i>Citrus limon</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous
Citrus Medica Vulgaris Peel Oil	Citrus Medica Vulgaris Peel Oil is the volatile oil obtained from the peel of <i>Citrus medica vulgaris</i> .	Fragrance Ingredients
Citrus Nobilis (Mandarin Orange) Peel Oil CAS No. 8008-31-9; 84696-35-5	Citrus Nobilis (Mandarin Orange) Peel Oil is the oil obtained from the peel of the mandarin orange, <i>Citrus nobilis</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous
Citrus Reticulata (Tangerine) Peel Oil CAS No. 8008-31-9	Citrus Reticulata (Tangerine) Peel Oil is the volatile oil obtained from the peel of <i>Citrus reticulata</i> .	Deodorant Agents; Flavoring Agents; Fragrance Ingredients
Citrus Tachibana/Reticulata Peel Oil	Citrus Tachibana/Reticulata Peel Oil is the volatile oil obtained from the peel of the hybrid of <i>Citrus tachibana</i> and <i>Citrus reticulata</i> .	Skin-Conditioning Agents - Emollient
Citrus Tangerina (Tangerine) Peel Oil	Citrus Tangerina (Tangerine) Peel Oil is the volatile oil obtained from the peel of <i>Citrus tangerina</i> .	Fragrance Ingredients; Skin-Conditioning Agents - Miscellaneous

**Table 2. Citrus-ingredients that potentially function solely as fragrance ingredients.**

Citrus Aurantifolia (Lime) Peel Oil  
 Citrus Aurantium Currassuviensis Peel Oil  
 Citrus Medica Vulgaris Peel Oil

**Table 3. Physical and chemical properties of Citrus-derived peel oils.**

Property	Description	Reference
<b>Bitter Orange Oil (Cold-Pressed)</b>		
Color	pale yellow or yellow-brown	1
Odor	characteristic aromatic odor of the Seville orange	1
optical rotation/angular rotation	+88° to +98°	1
Solubility	miscible with absolute alcohol and with an equal volume of glacial acetic acid; soluble in fixed oils and mineral oil; slightly soluble in propylene glycol; relatively insoluble in glycerin	1
Aldehydes	no less than 0.5% and no more than 1.0% of aldehydes, calculated as decyl aldehyde	1
refractive index	1.472-1.476 at 20° C	1
residue of evaporation	2.0-5.0%	1
specific gravity	0.845-0.851	1
<b>Grapefruit Oil (Cold-Pressed)</b>		
Color	yellow, sometimes red	1
optical rotation/angular rotation	+91° to +96°	1
Solubility	soluble in most fixed oils and mineral oil with opalescence or cloudiness; slightly soluble in propylene glycol; insoluble in glycerin	1
refractive index	1.475-1.478 at 20° C	1
residue of evaporation	5.0% -10.0%	1
specific gravity	0.848-0.856	1
<b>Citrus Aurantifolia (Lime) Oil</b>		
Color	colorless to greenish yellow	6
Odor	fresh citrus, intense	6
optical rotation	+34° to +47°	6
Solubility	insoluble in water, soluble in ethanol and propylene glycol	6
refractive index	1.4477-1.4745	6
specific gravity	0.855-0.863	6
<b>Lime Oil (Distilled)</b>		
Color	colorless to greenish yellow	1
Odor	mild citrus, floral	1
optical rotation/angular rotation	+34° to +47°	1
Solubility	soluble in most fixed oils and mineral oil; insoluble in glycerin and propylene glycol	1
solubility in alcohol	1 ml sample dissolves in 5 ml of 90% alcohol	1
Aldehydes	between 0.5% and 2.5% of aldehydes, calculated as citral	1
refractive index	1.474 – 1.477 at 20 °C	1
specific gravity	0.855-0.863	1
<b>Lime Oil (Cold-Pressed)</b>		
Color	yellow to brown green to green	1
Odor	fresh lime peel	1
optical rotation/angular rotation	Mexican type: +35° to +41°; Tahitian type: +38° to +53°	1
Solubility	soluble in most fixed oils and mineral oil; insoluble in glycerin and propylene glycol	1
Aldehydes	Mexican type: no less than 4.5% and no more than 8.5% of aldehydes, calculated as citral; Tahitian type: no less than 3.2% and no more than 7.5% of aldehydes, calculated as citral	1
refractive index	Mexican type: 1.482-1.486; Tahitian type: 1.476-1.486	1
residue of evaporation	Mexican type: 10.0% to 14.5%; Tahitian type: 5.0% to 12.0%	1
specific gravity	Mexican type: 0.872-0.881; Tahitian type: 0.858-0.876	1
UV absorbance	max. at 315 nm; Mexican type: no less than 0.45; Tahitian type: no less than 0.24	1
<b>Citrus Limon (Lemon) Oil</b>		
Color	pale to deep yellow or greenish yellow	6
Odor	fresh citrus, intense	6
optical rotation	+57 to +65.6	6
Solubility	insoluble in water, soluble in ethanol and propylene glycol	6
refractive index	1.474-1.467	6
specific gravity	0.849-0.855	6
<b>Lemon Oil (Distilled)</b>		
Color	colorless to pale yellow	1
Odor	fresh lemon peel	1
optical rotation/angular rotation	+55° to +75°	1
Solubility	soluble in most fixed oil, mineral oil, and alcohol (with haze); insoluble in glycerin and propylene glycol	1
solubility in alcohol	1 ml sample dissolves in 5 ml of 90% alcohol	1
Aldehydes	between 1.0% and 3.5% of aldehydes, calculated as citral	1
refractive index	1.470 – 1.475 at 20 °C	1
specific gravity	0.842-0.856	1
UV absorbance	max. at 315 nm, no less than 0.01	1

**Table 3. Physical and chemical properties of Citrus-derived peel oils.**

Property	Description	Reference
<b>Lemon Oil (Cold-Pressed)</b>		
Color	pale to deep yellow or green-yellow	1
Odor	fresh lemon peel	1
optical rotation/angular rotation	California and Italian types: +57° to +65.6°; Desert type: +67° to +78°	1
Solubility	miscible with dehydrated alcohol and glacial acetic acid	1
solubility in alcohol	1 ml of sample dissolves in 3 ml of 95% alcohol, slight haze possible	1
Aldehydes	Desert type: no less than 1.7% of aldehydes, calculated as citral; California type: no less than 2.2% and no more than 3.8% of aldehydes, calculated as citral; Italian type: no less than 3.0% and no more than 5.5% of aldehydes, calculated as citral	1
refractive index	1.473-1.476 at 20 °C	1
residue of evaporation	between 5.0% to 14.5%	1
specific gravity	Desert type: 0.846-0.851; California and Italian types: 0.849-0.855	1
UV absorbance	max. at 315 nm; Desert and California types: no less than 0.2; Italian type: no less than 0.49	1
<b>Orange Oil (Distilled)</b>		
Color	colorless to pale yellow	1
Odor	mild citrus floral	1
optical rotation/angular rotation	+94° to +99°	1
Solubility	soluble in most fixed oil, mineral oil, and alcohol (with haze); insoluble in glycerin and propylene glycol	1
solubility in alcohol	1 ml sample dissolves in 5 ml of 90% alcohol	1
refractive index	1.471 – 1.474 at 20 °C	1
specific gravity	0.840-0.844	1
UV absorbance	max. at 330 nm, no less than 0.01	1
<b>Orange Oil (Cold-Pressed)</b>		
Color	intensely yellow, orange, or deep orange	1
Odor	characteristic of fresh, sweet orange peel	1
optical rotation/angular rotation	+94° to +99°	1
Solubility	miscible with dehydrated alcohol and carbon disulfide; soluble in glacial acetic acid	1
Aldehydes	no less than 1.2% and no more than 2.5% of aldehydes, calculated as decyl aldehyde	1
refractive index	1.472-1.474 at 20 °C	1
specific gravity	0.842-0.846	1
UV absorbance	max. at 330 nm; California type: no less than 0.130; Florida type: no less than 0.240	1
<b>Citrus Reticulata Peel Oil</b>		
physical state and appearance	clear, mobile, dark-orange to reddish-orange or brownish-orange liquid	7
Odor	orange-like	7
optical rotation	+63° to +78°	7
refractive index	1.4730-1.4770 (20°C)	7
specific gravity	0.847-0.853 (25/25°C)	7
<b>Tangerine Oil (Cold-Pressed)</b>		
Color	red-orange to brown-orange	1
Odor	pleasant, orange	1
optical rotation/angular rotation	+88° to +96°	1
Solubility	soluble in most fixed oils and mineral oil; slightly soluble in propylene glycol; relatively insoluble in glycerin	1
Aldehydes	0.8% to 1.9% of aldehydes, calculated as decyl aldehyde	1
refractive index	1.473-1.476 at 20 °C	1
residue of evaporation	2.3% - 5.8%	1
specific gravity	0.844-0.854	1



**Table 4. Chemical composition (%) of citrus peel oils**

	<i>C. aurantifolia</i> <sup>a</sup> (lime) peel oil, cold pressed <sup>10</sup>		<i>C. aurantium</i> <i>amara</i> <sup>b</sup> (bitter orange) essential oil, cold-pressed <sup>11</sup>		<i>C. aurantium</i> <i>amara</i> <sup>b</sup> (bitter orange) essential oil, hydrodistilled <sup>13</sup>		<i>C. aurantium</i> <i>dulcis</i> <sup>b</sup> (orange) essential oil, cold pressed <sup>11</sup>		<i>C. limon</i> <sup>c</sup> (lemon) peel essential oils, cold pressed <sup>9,10</sup>		<i>C. nobilis</i> <sup>b</sup> (mandarin orange) essential oil, cold pressed <sup>11</sup>		<i>C. sinensis</i> <sup>d</sup> (orange) peel oil, cold- pressed <sup>8,9,12</sup>		<i>C. sinensis</i> <sup>b</sup> (orange) peel oil,** hydro- distilled <sup>14</sup>		<i>C. sinensis</i> <sup>b</sup> (orange) peel oil, steam distilled <sup>16</sup>		<i>C. reticulata</i> <sup>e</sup> (tangerine) peel oil,** hydro- distilled <sup>14,15</sup>	
Essential Oil (%) Content					1.67 <sup>13</sup>				1.12 <sup>9</sup>				0.98-1.21 <sup>9</sup>		0.24-1.07 <sup>14</sup>		2.49 <sup>16</sup>		0.30-0.50 <sup>14</sup>	
Constituent	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
7-methoxy-8-(2',3'-epoxy)isopentenylcoumarin			X																	
7-methoxy-8-isopentenylcoumarin			X																	
7-methoxy-8-(2'-one-isopentyl)coumarin)			X																	
<i>allo</i> -ocimene		trace*																		
allyl isovalerate																				0.36*
benzaldehyde									0.11*											
bicyclogermacrene	trace	0.4												trace*						
borneol									0.16*					7.63						
bornyl acetate	trace	trace							trace	trace										
camphene	trace	0.2							trace	0.13				0.32						
capraldehyde													0.35	5.62						
caprinaldehyde										0.26*				2.10						
caryophyllene oxide	trace	0.1							trace	0.3										
carvone																		0.17	0.47	0.62*
d-carvone														0.39						
cephrol																		0.15		
<i>cis</i> -carveol																		0.22		
<i>cis</i> -limonene-1,2-oxide	trace	0.1							trace	0.5										
<i>cis</i> -linalool oxide THF		trace*																		
<i>cis</i> - $\beta$ -farnesene																				0.1**
<i>cis</i> - <i>p</i> -ment-2-en-1-ol										0.1*										
<i>cis</i> - $\beta$ -ocimene						0.30								0.26*						
citral										0.27*			1.74	7.74						
citranellyl acetate													0.01	0.22						
citronellal	trace	1.6							trace	0.4			0.06	0.2					0.45	0.78*
citronellol	trace	0.6							trace	0.15				4.18	0.71	1.6			0.8	1.2*
citronellyl acetate	0.1	0.2							trace	0.3							0.12			
copaene																				0.89*
decanal	trace	0.3				0.16			trace	trace				0.21*	0.71	1.02		0.11	2.33	7.71*
decanol														0.35						
dehydrolinalool																		0.40		
dodecanol		trace*												0.03*					0.42	0.65*
elemol																			0.35	0.89*
eugenol															0.53					



**Table 4. Chemical composition (%) of citrus peel oils**

	<i>C. aurantifolia</i> <sup>a</sup> (lime) peel oil, cold pressed <sup>10</sup>		<i>C. aurantium</i> <i>amara</i> <sup>b</sup> (bitter orange) essential oil, cold-pressed <sup>11</sup>		<i>C. aurantium</i> <i>amara</i> <sup>b</sup> (bitter orange) essential oil, hydrodistilled <sup>13</sup>		<i>C. aurantium</i> <i>dulcis</i> <sup>b</sup> (orange) essential oil, cold pressed <sup>11</sup>		<i>C. limon</i> <sup>c</sup> (lemon) peel essential oils, cold pressed <sup>9,10</sup>		<i>C. nobilis</i> <sup>b</sup> (mandarin orange) essential oil, cold pressed <sup>11</sup>		<i>C. sinensis</i> <sup>d</sup> (orange) peel oil, cold- pressed <sup>8,9,12</sup>		<i>C. sinensis</i> <sup>b</sup> (orange) peel oil,** hydro- distilled <sup>14</sup>		<i>C. sinensis</i> <sup>b</sup> (orange) peel oil, steam distilled <sup>16</sup>		<i>C. reticulata</i> <sup>e</sup> (tangerine) peel oil,** hydro- distilled <sup>14,15</sup>	
Essential Oil (%) Content					1.67 <sup>13</sup>				1.12 <sup>9</sup>				0.98-1.21 <sup>9</sup>		0.24-1.07 <sup>14</sup>		2.49 <sup>16</sup>		0.30-0.50 <sup>14</sup>	
Constituent	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
terpineol-4									trace	0.1										
terpinen-4-ol	trace	1.7																		0.1*
terpinolene	trace	1.1							trace	0.8				0.08*						
terpinyl acetate	trace	trace								0.5*										
tetradecane														0.2*						
thymol									trace	1.1				trace*						
thymyl methyl oxide	1.2	1.6																		
<i>trans</i> - $\alpha$ -bergamotene	0.2	1.6							0.2	1.3										
<i>trans</i> -carveol																		0.44		
<i>trans</i> -limonene oxide														0.01*				0.20		
<i>trans</i> -limonene-1,2-oxide	trace	0.2							trace	0.6										
<i>trans</i> -linalool oxide THF									trace	trace										
<i>trans</i> -p-1,8-dienol																				0.52*
<i>trans</i> -p-menth-2-en-1-ol									trace	0.1										
<i>trans</i> -p-2,8-menthadien-1-ol														0.79	1.07					
<i>trans</i> -sabinene hydrate	trace	0.1							trace	0.1										
undecanal	trace	0.1																		
valencene														0.05*	0.41	1.2				
$\alpha$ -bisabolene										0.2*										
$\alpha$ -cadinol																				0.46*
$\alpha$ -copaene														0.04*						
$\alpha$ -cubebene																0.7				0.48*
$\alpha$ -farnesene																			0.36	0.48*
$\alpha$ -humulene	trace	0.2							trace	0.2										
$\alpha$ -phellandrene	trace	0.1							trace	0.6						0.46				
$\alpha$ -pinene	0.2	2.7				0.53			0.1	2.63			0.76	1.4	1.65	2.48		1.49	0.6	1.67
$\alpha$ -sinensal															0.35	0.49			0.93	5.0*
$\alpha$ -terpinene	trace	0.4							trace	0.4										
$\alpha$ -terpineneol																				1.51*
$\alpha$ -terpineol	trace	4.7				0.13			trace	0.4				0.07*	2.34	3.1		0.14	0.2	1.1
$\alpha$ -terpinolene										0.25*			1.56	2.06				0.38		0.1*
$\alpha$ -thujene	trace	0.7							trace	1.7			0.04	0.11				0.11		
$\beta$ -bisabolene	0.3	2.4							0.2	2.0										
$\beta$ -caryophyllene																		0.21		1.39*
$\beta$ -cubebene														0.03*						0.37*
$\beta$ -elemene	trace	0.8							trace	0.5				0.1*						



**Table 4. Chemical composition (%) of citrus peel oils**

	<i>C. aurantifolia</i> <sup>a</sup> (lime) peel oil, cold pressed <sup>10</sup>		<i>C. aurantium amara</i> <sup>b</sup> (bitter orange) essential oil, cold-pressed <sup>11</sup>		<i>C. aurantium amara</i> <sup>b</sup> (bitter orange) essential oil, hydrodistilled <sup>13</sup>		<i>C. aurantium dulcis</i> <sup>b</sup> (orange) essential oil, cold pressed <sup>11</sup>		<i>C. limon</i> <sup>c</sup> (lemon) peel essential oils, cold pressed <sup>9,10</sup>		<i>C. nobilis</i> <sup>b</sup> (mandarin orange) essential oil, cold pressed <sup>11</sup>		<i>C. sinensis</i> <sup>d</sup> (orange) peel oil, cold- pressed <sup>8,9,12</sup>		<i>C. sinensis</i> <sup>b</sup> (orange) peel oil, ** hydro- distilled <sup>14</sup>		<i>C. sinensis</i> <sup>b</sup> (orange) peel oil, steam distilled <sup>16</sup>		<i>C. reticulata</i> <sup>e</sup> (tangerine) peel oil, ** hydro- distilled <sup>14,15</sup>			
Essential Oil (%) Content					1.67 <sup>13</sup>				1.12 <sup>9</sup>				0.98-1.21 <sup>9</sup>		0.24-1.07 <sup>14</sup>		2.49 <sup>16</sup>		0.30-0.50 <sup>14</sup>			
Constituent	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
β-elemene																				0.17		
β-farnesene																					3.64	
β-gurjurene														0.01*								
β-myrcene														1.88*	3.76	4.41					3.27	4.05*
β-ocimene																				0.27		
β-phellandrene	0.2	0.8							0.1	4.2											1.8*	
β-pinene	trace	19.2				0.62			0.1	15.8				5.45					0.41	0.2	0.4	
β-sinensal	trace	0.1													0.33	0.83					0.67*	
γ-eudesmol																					1.08*	
γ-munrolene																					1.16*	
γ-terpinene	trace	21.5							trace	18.57				0.2	1.21				3.34	0.23	2.6	
δ-amorphene														0.05*								
δ-cadinene																0.32					0.88*	
δ-3-carene						0.17								0.14*					0.69			
Δ <sup>3</sup> -carene									0.1	4.2						0.78	1.03					

<sup>a</sup> determined in up to 21 varieties

<sup>b</sup> determined in one variety

<sup>c</sup> determined in up to 19 varieties

<sup>d</sup> determined in up to 4 varieties

<sup>e</sup> determined in up to 2 varieties

\* only reported in 1 variety

\*\*peels were fresh-, ambient, or oven-dried prior to hydrodistillation

X – denotes these compounds were present; however, the amount present was not specified

**Table 5. Typical levels of 5-methoxypsoralen (5-MOP)**

Ingredient	5-MOP level <sup>20</sup>
Tangerine oil cold pressed	50 ppm
Mandarin oil cold pressed	250 ppm

**Table 6. Levels of major coumarins and furocoumarins in lemon oil and lime oil**

Compound	% in Lemon Oil <sup>6</sup>	% in Lime Oil <sup>6</sup>	Photosensitizing Activity <sup>6</sup>
5-geranoxypsoralen	0.0387	2.2-2.5	0
5-geranoxo-7-methoxycoumrin	0.0603	2.2-5.2	0
5-geranoxo-8-methoxypsoralen	not analyzed	0.945	0
5,7-dimethoxycoumarin	0.0295	0.464	0
5,8-dimethoxypsoralen	not analyzed	0.508	0
Oxypeucedanin	0.005-0.073	0.0025	+
5-methoxypsoralen	0.0001-0.0087	0.17-0.33	++++

**Table 7. Constituents that are established contact allergens in humans, according to the SCCS**

Constituent	categorized according to number of patients reacting positively and to the number of patients tested (>1000 patients tested, unless indicated as r.t., i.e., rarely tested) <sup>36</sup>
$\beta$ -caryophyllene	$\leq 10$ (oxidized and non-oxidized)
carvone	$\leq 10$ (r.t.)
citral	101 to 1000
citronellol	11-100
coumarin	101 to 1000
farnesol	101 to 1000
geraniol	101 to 1000
linalyl acetate	$\leq 10$
$\alpha$ - and $\beta$ -pinene	11-100
(DL)-limonene	11-100 (non-oxidized); 101 to 1000 (oxidized)
terpineol (mixture of isomers)/ $\alpha$ -terpineol	$\leq 10$
terpinolene	11-100

**Table 8. Frequency (2014) and concentration of use (2013) according to duration and type of exposure for Citrus-derived ingredients.** <sup>17,18</sup>

	<i># of Uses</i>	<i>Max Conc of Use (%)</i>	<i># of Uses</i>	<i>Max Conc of Use (%)</i>	<i># of Uses</i>	<i>Max Conc of Use (%)</i>	<i># of Uses</i>	<i>Max Conc of Use (%)</i>
	<b>Citrus Aurantium Amara (Bitter Orange) Peel Oil</b>		<b>Citrus Aurantium Dulcis (Orange) Peel Oil (listed as Citrus Sinensis (Sweet Orange) Peel Oil in VCRP)</b>		<b>Citrus Grandis (Grapefruit) Peel Oil</b>		<b>Citrus Junos Peel Oil</b>	
<b>Totals<sup>1</sup></b>	<b>127</b>	<b>0.05-2</b>	<b>289</b>	<b>0.00002-29</b>	<b>NR</b>	<b>0.00004-0.05</b>	<b>6</b>	<b>NR</b>
<b><i>Duration of Use</i></b>								
Leave-On	74	0.2-2	156	0.00038-0.54	NR	0.0004-0.0008	4	NR
Rinse-Off	45	0.05-0.25	110	0.00002-29	NR	0.00004-0.05	2	NR
Diluted for (Bath) Use	8	NR	23	0.33	NR	0.0014	NR	NR
<b><i>Exposure Type</i></b>								
Eye Area	2	NR	3	0.1	NR	NR	NR	NR
Incidental Ingestion	1	0.75	4	NR	NR	NR	NR	NR
Incidental Inhalation-Spray? <sup>2,6</sup>	55	NR	124	0.00038	NR	NR	2	NR
Reported Spray <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Incidental Inhalation-Powder? <sup>4,6</sup>	47	NR	99	NR	NR	NR	1	NR
Reported Powder <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Dermal Contact	115	0.05-2	218	0.001-0.4	NR	0.00004-0.05	6	NR
Deodorant (underarm)-Spray? <sup>2</sup>	NR	NR	1	NR	NR	NR	NR	NR
Reported Spray <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Reported as Not Spray <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Hair - Non-Coloring	11	NR	65	0.00002-29	NR	0.005	NR	NR
Hair-Coloring	NR	NR	NR	NR	NR	NR	NR	NR
Nail	NR	NR	2	0.5-0.54	NR	NR	NR	NR
Mucous Membrane	21	0.25-0.75	56	0.1-0.33	NR	0.0014	1	NR
Baby Products	6	NR	8	NR	NR	NR	NR	NR

	<b>Citrus Limon (Lemon) Peel Oil</b>		<b>Citrus Nobilis (Mandarin Orange) Peel Oil</b>		<b>Citrus Reticulata (Mandarin Orange) Peel Oil<sup>7</sup></b>		<b>Citrus Sinensis Sanguinello (Blood Orange) Peel Oil<sup>7</sup></b>	
<b>Totals<sup>1</sup></b>	<b>490</b>	<b>0.0001-0.5</b>	<b>152</b>	<b>0.00005-0.1</b>	<b>2</b>	<b>NR</b>	<b>8</b>	<b>NR</b>
<b><i>Duration of Use</i></b>								
Leave-On	297	0.0001-0.5	86	0.00005-0.1	1	NR	4	NR
Rinse-Off	165	0.0006-0.001	58	0.00005-0.03	1	NR	4	NR
Diluted for (Bath) Use	28	0.012	8	NR	NR	NR	NR	NR
<b><i>Exposure Type</i></b>								
Eye Area	9	NR	NR	NR	NR	NR	NR	NR
Incidental Ingestion	8	NR	1	0.0099	NR	NR	NR	NR
Incidental Inhalation-Spray? <sup>2,6</sup>	201	0.06	74	NR	1	NR	4	NR
Reported Spray <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Incidental Inhalation-Powder? <sup>4,6</sup>	163	0.06	66	NR	1	NR	3	NR
Reported Powder <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Dermal Contact	411	0.0001-0.5	136	0.00005-0.1	2	NR	8	NR
Deodorant (underarm)-Spray? <sup>2</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Reported Spray <sup>3</sup>	NR	NR	NR	NR	NR	NR	NR	NR
Reported as Not Spray <sup>3</sup>	NR	0.002	NR	NR	NR	NR	NR	NR
Hair - Non-Coloring	67	NR	15	0.00005-0.03	NR	NR	NR	NR
Hair-Coloring	NR	NR	NR	NR	NR	NR	NR	NR
Nail	3	0.0001-0.14	NR	0.012	NR	NR	NR	NR
Mucous Membrane	96	0.001-0.012	40	0.0099	NR	NR	4	NR

**Table 8. Frequency (2014) and concentration of use (2013) according to duration and type of exposure for Citrus-derived ingredients.** <sup>17,18</sup>

	<i># of Uses</i>	<i>Max Conc of Use (%)</i>	<i># of Uses</i>	<i>Max Conc of Use (%)</i>	<i># of Uses</i>	<i>Max Conc of Use (%)</i>	<i># of Uses</i>	<i>Max Conc of Use (%)</i>
Baby Products	8	NR	NR	NR	NR	NR	NR	NR
<b>Citrus Tangerina (Tangerine)</b>								
<b>Peel Oil</b>								
<b>Totals<sup>1</sup></b>	<b>34</b>	<b>0.000013</b>						
<b><i>Duration of Use</i></b>								
Leave-On	18	0.000013						
Rinse-Off	15	0.000013						
Diluted for (Bath) Use	1	NR						
<b><i>Exposure Type</i></b>								
Eye Area	NR	NR						
Incidental Ingestion	1	NR						
Incidental Inhalation-Spray? <sup>2,6</sup>	14	0.000013						
Reported Spray <sup>3</sup>	NR	NR						
Incidental Inhalation-Powder? <sup>4,6</sup>	13	NR						
Reported Powder <sup>3</sup>	NR	NR						
Dermal Contact	26	NR						
Deodorant (underarm)-Spray? <sup>2</sup>	NR	NR						
Reported Spray <sup>3</sup>	NR	NR						
Reported as Not Spray <sup>3</sup>	NR	NR						
Hair - Non-Coloring	7	0.000013						
Hair-Coloring	NR	NR						
Nail	NR	NR						
Mucous Membrane	7	NR						
Baby Products	NR	NR						

NR = Not reported.

1. Because each ingredient may be used in cosmetics with multiple exposure types, the sum of all exposure types may not equal the sum of total uses.
2. It is possible these products may be sprays, but it is not specified whether the reported uses are sprays.
3. Use in a spray product has been reported in response to a survey conducted by the Council.
4. It is possible these products may be powders, but it is not specified whether the reported uses are powders.
5. Use in a powder product has been reported in response to a survey conducted by the Council.
6. Not specified whether a powder or a spray, so this information is captured for both categories of incidental inhalation.
7. Not listed as an INCI name; included because of similarity

**Table 9. Ingredients that are not reported to be in use**

Citrus Aurantifolia (Lime) Peel Oil  
 Citrus Aurantium Curassaviensis Peel Oil  
 Citrus Clementina Peel Oil  
 Citrus Iyo Peel Oil  
 Citrus Medica Vulgaris Peel Oil  
 Citrus Reticulata (Tangerine) Peel Oil  
 Citrus Tachibana/Reticulata Peel Oil

**Table10 . Genotoxicity**

Test Article	Concentration/Dose	Procedure	Results	Reference
<b>IN VITRO</b>				
lemon oil in ethanol	10-5000 µg/plate	Reverse mutation assay using <i>Salmonella typhimurium</i> strains TA98, TA100, TA1535, and TA1537 and <i>Escherichia coli</i> strain WP2uvrA, with and without S9 metabolic activation.	Toxicity was observed in all test strains except WP2uvrA with and without S9; no significant dose-related increases in the number of revertant colonies in any test strain at any dose level, with or without metabolic activation; controls yielded expected results; lemon oil was not mutagenic in this assay.	3
lemon oil in ethanol	40-100 µg/ml	Cell mutation assay in mouse lymphoma L5178Y TK+/- cells in accordance with OECD guideline 476 in 2 independent experiments; with and without S9 metabolic activation	No significant increases in the mutation frequency were observed in either experiment, with or without S9 activation; controls yielded the expected results; lemon oil did not induce gene mutations in mouse lymphoma cells	3
lemon oil in ethanol	up to 0.125 mg/ml	Chromosome aberration study using Chinese hamster lung fibroblasts (CHL) in accordance with OECD guideline 473, without metabolic activation, 100 metaphases examined	The incidence of polyploidy cells at 24 h post-treatment was 1.0%, and the incidence of cells with structural chromosome aberrations at 24 h after treatment was 2.0%; the test material did not significantly induce chromosomal aberrations in CHL cells; lemon oil was not considered clastogenic.	3
sweet orange oil in ethanol	1-5000 µg/plate	Reverse mutation assay using <i>Salmonella typhimurium</i> strains TA98, TA100, TA1535, and TA1537 and <i>Escherichia coli</i> strain WP2uvrA, with and without S9 metabolic activation.	Cytotoxicity was observed in all test strains except WP2uvrA with and without S9; no significant dose-related increases in the number of revertant colonies in any test strain at any dose level, with or without metabolic activation; controls yielded expected results; sweet orange oil was not mutagenic in this assay.	4
<u>sweet orange oil in ethanol</u>	40-100 µg/ml	Cell mutation assay in mouse lymphoma L5178Y TK+/- cells in accordance with OECD guideline 476 in 2 independent experiments; with and without S9 metabolic activation	The test material did not induce a significant increase in the mutation frequency in both experiments, with or without metabolic activation; sweet orange oil did not induce gene mutations in mouse lymphoma cells	4
sweet orange oil in ethanol	up to 0.125 mg/ml	Chromosome aberration study using Chinese hamster lung fibroblasts (CHL) in accordance with OECD guideline 473, without metabolic activation, 100 metaphases examined	The incidence of polyploidy cells at 48 h post-treatment was 1.0%, and the incidence of cells with structural chromosome aberrations at 48 h after treatment was 1.0%; the test material did not significantly induce chromosomal aberrations in CHL cells; sweet orange oil was not considered clastogenic.	4

**Table 11. Dermal irritation studies for Citrus-derived ingredients**

Test Article	Concentration/Dose	Test Population	Procedure	Results	Reference
<b>NON-HUMAN</b>					
lemon oil	5 ml/kg <sup>1</sup>	6 New Zealand White rabbits	acute dermal toxicity limit test scored under the Draize method; 24-h occlusive patches on intact and abraded skin	irritating	<sup>3</sup>
orange oil, cold pressed	0.5 ml of undiluted material	3 male albino rabbits	skin irritation study conducted according to OECD guideline 404; semiocluded patch for 4 h	mean erythema/eschar scores were 2.0, 1.7, and 2.0; mean edema scores were 2.0, 1.3, and 1.3; irritating to skin	<sup>4</sup>
mandarin peel oil, expressed (described as <i>Citrus reticulata</i> )	5 mg/kg	7 rabbits	24-h occlusive, single dose study	slight erythema and edema	<sup>7</sup>
mandarin peel oil, expressed (described as <i>Citrus reticulata</i> )	not reported	hairless mice and miniature swine; details not provided	open patch tests; details not provided	2 of 3 samples were irritating	<sup>7</sup>
<b>HUMAN</b>					
lemon oil	0.3%, 2% or 20%; multiple vehicles	34 subjects at 0.3%, 30 subjects at 2%, and 35 subjects at 20%	24-72 h occlusive patch tests	no irritation at 0.3% and 20%, 1 ± reaction at 2%	<sup>28</sup>
mandarin peel oil, expressed (described as <i>Citrus reticulata</i> )	8% in petrolatum	5 subjects	48 h closed patch test; details not provided	no irritation	<sup>7</sup>

**Table 12. Sensitization studies for Citrus-derived ingredients**

Test Article	Concentration/Dose	Test Population	Procedure	Results	Reference
<b>HUMAN - Patch</b>					
bitter orange oil	2% in paraffin	200 patients with dermatitis tested with 35 essential oils plus an additional 50 patients with balsam sensitivity	sensitization patch study, details not provided	6 positive reactions	29
lemon oil	2% in paraffin	200 patients with dermatitis tested with 35 essential oils plus an additional 50 patients with balsam sensitivity	sensitization patch study, details not provided	4 positive reactions, details not provided	29
lemon oil	not reported	100 subjects	Marzulli-Maibach sensitization technique; open patches	2% of the subjects had a positive skin reaction at the first reading after challenge, no reactions were noted at the 48 and 72 h readings, study concluded the test material was not sensitizing	3
mandarin oil, expressed (described as <i>Citrus reticulata</i> )	8% in petrolatum	25 subjects	maximization study, details not provided	not sensitizing	7
sweet orange oil	2% in paraffin	200 patients with dermatitis tested with 35 essential oils plus an additional 50 patients with balsam sensitivity	sensitization patch study, details not provided	3 positive reactions, details not provided	29
sweet orange oil	not reported	100 subjects	Marzulli-Maibach sensitization technique; open patches	4% of the subjects had positive skin reaction at the first reading after challenge, no reactions were noted at the 48 and 72 h readings, study concluded the test material was not sensitizing	4

**Table 13. Photosensitization and phototoxicity studies**

Test Article	Concentration/Dose*	Test Population	Procedure	Results	Reference
<b>ALTERNATIVE STUDIES</b>					
sweet orange oil, including deterpenated kind	concentrations not reported; tested in PBS, ethanol, or DMSO with samples from 3 suppliers	3T3 Balb/c fibroblasts	-3T3 neutral red uptake phototoxicity test -light source was a doped mercury-metal halide lamp, filtered with 50% transmission at 335 nm to diminish UVB	borderline phototoxic, positive phototoxic results observed more frequently with the vehicles PBS and ethanol with certain supplied samples	31
lemon oil, including deterpenated kind	same as above	same as above	same as above	borderline phototoxic, positive phototoxic results observed in all 3 vehicles, but were more prominent in the deterpenated sample	31
sweet orange oil, including deterpenated kind	up to 3.16% in water with samples from 3 suppliers	same as above	same as above	potential for phototoxicity observed	31
lemon oil, including deterpenated kind	same as above	same as above	same as above	cytotoxicity observed with deterpenated lemon oil; potential for phototoxicity observed	31
<b>NON-HUMAN</b>					
lime oil, distilled (psoralen-free)	undiluted; 20 µl	hairless mice, 6/grp	- a single dose was applied to a 2 cm <sup>2</sup> area on the back; animals were exposed to irradiation 30 min after dosing - one group was exposed to a compact-arc xenon lamp for 2 min (wavelengths <295 nm or 320-280 nm excluded) - one group was exposed to a long-arc xenon lamp for 40 min at a distance of 1 m; the weighted energy was 0.1667 W/m <sup>2</sup> - one group was exposed to 4 fluorescent black light lamps (UVB eliminated) for 1 h at an integrated UVA intensity of 3 W/m <sup>2</sup> -positive controls were treated with 0.01% 8-methoxypsoralen in methanol; negative controls with an appropriate vehicle - test sites were examined 4, 24, 48, 72, and 96 h after exposure	- a phototoxic response was not observed with any of the light sources	33
lime oil, distilled (psoralen-free)	undiluted; 20 µl	miniature swine, 2/grp	as above	- a phototoxic response was not observed with any of the light sources	33
lime oil, expressed	undiluted and diluted; 20 µl	hairless mice, 6/grp	as above	- a phototoxic response was observed with all three light sources - the lowest phototoxic concentration was 15%	33
lime oil, expressed	undiluted and diluted; 20 µl	miniature swine, 2/grp	as above	- a phototoxic response was observed with all three light sources - the lowest phototoxic concentration was 30%	33
grapefruit oil	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
lime oil distilled (psoralen-free)	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
lime oil; expressed and rectified	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
lime oil Persian Florida; expressed and rectified	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33



**Table 13. Photosensitization and phototoxicity studies**

Test Article	Concentration/Dose*	Test Population	Procedure	Results	Reference
mandarin oil	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
mandarin oil, Italian	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
oil of lemon, California	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
oil of lemon, distilled	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
oil mandarin, Italian	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
oil of tangerine	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
orange oil; cold pressed	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	not photosensitizing	33
California lemon oil	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
Italian lemon oil	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
oil lemon, Greek; cold pressed	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
oil lemon, Italian	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
oil lemon, IC (not defined)	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
lime oil expressed	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
oil limes Persian	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
oil limes, expressed and rectified	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
lime oil, expressed and rectified	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
bitter orange oil	undiluted; 20 µl	6 hairless mice and 2 miniature swine	- as above	- a phototoxic response was observed	33
lemon oil from multiple regional sources	20, 50, or 100% in ethanol; 0.02 ml	albino guinea pigs	- the oil was applied to the shaved back of the animals - the animals were then exposure to UVA radiation (320-400 nm, 13 J/cm <sup>2</sup> ) - erythema was evaluated 24, 48, and 72 h after irradiation - the samples were then fractionated subsequent phototoxicity testing of the isolated components was performed	-concentrations of 50% and 100% elicited phototoxicity in most of the samples tested - lemon oils from different regions had different phototoxicity potencies -oxypeucedanin and 5-methoxypsoralen (furocoumarins) were identified as phototoxic	34

**Table 13. Photosensitization and phototoxicity studies**

Test Article	Concentration/Dose*	Test Population	Procedure	Results	Reference
<b>HUMAN</b>					
bitter orange peel oil	undiluted; 5 µl/cm <sup>2</sup>	8 subjects	- an occlusive patch was applied to a 2 cm x 2 cm area - 1 cm site on each subject was exposed to visible light t of 20 J/cm <sup>2</sup> UVA - the test sites were scored after 24 and 48 h	all subjects reacted (details not provided)	22
lemon oil, including deterpenated kind	up to 1% in water from samples from 3 supplier; dose not provided	5 female subjects	-2 occlusive 10 mm diameter Finn Chambers on both sides of the lower back -exposure time to test material was 1 h -irradiation immediately to 1 site after patch removal at a dose of 5 J/cm <sup>2</sup> as measured in the UVA range -test sites scored after 24, 48, and 72 h -light source was a doped mercury-metal halide lamp, filtered with 50% transmission at 335 nm to diminish UVB	-phototoxic reactions concurrent with an irritation reactions were observed in lemon oil at 1% in 4/5 subjects up to 72 h after irradiation -phototoxic reactions were observed in deterpenated lemon oil at 0.1% in 2/5 subjects at 48 and 72 h after irradiation -no reactions were observed at concentrations of 0.1% or lower in lemon oil and 0.01% in deterpenated lemon oil	31
sweet orange oil, including deterpenated kind	same as above	same as above	-same as above	-phototoxic reaction were observed in orange oil at 1% in 3/5 subjects at 24 h and 2/5 subjects at 48 and 72 h after irradiation -no reactions were observed at concentrations of 0.1% or lower in orange oil or 0.1% and 0.01% in deterpenated orange oil	31
lime oil, distilled	undiluted	10 Caucasian subjects	- a single dose was applied to a 2 cm <sup>2</sup> area on the back - 30 min after dosing, subjects were exposed to sunlight for 30 min or a compact-arc xenon lamp for 2 min (wavelengths <295 nm or 320-280 nm excluded) -positive controls were treated with 0.01% 8-methoxypsoralen in methanol; negative controls with an appropriate vehicle - test sites were examined 4, 24, 48, 72, and 96 h after exposure	no phototoxic response was observed	33
lime oil, expressed	undiluted and diluted; 20 µl	10 Caucasian subjects	- a single dose was applied to a 2 cm <sup>2</sup> area on the back - 30 min after dosing, 1 treated site and the control untreated site were exposed to sunlight for 30 min, a compact-arc xenon lamp for 2 min (wavelengths <295 nm or 320-280 nm excluded), or 4 fluorescent black light lamps (UVB eliminated) for 1 h at an integrated UVA intensity of 3 W/m <sup>2</sup> -positive controls were treated with 0.01% 8-methoxypsoralen in methanol; negative controls with an appropriate vehicle - test sites were examined 4, 24, 48, 72, and 96 h after exposure	- a phototoxic response was observed with all three light sources - the lowest phototoxic concentration with the simulated light sources was 30%	33

\* the solvent is specified when known



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