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Development of an Eco-Friendly Room Freshener Based on Seaweed and Orange Peel Extract as an Anti-Cockroach Product

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A B S T R A C T

This study examined the development of a natural room fragrance based on Eucheuma cottonii seaweed extract and orange peel extract as an anti-cockroach product for household application. The research was motivated by the need for safer and more environmentally friendly alternatives to synthetic air fresheners and chemical insect repellents, particularly for indoor spaces where odor problems and cockroach infestation often occur simultaneously. The study employed an experimental formulation approach using three extract ratios: F1 (25% seaweed extract and 75% orange peel extract), F2 (50% seaweed extract and 50% orange peel extract), and F3 (75% seaweed extract and 25% orange peel extract). The products were prepared through extraction and spray formulation, then evaluated through organoleptic testing covering aroma, texture, and color, followed by an effectiveness assessment against cockroaches. The results showed a consistent pattern across all measured variables. F3 produced the highest organoleptic scores, with values of 4.4 for aroma, 4.24 for texture, and 4.28 for color, indicating the strongest panelist acceptance. The same formulation also showed the highest anti-cockroach effectiveness, with an approximately 75% reduction in cockroach presence, compared with 60% for F2 and 40% for F1

INTRODUCTION

Indoor environmental quality is closely associated with human comfort, sanitation, and health, particularly in residential spaces where people spend a substantial portion of their daily lives. Among the most persistent household concerns are unpleasant room odor and the presence of insect pests, both of which reduce quality of life and may indicate poor hygienic conditions. In tropical and subtropical settings, cockroaches are among the most common pests encountered in kitchens, bathrooms, storage spaces, and waste-prone indoor environments. Their presence is not merely an aesthetic nuisance; cockroaches are widely recognized as mechanical vectors that can spread pathogens and contaminate surfaces, food, and household utensils. For this reason, the management of cockroach populations is not only a matter of convenience but also a matter of environmental hygiene and preventive health.

The significance of this issue is reinforced by evidence showing that cockroaches are highly adaptable organisms capable of thriving in habitats modified by human activity. Their resilience is partly due to their ability to exploit suitable microhabitats in urban areas, allowing them to overcome climatic limitations and expand their distribution globally (Schapheer et al., 2018). In residential environments, infestation is a recurring problem, and the challenge is compounded by the fact that control measures often rely heavily on synthetic insecticides. While these compounds may provide rapid knockdown effects, repeated application can leave residues indoors and create health-related concerns for household occupants (Zha et al., 2018). Accordingly, the need for safer, more sustainable, and multifunctional household products has become increasingly important, especially those capable of addressing odor problems while simultaneously discouraging pest presence.

At the same time, the market for room fragrance products has expanded significantly, reflecting growing consumer demand for pleasant indoor atmospheres. However, many commercial air fresheners are formulated with synthetic fragrance compounds, solvents, and preservatives that may pose health risks when used continuously in enclosed spaces. Exposure to these substances has been associated with allergies, respiratory irritation, and other adverse effects, and some products are reported to contain potentially hazardous chemical ingredients. As a consequence, the development of natural and health-conscious alternatives has become a relevant research direction in both household product technology and environmental health studies (Astuti, D 2020). This issue is particularly important in communities where product safety, environmental compatibility, and the valorization of local natural resources are increasingly prioritized.

A promising general solution lies in the formulation of natural room fresheners that combine deodorizing functions with insect-repellent activity. Rather than relying on separate products for fragrance and pest control, a dual-function preparation offers greater practicality and may reduce household dependence on synthetic chemicals. Previous studies have indicated that various essential oils and plant extracts possess fragrance, antibacterial, and insect-repelling properties, making them suitable for multifunctional indoor

applications. Eucalyptus oil, for example, has been incorporated into air-freshener formulations due to its refreshing aroma and antibacterial properties, suggesting its suitability as a natural fragrance base with added protective value (Stashenko et al., 2018; Guangxin, 2016). This broader body of work supports the concept that room fragrances can be designed not only for sensory enhancement but also for hygienic and protective purposes.

The literature also shows that other botanical ingredients can strengthen the performance of natural air-freshening products. Extracts from mint and jasmine, for instance, have been recognized for odor-neutralizing and antimicrobial functions, thereby improving the capacity of indoor fragrance products to maintain a clean and pleasant atmosphere (Jiansheng, 2017; Li, 2018). The integration of such natural materials is advantageous because it creates a non-toxic and environmentally friendly alternative to conventional chemical repellents. More importantly, these materials can be safer for routine human exposure and may reduce the risk of adverse health effects associated with synthetic formulations (Xuxia, 2014; Bin et al., 2020). These findings collectively indicate that the transition from synthetic to natural room fragrance systems is scientifically plausible and socially relevant, particularly when the selected ingredients provide both olfactory and biological functionality.

Within this context, seaweed and orange peel represent two abundant natural resources in Indonesia with considerable application potential. Seaweed has been reported to possess odor-absorbing characteristics, while orange peel contains limonene, a volatile compound known for its fresh citrus aroma and repellent action against insects such as cockroaches. The use of these materials as the basis for room fragrance formulation is therefore attractive from both functional and sustainability perspectives (Setiawan, R.2019). In addition to their direct utility, both materials align with resource-efficiency objectives: seaweed is a widely cultivated marine commodity with diverse industrial uses, and orange peel is an agricultural by-product that is often discarded despite containing valuable bioactive compounds.

More specifically, seaweed—particularly Eucheuma cottonii or related red algae—has been associated with bioactive constituents such as saponins and phenolic compounds that may contribute antimicrobial and insect-related effects, while orange peel is rich in limonene, a compound widely recognized as a natural insect repellent with a strong and refreshing aroma. The combination of these two materials is therefore conceptually compelling. Seaweed may contribute matrix-forming, deodorizing, and bioactive functions, whereas orange peel may provide a characteristic fragrance and repellent performance. The utilization of natural ingredients such as seaweed and orange peel also offers a practical route for reducing the use of synthetic chemicals in household products while simultaneously supporting the valorization of organic waste streams. In this regard, innovations based on these materials do not merely replace commercial fragrances; they potentially offer added value in natural pest management and circular resource use (Aryee, A. N. A., 2020 ; Haq, M. et al. 2018).

Despite the growing interest in natural room fragrances and botanical insect repellents, the literature remains fragmented. Existing studies tend to focus on

single-purpose products, either emphasizing fragrance quality, antimicrobial performance, or insect repellency, rather than integrating all three into one formulation. Studies on essential oils and plant extracts demonstrate the feasibility of natural indoor products, while the reported properties of seaweed and citrus-derived materials suggest that these resources may be suitable candidates for multifunctional applications. However, there is still limited evidence regarding the formulation of a room fragrance based specifically on Eucheuma cottonii seaweed extract and orange peel extract for anti-cockroach use, especially in a spray-based preparation designed for household practicality. Likewise, relatively little attention has been given to how different formulation ratios influence both sensory acceptance and repellency effectiveness at the same time. This gap is important because a product that is biologically effective but organoleptically unacceptable would have limited consumer adoption, whereas a pleasant product with weak repellent capacity would fail in its protective function.

Based on this background, the present study aims to develop and evaluate a natural room fragrance made from Eucheuma cottonii seaweed extract and orange peel extract as an anti-cockroach formulation. The study is directed toward determining whether these natural materials can be combined into a household product that provides a fresh indoor aroma while reducing cockroach presence. In particular, the study examines how different proportions of seaweed extract and orange peel extract affect product acceptability in terms of aroma, texture, and color, as well as product effectiveness in repelling cockroaches. The novelty of the work lies in the integration of marine-derived and citrus-based natural materials into a dual-function room fragrance system with both sensory and protective household utility. The underlying premise is that formulation balance is critical: the selected ratio must support consumer preference without compromising repellency performance. Accordingly, the scope of the study includes extraction, formulation, organoleptic evaluation, and effectiveness testing, with the broader goal of contributing to the development of safer, environmentally friendly, and locally sourced alternatives to synthetic air fresheners and chemical cockroach repellents.

LITERATURE REVIEW

Indoor environmental quality is strongly linked to human comfort, sanitation, and health, particularly in residential spaces where unpleasant odors and insect infestations frequently occur together. Among household pests, cockroaches are especially important because they are highly adaptable to human-modified habitats and may act as mechanical carriers of pathogenic microorganisms and allergens. Recent review evidence shows that cockroaches remain a major urban public-health concern, not only because of their contamination potential but also because insecticide resistance complicates conventional control measures. These concerns justify the search for safer and more sustainable household products that can reduce cockroach presence while improving indoor comfort (Abbasi, 2025).

At the same time, indoor fragrance products are widely used to mask unpleasant smells and improve perceived room quality. However, the literature

has raised substantial concerns regarding the chemical composition of many commercial air fresheners. Air fresheners can emit volatile organic compounds and secondary pollutants that may adversely affect indoor air quality, while exposure to indoor pollutants is particularly relevant for sensitive groups, including children and individuals with pre-existing respiratory conditions. This has encouraged researchers to promote natural and lower-risk alternatives that can maintain the desired aromatic function without relying heavily on synthetic chemicals (Steinemann, 2017; Maung et al., 2022).

Botanical materials have received increasing attention as eco-friendly ingredients for household fragrance and pest-control products. Citrus peel is especially promising because it is abundant as an agro-industrial by-product and contains valuable volatile compounds. A recent review on orange peel waste reported that d-limonene is the major constituent of orange essential oil, commonly accounting for about 90–98% of the oil fraction, and that orange peel waste can be valorized into bioactive compounds with industrial and household relevance. In parallel, studies on citrus peel essential oils have shown meaningful insecticidal and fumigant properties, indicating that citrus-derived materials can serve both fragrance and insect-management functions (Siddiqui et al., 2022; Visakh et al., 2022).

More specifically, orange peel has direct relevance to cockroach control. Ezeonu et al. (2001) reported that volatile extracts of orange peels showed insecticidal activity against mosquitoes, houseflies, and cockroaches, with cockroaches being among the most susceptible target insects in the study. This finding is important because it supports the practical use of citrus peel derivatives in domestic pest management. In addition to their insecticidal value, citrus peels provide a fresh and familiar aroma profile, which makes them particularly suitable for multifunctional room-fragrance formulations intended for everyday household use (Ezeonu et al., 2001; Siddiqui et al., 2022).

Seaweed is another promising natural resource for functional household-product development. Review studies have shown that seaweeds contain a broad range of bioactive compounds with antimicrobial, antioxidant, and other biologically active properties. In addition, red seaweeds in the Eucheuma/Kappaphycus group are widely recognized as important sources of carrageenan, a polysaccharide valued for its thickening, stabilizing, and gelling properties in food and non-food applications. This functional profile is relevant for room-fragrance formulations because seaweed-derived materials may contribute not only bioactivity but also formulation structure, viscosity, and product stability. Importantly, the literature also notes that Kappaphycus alvarezii is commonly known as Eucheuma cottonii, reinforcing the relevance of this species to applied product development (Zerrifi et al., 2018; Shah et al., 2022; Toumi et al., 2023).

Taken together, the literature supports the scientific rationale for combining orange peel and Eucheuma cottonii in a natural room-fragrance product. Citrus peel contributes a pleasant aroma and insect-repellent potential, while seaweed contributes functional biomaterials and bioactive compounds. Even so, the available literature has tended to examine these materials separately, either as

citrus-based insecticidal agents or as seaweed-based bioactive and structural materials. This indicates a meaningful research gap for studies that integrate both resources into a single room-fragrance formulation with dual deodorizing and anti-cockroach functions. Accordingly, the present study is well positioned to contribute to the development of an eco-friendly household product that combines sensory acceptability, waste valorization, and natural pest management (Siddiqui et al., 2022; Ezeonu et al., 2001; Zerrifi et al., 2018; Toumi et al., 2023).

METHODOLOGY

Research Design and Study Site

This study was conducted from April to June 2025 in the Chemistry Laboratory, Department of Agricultural Technology, Politeknik Pertanian Negeri Pangkajene Kepulauan. The research was structured as an experimental formulation study using a Completely Randomized Design to evaluate natural room-fragrance preparations made from seaweed extract and orange peel extract. The product quality was assessed through sensory testing and effectiveness testing, with the sensory parameters focusing on aroma, texture, and color. The best-performing formulation was then subjected to further effectiveness assessment as an anti-cockroach room fragrance. Data from the hedonic evaluation were analyzed using the Kruskal–Wallis test.

Materials and Equipment

The main raw materials used in this study were dried seaweed, orange peel, ethanol 96%, and distilled water. These ingredients were selected as the core components in producing a natural anti-cockroach room fragrance. The equipment used in the preparation process included a blender or food processor, bowls or containers, knives and cutting boards, stirring spoons, an oven, filter cloth or sieve, spray bottles, a digital balance, measuring cylinders, wooden or stainless-steel stirrers, a funnel, and clamps. The combination of these materials and instruments supported the extraction, mixing, and packaging stages of the product development process.

Extraction and Formulation Procedure

The preparation of the product began with the extraction of seaweed. The seaweed was first dried and ground into powder, then extracted using a maceration method with 96% ethanol as the solvent. After extraction, the filtrate was separated and heated on a hot plate until a concentrated extract was obtained. A similar procedure was applied to the orange peel. The peel was dried, ground, and extracted by maceration using ethanol, after which the extract was filtered and concentrated using a hot plate to produce a thick extract. This approach was intended to obtain concentrated natural materials that could function both as fragrance sources and as active ingredients in the anti-cockroach formulation.

After the concentrated extracts had been prepared, the seaweed extract and orange peel extract were weighed according to the predetermined treatment ratios. Three formulations were used in the study, namely F1 consisting of 25%

seaweed extract and 75% orange peel extract, F2 consisting of 50% seaweed extract and 50% orange peel extract, and F3 consisting of 75% seaweed extract and 25% orange peel extract. Each extract mixture was placed into a measuring cylinder, diluted with alcohol, homogenized, and then transferred into 30 mL spray bottles. Through this formulation stage, the study compared how different proportions of seaweed and orange peel extracts influenced the characteristics and functional performance of the resulting room-fragrance product.

Organoleptic Evaluation

The resulting formulations were evaluated through organoleptic or hedonic testing to determine the level of panelist preference for the product. The sensory assessment covered three principal attributes, namely aroma, texture, and color. These parameters were chosen because they represent the most immediate quality indicators perceived by users of room-fragrance products. Aroma was assessed to determine the acceptability of the fragrance profile produced by each formulation. Texture evaluation was directed toward the perceived consistency, smoothness, and uniformity of the preparation, while color evaluation was used to judge the visual acceptability of the product. Through this stage, the study sought to identify the formulation with the most favorable sensory response before proceeding to effectiveness testing.

Effectiveness Test and Data Analysis

Following the sensory evaluation, the selected formulation results were continued to an effectiveness test to assess the product's ability to repel cockroaches. The effectiveness assessment was designed to determine how the variation in the proportion of seaweed extract and orange peel extract influenced anti-cockroach performance. In parallel with the sensory evaluation, the analytical framework of the study aimed to compare treatment performance across formulations and to identify the most suitable composition in terms of both user preference and functional efficacy. The overall analysis therefore integrated organoleptic quality and repellency performance as the basis for evaluating the potential of seaweed- and orange-peel-based room fragrance as a natural household anti-cockroach product.

RESEARCH RESULT

This chapter reorganizes the findings reported in the original manuscript into a clearer Results section. The source document presents the findings under a combined "Results and Discussion" heading, with organoleptic assessment covering aroma, texture, and color, followed by an effectiveness test against cockroaches. The tested formulations were F1 (25% seaweed extract + 75% orange peel extract), F2 (50% seaweed extract + 50% orange peel extract), and F3 (75% seaweed extract + 25% orange peel extract). The manuscript states that sensory quality was used to identify the best formulation, after which product effectiveness was examined descriptively. Although the methodology mentions Kruskal–Wallis analysis, no inferential statistics are reported in the results text, so the findings below are presented according to the descriptive scores and percentage reductions stated in the source document.

Table 1. Summary of sensory scores and anti-cockroach effectiveness of the formulated products

Formulation	Seaweed extract : Orange peel extract	Aroma score	Texture score	Color score	Reported anti-cockroach effectiveness
F1	25 : 75	3.28	3.24	3.28	40% reduction
F2	50 : 50	3.60	3.36	3.36	60% reduction
F3	75 : 25	4.40	4.24	4.28	75% reduction

The values in Table 1 show a consistent trend across all evaluated dimensions. F1 produced the lowest scores for aroma, texture, and color, while F3 produced the highest scores in all three sensory categories. The reported effectiveness test followed the same pattern, with F3 showing the greatest reduction in the number of cockroaches remaining in the room, followed by F2 and F1. Taken together, the data indicate that increasing the proportion of seaweed extract in the formulation was associated with higher panelist acceptance and stronger anti-cockroach performance in the tested preparations.

Product Characteristics of the Formulated Room Fragrances

The three formulations produced distinguishable product profiles even before the effectiveness test was considered. Based on the sensory descriptions provided in the manuscript, F1 tended to appear lighter in color and more fluid in texture, while F2 occupied an intermediate position in both appearance and consistency. F3 was described as having the darkest color and the thickest texture, suggesting a more concentrated character compared with the other formulations. These differences indicate that varying the ratio of seaweed extract and orange peel extract changed the visual and physical identity of the product in a clear and observable way.

The manuscript also suggests that these physical distinctions were not merely cosmetic. The thinner consistency of F1 was associated with faster spread, while the thicker consistency of F3 was associated with a more focused and longer-lasting aromatic impression. Likewise, the lighter visual appearance of F1 was linked to a cleaner and more modern perception, whereas the darker appearance of F2 and especially F3 gave a stronger impression of potency. In practical terms, the room-fragrance formulations therefore differed not only in ingredient ratio but also in the way they might be perceived during use, both physically and functionally.

Aroma Acceptability

The aroma test showed that F3 achieved the highest sensory score among all formulations, while F1 obtained the lowest score. The manuscript explicitly states that F3 was the most preferred formulation in terms of aroma and that F1 was less favored than the others. This result places F3 as the strongest candidate for product acceptance from the perspective of fragrance quality, which is central to the intended function of a room freshener.

In more detail, the original text reports an aroma score of 3.28 for F1, 3.60 for F2, and 4.40 for F3. F1 was described as producing a lighter and less sharp scent, which may be suitable for smaller rooms or users who prefer a milder fragrance. F2 generated a stronger and more detectable aroma than F1, making it more appropriate for larger spaces or for users who prefer a more noticeable scent. F3 showed the highest aroma intensity and was described as producing a very strong and easily detected fragrance, suitable for large rooms or for users seeking a pronounced aromatic presence. These descriptions indicate a gradient of aroma intensity across the three formulations, with F3 representing the most concentrated and sensorially dominant profile.

The manuscript further suggests that the higher acceptability of F3 may be related to the balance of aromatic active ingredients in the formulation. It notes that differences in the composition of seaweed extract, orange peel extract, and possibly other aromatic components may explain why one formula was better received than another. The text specifically argues that F3 likely achieved a better balance between aroma strength and natural fragrance character, thereby making it more acceptable organoleptically. It also states that higher aroma sensory values reflect greater potential for consumer acceptance, again reinforcing the position of F3 as the best-performing formula on this parameter.

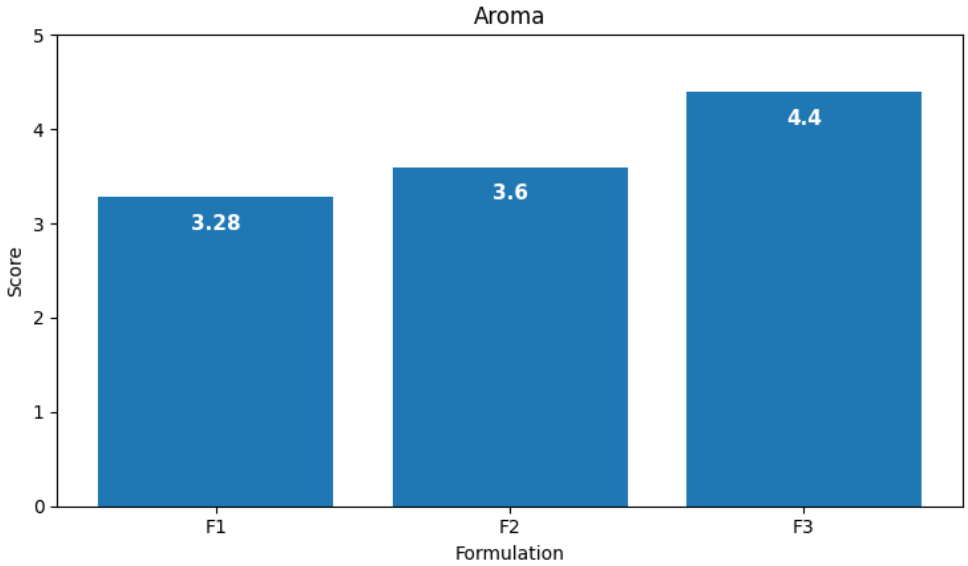

Figure 1. Organoleptic aroma scores of F1, F2, and F3

Texture Acceptability

Texture assessment was also included in the organoleptic evaluation. The manuscript introduces texture as a sensory parameter that can be judged through tactile perception, referring to Setiawati et al. (2020) when explaining that texture is a relevant attribute in sensory evaluation. In the present study, panelists were asked to evaluate the room-fragrance products based on viscosity, smoothness, and uniformity. These observations were then used to determine which formulation produced the most acceptable texture profile.

The reported texture scores followed the same ranking pattern observed for aroma. F1 obtained a score of 3.24 and was described as thinner and smoother, with faster and more even spreading characteristics. This lower viscosity was

also associated with a quicker release of the expected aroma. F2 obtained a score of 3.36 and was characterized as having a moderate texture, neither too thin nor too thick. According to the manuscript, this intermediate consistency was perceived as sufficiently good for even dispersion, although slightly slower than F1. F3 reached the highest texture score, 4.24, and was described as thicker than the other formulations. While panelists considered it somewhat slower to spread, they also associated it with a more focused aroma and a longer-lasting presence in the room.

These results show that the panelists did not simply favor the thinnest or easiest-to-disseminate formulation. Instead, the thicker character of F3 appears to have been perceived positively, likely because it conveyed product concentration and better aroma persistence. The manuscript therefore frames F1 as suitable for rapid fragrance distribution, F2 as a balanced option, and F3 as the preferred choice for users who value a more concentrated and enduring aromatic effect. Accordingly, texture did not function merely as a physical property, but as an attribute directly linked to perceived product performance.

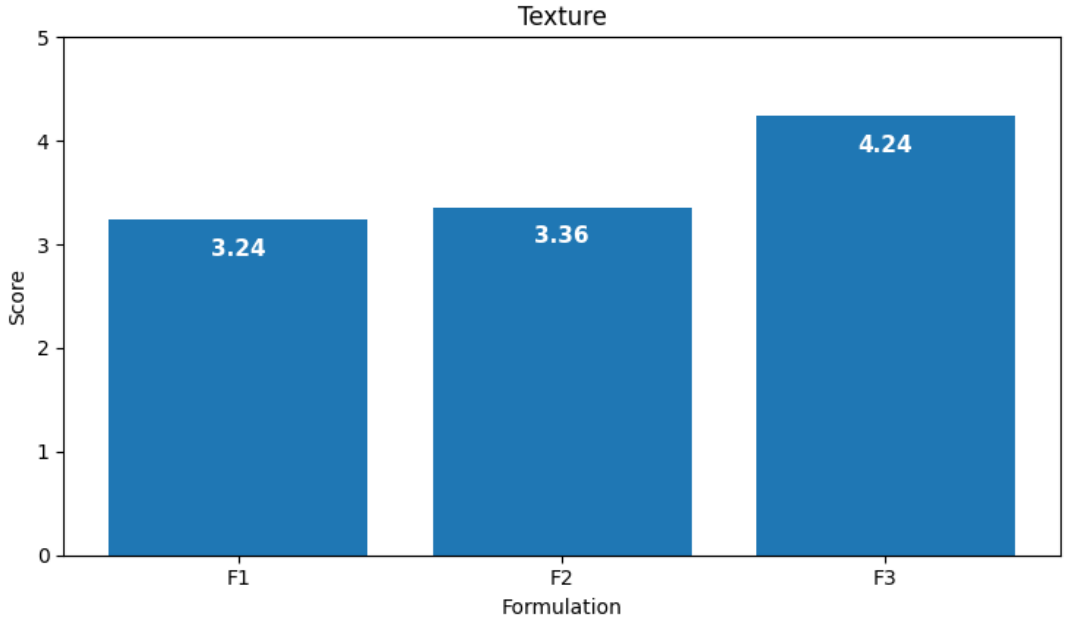

Figure 2. Organoleptic texture scores of F1, F2, and F3

Color Acceptability

Color was the third sensory parameter evaluated. The source manuscript notes that color is an important organoleptic attribute and cites Setiawan et al. (2022) to support the role of visual appearance in shaping consumer response. Even though that citation is drawn from food-quality evaluation, the manuscript applies the same principle to the present household product context, where visual appearance can influence first impressions and product trust.

The reported color scores were 3.28 for F1, 3.36 for F2, and 4.28 for F3. F1 was described as lighter and cleaner in appearance, giving a fresh and hygienic impression. Panelists considered the lighter color easier to accept for users who prefer products that look modern and clean. F2, by contrast, appeared darker than F1 and was perceived as stronger and potentially more effective, although

some panelists regarded the darker tone as less clean and less visually appealing. F3 had the darkest appearance of all formulations and also received the highest color score. The manuscript reports that this very dark appearance gave a very strong impression and was associated by panelists with greater anti-cockroach effectiveness, although some respondents still felt that the darker appearance made it look less clean or less modern than F1.

Overall, the color results suggest that visual preference did not move in the opposite direction of functional expectation. Although lighter color was associated with cleanliness and modernity, the darkest formula, F3, still achieved the highest score because it also conveyed a stronger functional identity. This means that panelists may have accepted a darker product appearance when it aligned with their perception that the product was more potent and more effective as a natural anti-cockroach room fragrance.

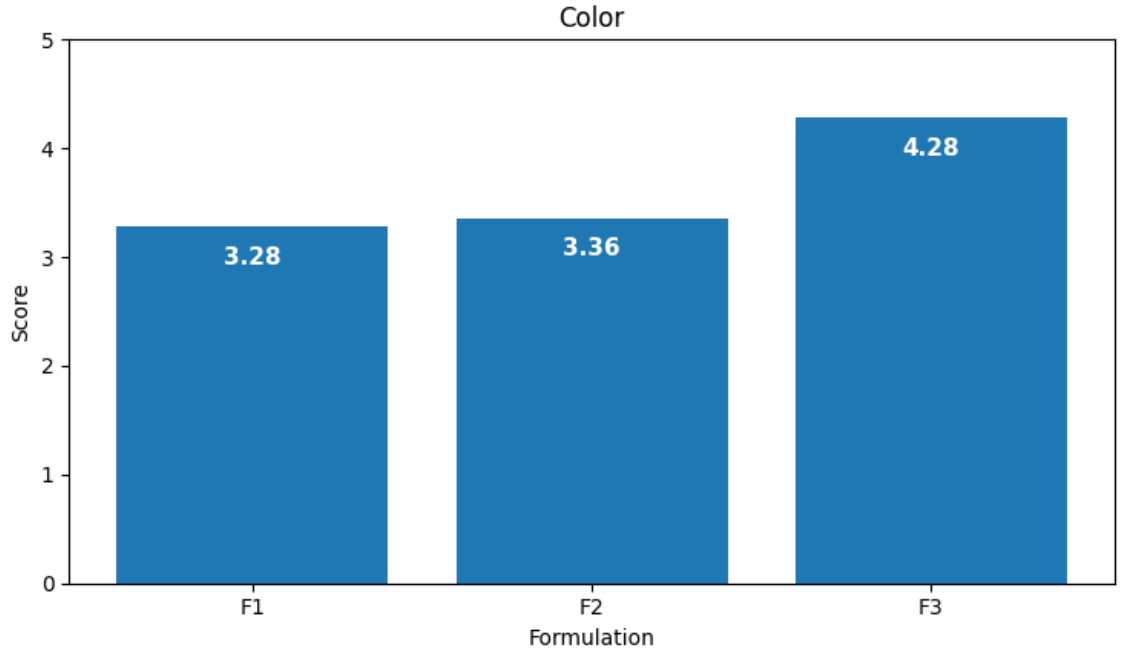

Figure 3. Organoleptic color scores of F1, F2, and F3

Anti-Cockroach Effectiveness

The final stage of the results concerned the effectiveness of the formulations in repelling cockroaches. The manuscript states that the effectiveness test was conducted to determine which formula most successfully reduced cockroach presence in the room. The findings show a progressive increase in effectiveness from F1 to F3, indicating that formulation ratio influenced repellent performance in a consistent manner.

F1, which contained 25% seaweed extract and 75% orange peel extract, reduced the number of cockroaches remaining in the room by approximately 40%. This result was described as reasonably good, although the manuscript notes that there was still room for improvement. F2, consisting of equal proportions of seaweed and orange peel extract, reduced the number of cockroaches by approximately 60%, showing a stronger repellent effect than F1. F3, which contained 75% seaweed extract and 25% orange peel extract, showed the highest effectiveness, with an approximately 75% reduction in the number of

cockroaches remaining after application. The manuscript explicitly identifies F3 as the most effective treatment among the three tested formulas.

The trend reported in the effectiveness test suggests that increasing the concentration of seaweed extract enhanced anti-cockroach performance under the conditions of this study. The manuscript interprets F2 as demonstrating the importance of balance between the two natural materials, while F3 indicates that a higher seaweed proportion produced the strongest repellent effect. Thus, the effectiveness data align with the sensory results in pointing to F3 as the leading formulation overall. When considered together with the aroma, texture, and color findings, the effectiveness test indicates that F3 offered the most favorable combined profile among the evaluated room-fragrance variants.

In summary, the results show a clear and consistent ranking across all measured outcomes. F1 represented the mildest profile, with the lowest sensory scores and the lowest reported reduction in cockroach presence. F2 performed at an intermediate level and provided a balanced profile across sensory and repellent attributes. F3 achieved the highest values for aroma, texture, and color, and also delivered the strongest anti-cockroach effectiveness. On the basis of the detailed results reported in the manuscript, F3 was the best-performing formulation and therefore the most promising candidate for further product development as a natural room fragrance with anti-cockroach functionality.

DISCUSSION

The findings of this study indicate that the formulation ratio of Eucheuma cottonii seaweed extract and orange peel extract played a decisive role in determining both user acceptance and anti-cockroach performance. Across all measured sensory parameters—aroma, texture, and color—the formulations followed the same ranking pattern, with F3 consistently receiving the highest scores, followed by F2 and F1. The repellency test also showed the same order, with F3 producing the greatest reduction in the number of cockroaches remaining in the room. This pattern suggests that the functional and sensory dimensions of the product were not opposed to one another in this experiment; instead, the most effective formulation was also the most preferred one. In practical terms, this is an important outcome because natural household products can only be considered viable alternatives to synthetic formulations if they are not only effective but also acceptable to users in everyday domestic use.

The superior aroma performance of F3 may be interpreted as evidence that the selected extract ratio was able to generate a more desirable balance between intensity and natural fragrance character. The source manuscript itself suggests that differences among formulations may be explained by variation in the composition of aromatic active substances and that, in F3, the balance between aroma strength and natural scent character was likely achieved more successfully than in the other formulations. This interpretation is relevant because the room-fragrance function of the product depends on consumer perception at the moment of use. A formulation that is too mild may fail to provide a noticeable indoor effect, while one that is too sharp or chemically unpleasant may be rejected despite having biological activity. The acceptance of F3 therefore implies

that the combination of seaweed extract and orange peel extract did not merely produce a stronger odor, but produced a sensory profile that panelists considered more suitable for a room-fragrance application. This aligns with the broader literature in the manuscript, which notes that natural air-freshener systems based on essential oils and plant extracts may successfully combine refreshing aroma with additional hygienic or repellent functions (Stashenko et al., 2018; Guangxin, 2016; Jiansheng, 2017; Li, 2018).

The texture results further reinforce the idea that consumer preference is shaped not only by fragrance intensity but also by how the product behaves physically after application. F1 was perceived as thinner and easier to disperse, F2 as intermediate, and F3 as thicker and slower to spread, yet F3 still received the highest texture score. This suggests that the panelists may have associated greater thickness with a more concentrated and persistent product character. In the context of room fragrance, a slightly thicker formulation may be advantageous when it supports a more focused release of aroma and a longer-lasting effect in the indoor environment. The source text explicitly interprets F3 as more suitable for users who want a scent that is more concentrated and more durable, while F1 is framed as more appropriate for rapid dissemination. Thus, the discussion of texture cannot be separated from the intended function of the product: what is preferred is not simply ease of spreading, but the sensory implication that the product will work effectively and remain perceptible for longer periods. This is consistent with the conceptual position of the study, namely that natural room fragrances should maintain their practical household function while reducing dependence on synthetic products that may present health risks (Astuti, 2020).

A similar pattern appears in the color evaluation. Although lighter color was associated with cleanliness, safety, and modern appearance, the darkest formulation still achieved the highest score. This indicates that visual acceptance was influenced by symbolic perceptions of product strength in addition to aesthetic preference. The manuscript repeatedly notes that darker color gave the impression of greater potency and stronger anti-cockroach action, even if some panelists considered it less clean-looking than a lighter preparation. From a product-development perspective, this is notable because it shows that users may tolerate or even prefer a less conventional appearance when it corresponds to perceived efficacy. In other words, visual quality in this product category is not defined only by brightness or clarity, but also by whether the appearance matches the user's expectation that the formulation is active, natural, and effective. Since the product was designed as a functional room fragrance rather than a purely decorative scent, the higher preference for F3 suggests that panelists valued visible indications of strength when combined with acceptable aroma and texture. The sensory data therefore point to an integrated response, where users seem to evaluate the preparation as a whole rather than as a set of isolated attributes.

The anti-cockroach effectiveness results provide the most direct support for the proposed functional value of the formulation. The gradual increase in repellency from F1 to F3 indicates that changing the concentration ratio of the

two extracts altered biological performance in a meaningful way. The manuscript interprets this trend as evidence that higher concentrations of seaweed extract strengthened repellent action, with F3 showing the highest reduction in cockroach presence. This is a particularly important result because it suggests that the role of seaweed in the formulation may extend beyond acting as a neutral deodorizing matrix. Earlier sections of the source text describe seaweed as having odor-absorbing capacity and note that seaweed, especially Eucheuma cottonii or related marine materials, may contain bioactive compounds such as saponins and phenolics, while orange peel is rich in limonene, a compound widely recognized for natural insect-repellent properties. The effectiveness of F3 therefore may reflect a synergistic interaction in which orange peel contributes a recognizable repellent volatile profile and seaweed supports or enhances the functional strength of the overall system. Even if the exact mechanism was not chemically analyzed in this study, the observed outcome remains consistent with the rationale established in the introduction and with previous work cited in the manuscript on natural repellent materials and eco-friendly household formulations (Setiawan, R. 2019; Aryee, A. N. A., 2020; Haq, M. et al. 2018).

Another important implication of this study is that it strengthens the case for multifunctional natural products in household use. The manuscript was motivated by the dual problem of unpleasant indoor odor and cockroach infestation, alongside concern over the health and environmental drawbacks of synthetic room fragrances and repeated insecticide use. In that context, a room freshener that also repels cockroaches offers a practical and conceptually attractive solution. The present findings support that idea by showing that the developed formulation was not only capable of reducing cockroach presence but also generated organoleptic responses that indicate potential consumer acceptance. This is significant because many natural products fail to progress beyond conceptual appeal if they cannot satisfy user expectations for aroma, appearance, and ease of use. Here, however, the best-performing formula combined these dimensions in a coherent way. Such a result is in line with the argument in the original manuscript that natural extracts and essential-oil-based systems can serve as safer, non-toxic, and environmentally friendlier alternatives to chemical household products (Xuxia, 2014; Bin et al., 2020).

At the same time, the study also reveals several limitations that are relevant for interpretation. First, the manuscript reports descriptive sensory scores and repellency percentages, but it does not present detailed inferential statistical outputs in the results section, despite mentioning Kruskal–Wallis analysis in the methodology. Second, the effectiveness test is summarized through percentage reduction in cockroach presence, but the observation period, environmental conditions, and repetition structure are not described in depth in the extracted text. Third, although the discussion infers that active compounds such as limonene and seaweed-associated bioactives contributed to the observed performance, no chemical characterization was conducted to confirm the specific compounds responsible for the effects. These limitations do not invalidate the findings, but they do suggest that the present study should be understood as an applied formulation study demonstrating promising product potential rather

than as a mechanistic investigation. For that reason, the manuscript's own recommendation to optimize the formula by adding other ingredients that may improve effectiveness and fragrance longevity is well founded and should be retained in future development work.

Overall, the discussion supports the conclusion that the seaweed–orange peel formulation has strong promise as a natural room fragrance with anti-cockroach functionality. Among the three tested treatments, F3 emerged as the most convincing candidate because it united the highest aroma, texture, and color scores with the strongest repellency effect. This outcome suggests that the higher seaweed proportion used in F3 improved not only product efficacy but also the overall sensory identity of the preparation. More broadly, the study contributes to the growing movement toward safer and more sustainable household products by demonstrating how locally available natural resources and agricultural by-products can be transformed into a value-added domestic application. The use of seaweed and orange peel therefore has relevance not only for product performance, but also for environmental practicality, waste valorization, and reduced reliance on synthetic chemicals in everyday indoor settings.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that a natural room fragrance formulated from Eucheuma cottonii seaweed extract and orange peel extract has strong potential as a dual-function household product that improves indoor aroma while reducing cockroach presence. The overall findings show that variation in the formulation ratio affected both organoleptic acceptance and repellent effectiveness. Among the tested formulations, F3, containing 75% seaweed extract and 25% orange peel extract, emerged as the best-performing treatment. It achieved the highest sensory scores for aroma, texture, and color, and also showed the greatest anti-cockroach effectiveness, with a reported reduction of about 75% in cockroach presence. These results indicate that increasing the proportion of seaweed extract enhanced the overall functional performance of the product while maintaining a sensory profile that was well accepted by panelists. The study therefore supports the use of seaweed and orange peel as natural, locally available, and environmentally friendly raw materials for household fragrance innovation. In addition to offering a safer alternative to synthetic air fresheners and chemical repellents, the formulation also contributes to the valorization of marine resources and citrus by-products. The present work adds to the growing body of knowledge on multifunctional natural household products by showing that fragrance acceptability and pest-repellent performance can be integrated in one formulation. Further research should focus on optimizing the composition, improving aroma longevity, testing storage stability, and verifying active compounds responsible for repellency.

Based on the findings of this study, the formulation containing 75% Eucheuma cottonii seaweed extract and 25% orange peel extract is recommended as the most promising composition for further development, as it demonstrated the best overall performance in terms of aroma, texture, color, and anti-cockroach effectiveness. For practical application, future product development should focus

on improving aroma stability, extending fragrance persistence, and enhancing the uniformity of the spray formulation to ensure better user acceptance and commercial feasibility. It is also recommended that the extraction and formulation procedures be standardized in order to obtain more consistent product quality across production batches. In addition, wider household-scale testing should be conducted to evaluate the product under real-use conditions, including different room sizes, ventilation levels, and infestation intensities. From an applied perspective, this natural room fragrance has good potential to be developed as an eco-friendly household product that can serve as an alternative to synthetic air fresheners and chemical cockroach repellents.

ADVANCED RESEARCH

Further research is needed to strengthen the scientific basis and application potential of this formulation. Future studies should investigate the chemical composition of both seaweed and orange peel extracts, particularly the active compounds responsible for fragrance characteristics and cockroach repellency. Instrument-based analysis such as gas chromatography or related techniques would be useful for identifying volatile and bioactive constituents, including limonene and other relevant compounds. Advanced research should also examine the stability, shelf life, and storage behavior of the product under different environmental conditions, as these factors are essential for product development and commercialization. In addition, broader sensory evaluation involving a larger and more diverse panel is recommended to validate consumer acceptance more robustly. Experimental studies using more detailed statistical analysis, repeated trials, and controlled bioassays on cockroach behavior would also improve the reliability of the findings. It would furthermore be valuable to explore the addition of other natural ingredients that may enhance fragrance longevity, antimicrobial activity, or repellent effectiveness, thereby expanding the multifunctional performance of the formulation.

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