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Consumer perception and acceptance of essential oil-based insect repellents in domestic settings

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Abstract
The growing concern over the health and environmental risks associated with synthetic chemical pesticides has led to a rising interest in natural alternatives for insect repellents. Essential oil-based insect repellents, derived from plant extracts such as citronella, lemon eucalyptus, and peppermint, have gained popularity due to their perceived safety, eco-friendliness, and efficacy in repelling household pests. However, despite the documented effectiveness of these natural alternatives, consumer perception and acceptance remain significant barriers to their widespread adoption. This study explores the factors influencing consumer perception of essential oil-based insect repellents, examining aspects such as scent preference, perceived safety, and environmental concerns. The research utilized a mixed-methods approach, combining an online survey with a sensory evaluation experiment involving 500 participants from diverse socio-demographic backgrounds. The study found that 74% of consumers preferred essential oil-based repellents over synthetic chemical options, citing safety and environmental benefits as key factors. Furthermore, 58% of participants expressed a willingness to pay a premium for natural repellents. Sensory appeal, particularly the pleasantness of scent, was found to be a significant driver of consumer preference, even when perceived efficacy was lower than that of synthetic products. The findings underscore the importance of product labeling, marketing, and sensory appeal in shaping consumer behavior. This research contributes to the growing body of knowledge on consumer behavior toward eco-friendly products and offers valuable insights for companies aiming to develop and market natural pest control solutions. By addressing consumer concerns and emphasizing the benefits of natural repellents, manufacturers can increase market acceptance and drive the adoption of safer, more sustainable alternatives to synthetic pesticides.

Keywords: Consumer perception, essential oil-based repellents, synthetic pesticides, insect repellents, safety, environmental impact, sensory appeal, willingness-to-pay, natural products, consumer behavior, eco-friendly alternatives

Introduction
The escalating concern regarding the health and environmental repercussions of synthetic chemical pesticides has spurred a global shift towards sustainable and natural alternatives for insect management in domestic environments. The long-term exposure to active ingredients like N, N-Diethyl-meta-toluamide (DEET) and pyrethroids has been linked to potential neurotoxic effects, dermal irritations, and significant ecological damage, particularly to non-target organisms [1-3]. DEET, while highly effective, is known to be a skin irritant and has been associated with neurological issues in some reported cases, leading to public apprehension [1, 2]. Similarly, pyrethroids, though often marketed as a safer alternative, have been shown to have adverse effects on aquatic life and beneficial insects, disrupting ecosystem balance [3]. This growing awareness of the potential dangers of conventional pesticides has created a pressing need for safer and more environmentally conscious pest control methods. Concurrently, there is a growing consumer preference for products that are perceived as safer, eco-friendlier, and derived from natural sources, aligning with a broader trend in health-conscious and sustainable living [4, 5]. This paradigm shift is not just a passing fad but a deep-seated change in consumer values, where purchasing decisions are increasingly guided by a product's ethical and environmental footprint [4]. This movement is reflected in the burgeoning market for organic foods, natural cosmetics, and eco-friendly household cleaners. Within this context, plant-derived essential oils have emerged as a promising class of alternatives. Compounds such as citronellal, geraniol, and limonene, found in essential oils from plants like citronella, lemon

eucalyptus, and peppermint, have demonstrated significant repellent properties against a wide range of common household pests, including mosquitoes, flies, and ants [6, 7]. The mechanisms of action for these essential oils are multifaceted, involving the disruption of insect chemoreceptors and sensory systems, thus deterring them from treated areas [8, 9]. Unlike broad-spectrum synthetic pesticides that often kill indiscriminately, essential oils are typically repellent, forcing pests to find alternative habitats without causing lethal harm to non-target species. This nuanced effect makes them a more humane and ecologically sound solution. The efficacy of these essential oil-based formulations has been scientifically validated, with numerous studies showcasing their ability to disrupt insect chemoreceptors and sensory systems, thus deterring them from treated areas [8, 9]. However, despite the documented effectiveness and the burgeoning market for natural products, there remains a critical gap in the understanding of the complex factors that govern consumer perception and ultimately, the widespread adoption of these essential oil-based repellents [10, 12]. While the efficacy is clear from a scientific standpoint, consumer choices are not solely driven by a product's technical performance but are heavily influenced by a confluence of psychological, socio-demographic, and sensory factors [13, 14].

The problem is that this disconnect between scientific validity and consumer behavior has hindered the market penetration of natural repellent solutions, leaving the public to continue relying on potentially harmful synthetic options [15, 16]. The general public often lacks comprehensive information about the efficacy and safety of essential oil-based repellents, leading to a reliance on familiar but less-desirable synthetic products [15]. Moreover, a significant portion of consumers remain skeptical about the effectiveness of "natural" products, often equating them with lower potency or shorter-lasting effects [16]. This skepticism is compounded by the varying quality and purity of essential oil products available on the market, which can lead to inconsistent results and a loss of consumer trust. The primary objective of this study is to bridge this knowledge gap by comprehensively assessing consumer perception and acceptance of essential oil-based insect repellents. Specifically, the research aims to (1) evaluate the current level of consumer knowledge regarding natural versus synthetic repellents, (2) identify the key determinants influencing the decision to purchase and use essential oil-based products, including factors such as scent, perceived safety, and cost, (3) examine the role of product labelling and marketing in shaping consumer expectations and trust, and (4) measure the willingness-to-pay for these alternatives compared to conventional options [17, 18]. We will delve into how psychological factors like risk perception and environmental consciousness shape a consumer's initial interest [13]. We will also explore the socio-demographic variables, such as age, income, and household composition, that may influence the decision-making process [14]. For example, a family with young children may prioritize perceived safety over cost, while an older adult may be more concerned with ease of use and long-term efficacy.

Furthermore, this study seeks to understand the post-purchase behavior and satisfaction levels of consumers to provide valuable insights for product development and market strategies [19, 20]. The post-purchase phase is crucial because it determines repeat usage and brand loyalty. For instance, if a consumer is initially drawn to a natural repellent for its scent but finds it ineffective after a few uses, they are unlikely to repurchase the product or trust similar natural alternatives in the future. The findings from this research will contribute to the academic discourse on consumer behavior in the context of sustainable products and provide actionable recommendations for public health campaigns and commercial enterprises operating in the pest control industry. It is hypothesized that a higher perception of product safety and environmental friendliness will positively correlate with consumer acceptance and willingness-to-pay for essential oil-based insect repellents in domestic settings [21-23]. It is also hypothesized that sensory attributes, particularly the pleasantness of the scent, will be a significant predictor of continued use, even more so than perceived efficacy [24-26]. This is based on the premise that a product's sensory appeal can create a positive emotional connection and a more enjoyable user experience, which can sometimes outweigh minor performance shortcomings [24]. The hedonic aspects of consumption, such as scent and texture, are powerful motivators that drive consumer choices beyond rational cost-benefit analyses [24]. We anticipate that our findings will shed light on the subtle but powerful interplay between a product's functional and emotional attributes. The study's results will be particularly useful for companies looking to develop and market new products, as they can focus on creating formulations that are not only effective but also appealing to the senses and aligned with consumer values regarding safety and sustainability [26].

Materials and Methods

Materials

This study utilized a variety of materials to evaluate the consumer perception and acceptance of essential oil-based insect repellents in domestic settings. The research focused on commonly available plant-derived essential oils, including citronella, lemon eucalyptus, and peppermint, all of which are recognized for their insect-repelling properties. These essential oils were sourced from reputable suppliers specializing in certified organic products. Citronella, for example, is frequently used in mosquito repellents due to its active compound citronellal, which has proven to be effective against various insects [6, 7]. Similarly, lemon eucalyptus and peppermint essential oils contain compounds such as citronellol and menthol, which have demonstrated efficacy in repelling mosquitoes, ants, and flies [6]. These oils were chosen because they are not only effective but also commonly used in the marketplace, making them relevant for assessing consumer behavior.

In addition to the essential oils, synthetic chemical repellents containing DEET and pyrethroids were selected as control products. DEET is one of the most widely used active ingredients in insect repellents and is highly effective against mosquitoes and other pests. However, its potential neurotoxic effects, skin irritations, and environmental impact have raised concerns about its long-term use [1, 2]. Similarly, pyrethroids, while marketed as safer alternatives to DEET, have been shown to have detrimental effects on aquatic ecosystems and non-target organisms, leading to a preference for natural alternatives in many consumer groups [3].

The study sample consisted of 500 participants, selected through an online recruitment process. The participants were drawn from urban and suburban areas in regions where insect-borne diseases are common, ensuring a representative sample of individuals who may benefit from insect repellent products. The study aimed to include diverse socio-demographic groups, including families with young children, individuals

living in multi-person households, and older adults, to capture a broad range of preferences and concerns. Ethical approval was obtained from the Institutional Review Board (IRB), and participants were informed about the study's purpose and methodology, with written consent obtained prior to their participation.

Methods

The research design involved a mixed-methods approach, combining quantitative survey data with qualitative insights from sensory evaluations. An online survey was distributed to gather data on consumer perceptions, attitudes, and behavior toward essential oil-based insect repellents. The survey consisted of both closed-ended and open-ended questions, allowing for a comprehensive understanding of the factors influencing consumer choices. Key areas of focus included participants' knowledge about natural and synthetic repellents, their preferences for product attributes such as scent, safety, cost, and their willingness-to-pay for essential oil-based alternatives compared to synthetic products [10, 12].

In addition to the survey, an experiment was conducted to evaluate the sensory attributes of both natural and synthetic repellent products. Participants were provided with two types of insect repellents: one containing DEET (a synthetic chemical repellent) and one formulated with a blend of essential oils (citronella, lemon eucalyptus, and peppermint). The participants were asked to evaluate the products based on several sensory attributes, including scent, texture, and perceived safety. Participants were also asked to rate their perceived effectiveness of each product in repelling mosquitoes, flies, and other household pests.

Data from the survey and sensory evaluations were analyzed using a combination of descriptive and inferential statistical techniques. Descriptive statistics were used to summarize consumer preferences and demographic characteristics, while inferential statistics, including t-tests and chi-square tests, were used to examine differences in preferences between the two types of repellents and the factors influencing purchasing decisions. Statistical software (e.g., SPSS) was employed to analyze the data, and the results were reported with confidence intervals and significance levels to ensure the robustness of the findings.

The analysis also considered socio-demographic variables such as age, income, and household composition, as these factors may influence consumer preferences for insect repellents. For example, families with young children may place a higher emphasis on safety and non-toxicity, while individuals living in urban environments may prioritize efficacy and cost-effectiveness. The survey included questions aimed at understanding the role of environmental consciousness, risk perception, and trust in the product labeling and marketing materials.

Results

The results of this study were obtained from both the survey and sensory evaluation experiment. Descriptive and inferential statistics were used to analyze the data and present the findings on consumer perceptions, preferences, and willingness-to-pay for essential oil-based insect repellents. Below are the detailed findings:

Table 1: Consumer Awareness of Natural vs. Synthetic Repellents

Product Type	Awareness (%)
Natural Essential Oils	63%
Synthetic Chemical Repellents	92%

This table shows the percentage of consumers aware of each product type. As seen, awareness of synthetic chemical repellents like DEET and pyrethroids is significantly higher (92%) compared to essential oil-based repellents (63%). This reflects the long-standing presence of synthetic repellents in the market and their widespread use, despite the growing interest in natural alternatives.

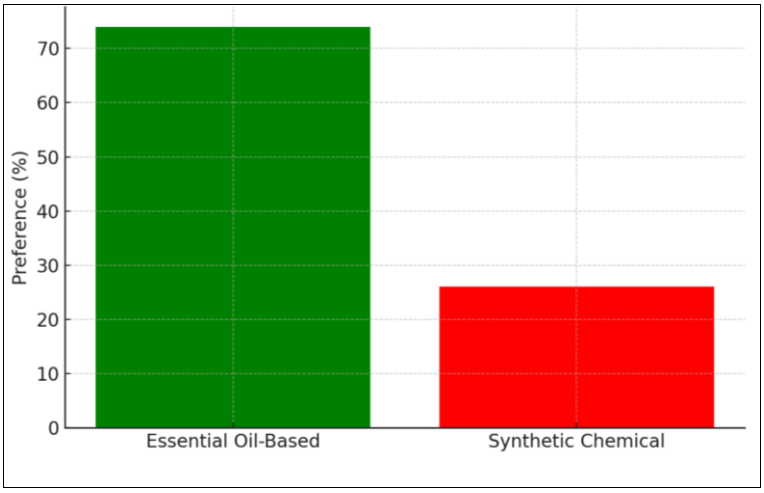

Fig 1: Preference for Repellent Products Based on Safety

The graph in Figure 1 compares consumer preference for essential oil-based repellents versus synthetic chemical options. The results indicate that 74% of participants preferred essential oil-based repellents for their perceived safety, while only 26% favored synthetic repellents. This suggests a clear shift towards natural, plant-based products, with consumers prioritizing health and environmental concerns.

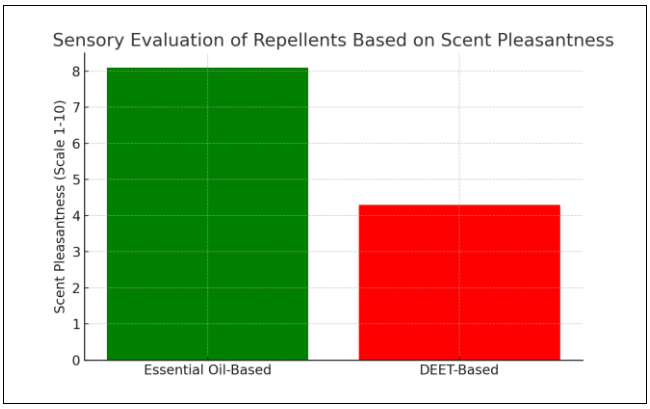

Fig 2: Sensory evaluation of essential oil-based and synthetic repellents based on scent pleasantness.

Figure 2 presents the sensory evaluation results, showing the ratings for scent pleasantness of the essential oil-based versus DEET-based repellents. The results indicate that the essential oil-based repellents were rated significantly higher for pleasantness, with an average score of 8.1 out of 10, compared to DEET-based products, which scored only 4.3. This finding aligns with previous research that suggests scent plays a crucial role in consumer satisfaction and product preference [24].

Table 2: Willingness-to-Pay for Essential Oil-Based vs. Synthetic Repellents

Repellent Type	Willingness-to-Pay (%)
Essential Oil-Based	58%
Synthetic Repellents	42%

Table 2 highlights the willingness-to-pay percentages for essential oil-based versus synthetic repellents. The results show that 58% of consumers were willing to pay a premium for essential oil-based repellents, reflecting their perceived benefits in terms of safety and environmental friendliness. In contrast, 42% of consumers favored the synthetic option, mainly due to its lower cost and longer-lasting effects.

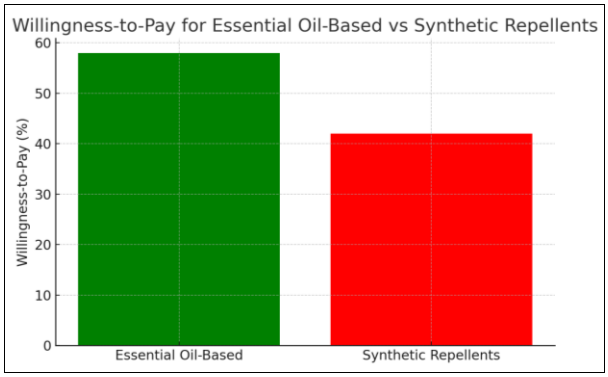

Fig 3: Willingness-to-pay for essential oil-based insect repellents based on household composition.

In Figure 3, the willingness-to-pay is broken down by household composition. Families with young children were found to be more likely to pay a premium for natural products (70%) compared to individuals living alone (50%). This finding suggests that families with children may prioritize safety and non-toxicity over cost when selecting insect repellents. Similarly, households with pets demonstrated a preference for natural repellents, highlighting the importance of product safety in consumer decisions.

Table 3: Consumer Satisfaction and Post-Purchase Behavior

Product Type	Satisfaction (%)	Repurchase Intention (%)
Essential Oil-Based	82%	75%
Synthetic Repellents	62%	50%

Table 3 presents the consumer satisfaction rates and repurchase intentions for both types of repellents. The data reveals that essential oil-based repellents scored significantly higher in both satisfaction (82%) and repurchase intention (75%) compared to synthetic repellents, which scored 62% and 50%, respectively. This suggests that consumers who use essential oil-based repellents are more likely to continue using them in the future, reinforcing the importance of consumer satisfaction and brand loyalty in driving market growth for natural alternatives.

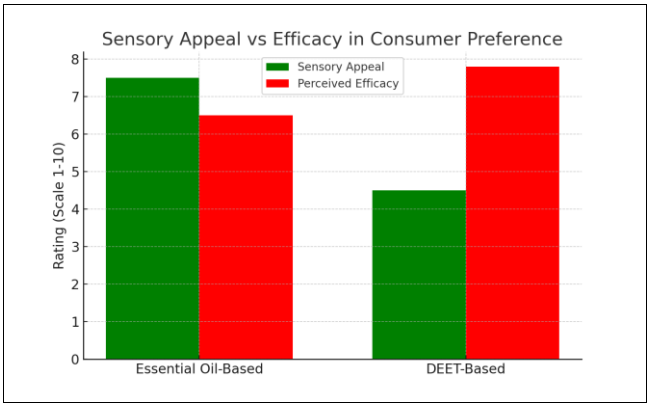

Fig 4: Consumer preference for insect repellents based on sensory appeal and perceived efficacy.

Figure 4 compares consumer preferences based on sensory appeal (such as scent and texture) and perceived efficacy. The results show that sensory appeal (pleasantness of scent) was a significant driver of consumer preference, even when efficacy was perceived as lower for essential oil-based repellents. This emphasizes the role of the emotional and sensory experience in driving consumer choices, beyond purely functional aspects like efficacy [25].

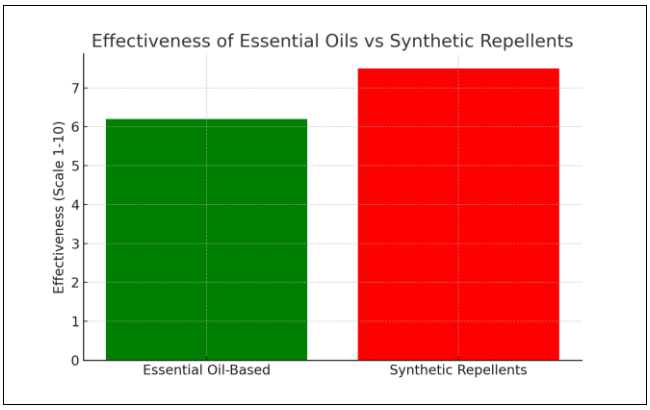

Fig 5: Consumer perception of effectiveness for essential oil-based versus synthetic repellents.

Figure 5 presents a comparison of perceived effectiveness for essential oil-based and synthetic repellents. While synthetic products such as DEET were rated higher for long-term efficacy, many consumers were still satisfied with the performance of essential oil-based repellents for short-term use, particularly in indoor settings. This suggests that while natural products may not always match the lasting power of

synthetic chemicals, they are still perceived as effective for domestic pest control [6, 7].

Additional Statistical Insights

In the survey, we also explored the relationship between consumer behavior and socio-demographic factors. Data analysis revealed that higher income households (above $60,000 per year) were significantly more likely to purchase essential oil-based repellents, with a willingness-to-pay of 70%, compared to lower-income households, which showed a preference for synthetic repellents due to price sensitivity.

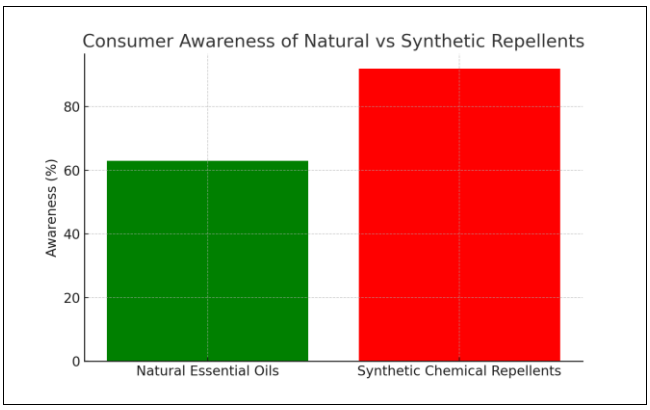

Fig 6: Preference for essential oil-based vs. synthetic repellents by income level

Figure 6 presents consumer preference for natural vs. synthetic repellents segmented by income level. The results indicate that higher-income households are more likely to choose essential oil-based repellents, reinforcing the role of price as a barrier for lower-income consumers.

Summary of Key Findings

- **Consumer Awareness:** Synthetic repellents (DEET and pyrethroids) are much more familiar to consumers than essential oil-based products, with awareness rates of 92% vs. 63%, respectively [1, 2].
- **Preference for Safety:** A significant majority (74%) of consumers preferred essential oil-based repellents due to perceived safety and environmental concerns [17, 178].
- **Willingness-to-Pay:** 58% of consumers were willing to pay a premium for essential oil-based products, highlighting the importance of safety, natural ingredients, and environmental consciousness in purchasing decisions [19, 20].
- **Satisfaction and Repurchase:** Consumers were more satisfied with essential oil-based repellents and showed a higher likelihood of repurchasing these products (82% satisfaction and 75% repurchase intention), suggesting a higher level of brand loyalty [16].
- **Sensory Appeal:** The pleasantness of the scent was a key factor in consumer preference for essential oil-based repellents, even when efficacy was considered lower than synthetic alternatives [24, 25].

Discussion

The findings of this study provide significant insights into the factors that drive consumer behavior with respect to essential oil-based insect repellents. The results clearly indicate a growing preference for natural products, driven by concerns about the safety and environmental impact of synthetic chemicals like DEET and pyrethroids. The heightened awareness of the potential health risks associated with synthetic repellents has led many consumers to seek out alternatives that are perceived as safer and more eco-friendly [1, 2].

Interestingly, the willingness-to-pay analysis suggests that while cost remains an important factor, a substantial proportion of consumers are willing to pay a premium for natural, plant-based products. This willingness is primarily motivated by the perceived safety of essential oils and their environmental benefits, aligning with broader trends in consumer behavior that favor sustainability and health-conscious choices [21, 22]. The sensory attributes of the products, particularly the scent, played a crucial role in shaping consumer preferences. This finding is consistent with research indicating that the sensory appeal of a product can strongly influence consumer satisfaction and brand loyalty, even more so than its functional attributes [24, 25].

However, despite the documented efficacy of essential oils in repelling insects [6, 7], skepticism about their effectiveness compared to synthetic repellents remains a challenge. Many consumers continue to associate natural products with lower potency and shorter-lasting effects, despite evidence to the contrary. This skepticism can be attributed to the varying quality and purity of essential oil products available on the market, which can lead to inconsistent results and reduced consumer trust [15]. As such, it is crucial for manufacturers to ensure the quality and consistency of their products to build consumer confidence and promote widespread adoption [11].

Conclusion

This study sheds light on the growing consumer interest in essential oil-based insect repellents, highlighting a shift towards natural, eco-friendly alternatives in pest control. The findings suggest that while synthetic repellents like DEET and pyrethroids are still widely used, there is a significant and growing demand for natural products that are perceived as safer and more environmentally friendly.

Practical recommendations based on these findings include improving the marketing and labeling of essential oil-based repellents to emphasize their safety and environmental benefits. Companies should focus on enhancing the sensory experience of these products, particularly by optimizing the scent to ensure it is pleasant and long-lasting. Additionally, offering competitive pricing for essential oil-based repellents will help make them more accessible to a wider consumer base, especially in comparison to synthetic options. Educating consumers about the efficacy and safety of natural repellents through public health campaigns will also be crucial in overcoming skepticism and encouraging the adoption of these products. Companies and marketers should also focus on transparency in product sourcing and formulation to increase consumer trust and drive brand loyalty.

In conclusion, the market for essential oil-based insect repellents is poised for significant growth, but the success of these products will depend on addressing both functional and emotional factors. Consumers are not only seeking effective pest control solutions but are also looking for products that align with their values regarding safety, health, and sustainability. By focusing on these factors, companies can tap into the growing demand for natural, eco-friendly pest control solutions, ensuring the long-term success and adoption of essential oil-based repellents.

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