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SCENT AND SEIZURE: *LANTANA CAMARA'S* EFFECT ON OLFACTION IN *DROSOPHILA* PARA EPILEPTIC MUTANT

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Olfactory dysfunction, Epilepsy, *Lantana camara*, Chemo taxis, Para bang senseless[1] *Drosophila* mutant

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ABSTRACT: *Drosophila melanogaster* serves as an ideal model for studying olfactory perception due to shared cellular and molecular odor-coding strategies with mammals. Olfactory dysfunction commonly appears as a non-motor symptom in neurological disorders like Epilepsy and Parkinson's disease, often before motor symptoms develop. This study examined *Lantana camara's* flower and leaf extracts on olfactory perception in Epileptic para bangsenseless[1] *Drosophila* mutant. *L. camara* flowers and leaves were shade dried, grounded, and prepared as aqueous extracts using Soxhlet apparatus. 2-5 day old adult flies were maintained on cornmeal-yeast-agar medium containing extracts at different concentrations for 24 hours, followed by 24-hour starvation. Olfactory behavioral assays were conducted using a vial-based setup with attractant (yeast paste) and repellent (citronella oil) stimuli, measuring response times to olfactory perception. High-dose flower extracts yielded the most significant enhancement, achieving response times similar to wild-type control flies. *L. camara* extracts modulate olfactory sensory neuron properties, potentially normalizing signal transduction disruptions in the epileptic model. These dose-dependent improvements suggest the plant can restore sensory circuit functionality in neurological conditions, warranting investigation into specific bioactive compounds and mechanisms.

INTRODUCTION: Epilepsy affects approximately 50 million people worldwide and is characterized by recurrent seizures resulting from abnormal neuronal activity in the brain [1]. Beyond well-documented motor manifestations, epilepsy is associated with sensory dysfunction, particularly olfactory impairment that can significantly impact quality of life [2]. Recent advances in epilepsy biomarker development have explored molecular, imaging, and physiological markers that could enhance diagnosis, predict seizure outcomes, and guide treatment strategies.

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Olfactory dysfunction has emerged as a promising common biomarker across multiple neurodegenerative disorders, suggesting that olfactory testing could serve as a non-invasive, accessible screening tool for early detection and monitoring of various neurological conditions, including epilepsy [3]. Olfactory dysfunction is well-documented in temporal lobe epilepsy (TLE). A study of 65 TLE patients using the Odor Stick Identification Test for Japanese (OSIT-J) showed they scored significantly lower than healthy controls, with deficits most pronounced in those with bilateral seizures or later onset [4].

The analysis identified substantial deficits in odor identification, memory, and discrimination abilities, with particularly severe impairments in patients with temporal lobe and mixed frontal epilepsy. These olfactory deficits were significantly associated with several demographic and clinical

variables, including gender, age, tobacco use, level of education, hand dominance, and the age at which epilepsy first developed [4-6].

Insects, particularly *Drosophila melanogaster*, navigate their environment using specialized taste and olfactory receptors that detect chemicals signaling food, mates, or dangers [7]. At the adult stage, the *Drosophila* brain contains approximately 100,000 neurons. Adult flies are equipped with two pairs of olfactory organs: the third antennal segments and the maxillary palps [8]. These organs are covered with several classes of sclerotized olfactory bristles, or sensilla, which house the dendrites of olfactory receptor neurons (ORNs) [9, 10]. The genetic basis of chemotaxis in *Drosophila* is rooted in its chemoreceptor superfamily, which includes odorant receptors and gustatory receptors. These receptors are responsible for detecting volatile and non-volatile chemicals in the environment. Odorant Receptors (ORs) are expressed in olfactory sensory neurons on the antennae and maxillary palps, while Gustatory Receptors (GRs) are found on the labellum and other taste organs. The activation of these receptors triggers signaling pathways that ultimately influence behavioral responses [11, 12]. ORs are tuned to specific odorant molecules and are essential for detecting volatile chemicals. GRs are primarily involved in detecting non-volatile compounds, such as sugars, bitter substances, and phytotoxins. These receptors play a key role in feeding behavior and the avoidance of toxic substances [11, 13].

Adult flies display a rich repertoire of behaviors driven, or modulated, by olfactory input. Odor cues modulate walking and flight behaviors [12-18] and adults rely on olfaction to identify food sources and acceptable sites for oviposition [19]. The para bang senseless [1] (para ^{bss1}) mutant of *Drosophila melanogaster* exhibits seizure-like behaviors analogous to human epilepsy, making it a valuable model for studying the relationship between epilepsy and sensory functions [20-22]. This *Drosophila* strain carries mutations in the voltage-gated sodium channel gene (*Para*) and loss of the bang-sensitive gene (*bss*) resulting in neuronal hyperexcitability similar to that observed in human epilepsy. The olfactory response assay used in this study determines the fly's response to an attractive or repulsive odor by measuring the time taken for flies to either approach or avoid the stimulus, an approach first developed by Robert Anholt [23]. This represents a strong innate behavior, since aversion to repellent odorants is necessary for survival and reproduction; when flies are exposed to a repulsive odor; they rapidly fly or walk away.

Lantana camara Linn. (Verbenaceae), a widely distributed weed and ornamental shrub, has been traditionally used in various indigenous medicine systems for treating neurological disorders [24]. The plant contains numerous bioactive compounds, including lantadenes [25, 26], triterpenes, flavonoids and phenylpropanoids, which have demonstrated anticonvulsant, neuroprotective, and anti-inflammatory properties in preclinical studies [27, 28]. Given the established neuroprotective effects of *L. camara* extracts [29] and the clinical significance of olfactory dysfunction in epilepsy [2, 6], this study aimed to investigate whether *L. camara* extracts could modulate olfactory perception in the epileptic para ^{bss1} *Drosophila* model. We hypothesized that the phytochemicals present in *L. camara* might influence neuronal excitability in olfactory pathways, potentially mitigating the sensory deficits associated with epileptic conditions.

MATERIALS AND METHODS:

***Drosophila* Strains and Maintenance:** The para ^{bss1} mutant strain of *Drosophila melanogaster* was obtained from the National Centre for Biological Sciences (NCBS). Wild-type *Drosophila melanogaster* flies served as controls and were obtained from Drosophila stock centre of Mysore University. All flies were maintained on standard cornmeal-yeast-agar medium at 22°C (±1°C) under a 12-hour light/dark cycle.

Plant Material Collection and Extract Preparation: The flowers and leaves of *L. camara* were collected from in and around Bangalore University. The collected plant samples were identified and confirmed as *Lantana camara* L., a member of the Verbenaceae family, by Dr. V. Rama Rao, a Research officer at the Central Ayurveda Research Institute, Bengaluru. A herbarium specimen with the designation RRCBI-15312 was submitted to the Institute. Only fresh, young, and healthy plant parts (flower and leaf) were selected for the experiment. The collected plant parts were cleaned thoroughly to remove

unwanted debris, such as dust, hidden insects, caterpillars, and spiders from leaves and the inflorescence. Flowers and leaves procured were shade-dried [30]. The dried plant parts were powdered separately with a blender and stored in airtight packets for further use. Soxhlet extraction was employed with aqueous/water as the chief extractant for the study. The dried plant component was loaded onto a thimble of Soxhlet extractor, and the obtained plant extracts were evaporated in a Rotary evaporator. The crude extracts, which were dark green, were utilized for further experimental studies.

Treatment Groups: *Drosophila melanogaster* and Para^{bss1} mutant *Drosophila* (2-5 days old) were housed in mixed-sex groups (n=10/vial) with naturally random sex distribution. Males (hemizygous for X-linked para^{bss1}) exhibit severe seizures while females (heterozygous) show mild symptoms, modeling clinical X-linked epilepsy heterogeneity where both phenotypes require treatment.

All experimental groups received identical housing protocols: mixed-sex composition, same vial density, and same handling procedures. This uniformity across control and treatment groups isolates plant extract effects from environmental, social variables. Flies were assigned to Eight treatment groups, each tested in triplicate (n=30 flies per treatment across 3 vials)

The Eight experimental groups were:

1. Control -*Drosophila melanogaster*- (Cornmeal-yeast-agar medium without addition of any extracts)
2. Diseased -Para^{bss1} -(Cornmeal-yeast-agar medium without addition of any extracts)
3. Leaf extract - low dose (500 mg)
4. Leaf extract - mid dose (1500 mg)
5. Leaf extract - high dose (3500 mg)
6. Flower extract - low dose (500 mg)
7. Flower extract - mid dose (1500 mg)
8. Flower extract - high dose (3500 mg)

The extracts were mixed separately in 100ml cornmeal-yeast-agar medium and then added to vials. Flies were exposed to these extracts first for 24 hours, followed by a 24 hour starvation period to enhance their olfactory sensitivity prior to behavioral testing [31].

Olfactory Response Assay: The olfactory assay evaluates the ability of flies to detect and respond to different odors using a simple vial-based setup, providing insights into sensory processing and chemotaxis behavior in the study population. Each treatment was replicated three times to account for experimental variation and strengthen the analysis. Ten flies from each treatment group were transferred to a testing vial. Two cotton plugs were prepared: one with yeast paste (attractive stimulus) and the other with citronella oil (repellent stimulus). Each plug was placed at the mouth of the vial in separate trials, and the time taken for flies to either approach (yeast) or avoid (citronella) the stimulus was recorded.

Statistical Analysis: Data were analyzed using Graph Pad Prism 5.01 software. One-way analysis of variance (ANOVA) was followed by Tukey's post-hoc test to determine statistical significance between the experimental groups ($p < 0.05$).

RESULTS:

Olfactory Response to Attractive and Repellent Stimuli: All four treatment combinations (flower-yeast, flower-citronella, leaf-yeast, and leaf-citronella) showed significant effects on olfactory responses. Statistical analysis revealed strong model fits across all conditions, with F-values ranging from 25.72 to 33.32 and R^2 values between 0.91 and 0.93 (all $p< 0.0001$).

Flower Extract Responses: When combined with yeast, flower extracts elicited significantly stronger responses than the diseased treatment group across all concentrations tested. The diseased insects showed consistently lower attraction values, with mean differences ranging from 76 to 81 units below the extract treatments. No significant differences were observed among the various extract concentration levels or between extracts and the control group. The flower-citronella combination produced a similar pattern. Diseased insects again showed significantly reduced responses compared

to all extract concentrations and controls, with mean differences between 22 and 40 units. However, unlike the yeast combination, the high concentration extract produced significantly stronger responses than the low concentration treatment, with a mean difference of 18.24 units.

Leaf Extract Responses: For the leaf-yeast combination, diseased insects exhibited substantially lower responses than all other treatments, with differences ranging from 71 to 80 units. The leaf-citronella pairing similarly showed diseased group values 25 to 40 units lower than extract treatments. In both leaf extract conditions, high concentrations proved more effective than low concentrations.

TABLE 1: POST-HOC COMPARISON OF FLOWER EXTRACTS TREATMENT EFFECTS ON YEAST AND CITRONELLA INHIBITION

Comparison of the Flower Extract	Flower-Yeast	Flower-Citronella
ANOVA (Tukey's Multiple Comparisons Tests)	p<0.0001	p<0.0001
F-Low vs F-Mid	ns	ns
F-Low vs F-High	ns	p<0.05*
F-Low vs Disease	p<0.001***	p<0.01**
F-Low vs Control	ns	ns
F-Mid vs F-High	ns	ns
F-Mid vs Disease	p<0.001***	p<0.001***
F-Mid vs Control	ns	ns
F-High vs Disease	p<0.001***	p<0.001***
F-High vs Control	ns	ns
Disease vs Control	p<0.001***	p<0.001***

One-way ANOVA followed by Tukey's multiple comparison tests. F = flower extract; LOW, MID, HIGH = extract concentrations. Significance levels: ns (p>0.05), * p<0.05, ** p<0.01, *** p<0.001

TABLE 2: POST-HOC COMPARISON OF LEAF EXTRACTS TREATMENT EFFECTS ON YEAST AND CITRONELLA INHIBITION

Comparison of the Leaf Extract	Leaf-Yeast	Leaf-Citronella
ANOVA (Tukey's Multiple Comparisons Tests)	F(4,10)=32.15, p<0.0001	F(4,10)=25.72, p<0.0001
L-Low vs L-Mid	ns	ns
L-Low vs L-High	ns	p<0.05*
L-Low vs Disease	p<0.001***	p<0.01**
L-Low vs Control	ns	ns
L-Mid vs L-High	ns	ns
L-Mid vs Disease	p<0.001***	p<0.001***
L-Mid vs Control	ns	ns
L-High vs Disease	p<0.001***	p<0.001***
L-High vs Control	ns	ns
Disease vs Control	p<0.001***	p<0.001***

One-way ANOVA followed by Tukey's multiple comparison tests. L = leaf extract; LOW, MID, HIGH = extract concentrations. Significance levels: ns (p>0.05), * p<0.05, ** p<0.01, *** p<0.001.

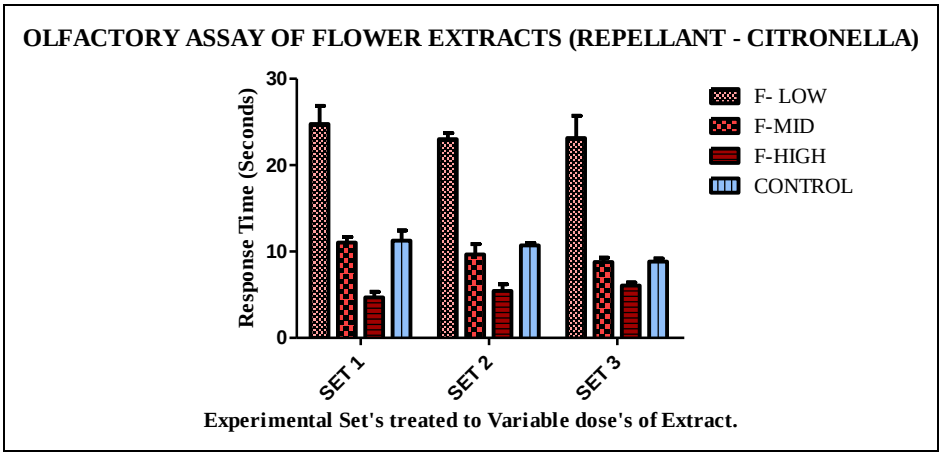

FIG. 1: OLFACTORY ASSAY OF FLOWER EXTRACT TREATMENTS WITH REPELLANT

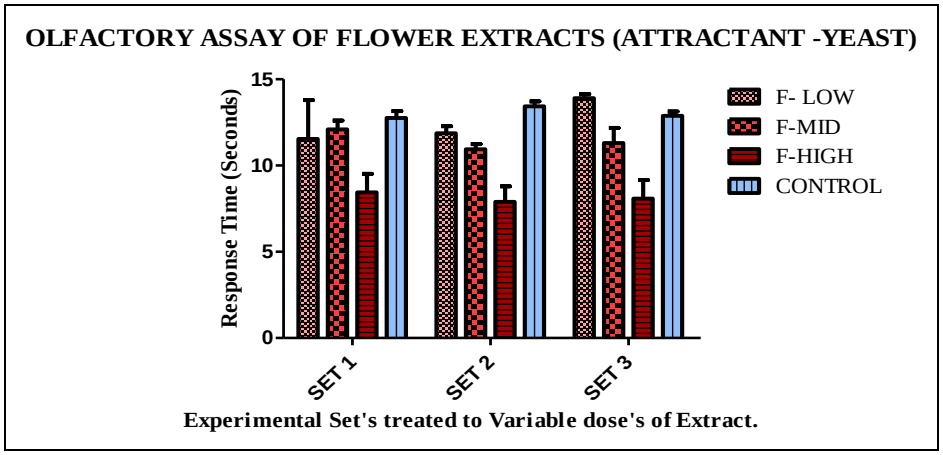

FIG. 2: OLFACTORY ASSAY OF FLOWER EXTRACT TREATMENTS WITH ATTRACTANT

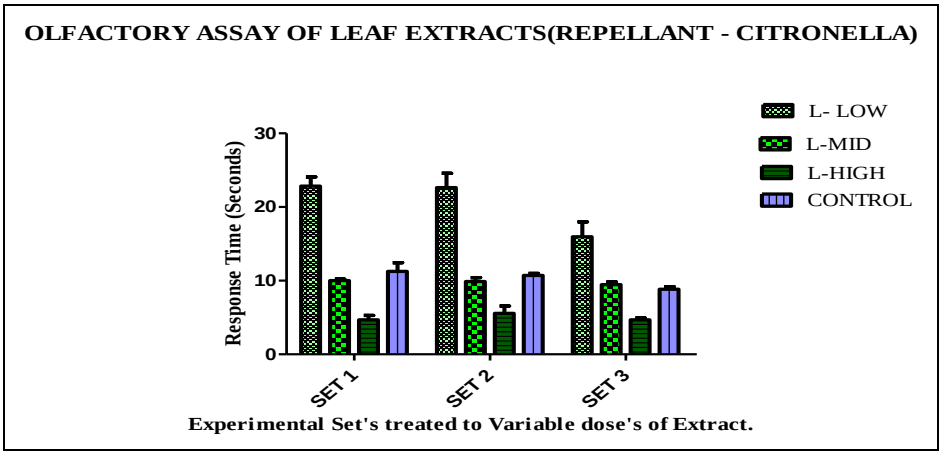

FIG. 3: OLFACTORY ASSAY OF LEAF EXTRACT TREATMENTS WITH REPELLANT

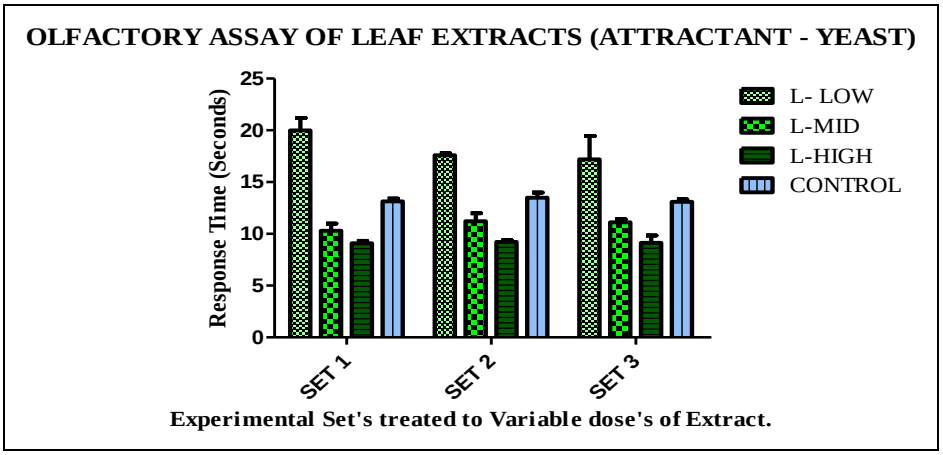

FIG. 4: OLFACTORY ASSAY OF LEAF EXTRACT TREATMENTS WITH ATTRACTANT

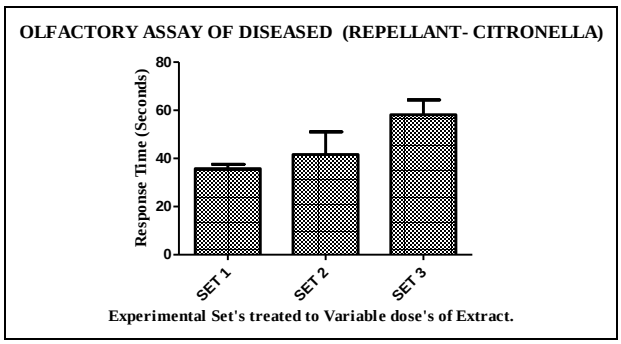

FIG. 5: OLFACTORY RESPONSE TO REPELLENT IN DISEASED FLIES

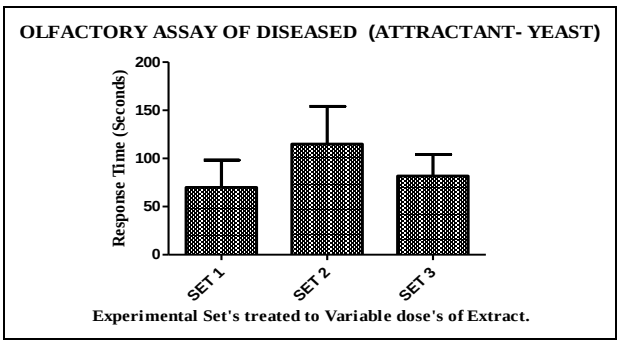

FIG. 6: OLFACTORY RESPONSE TO ATTRACTANT IN DISEASED FLIES

The **Fig. 1-6** Illustrate the response latency (in seconds) of Treated, Control and Diseased flies towards Attractant and Repellant Olfactory stimuli. Each treatment set consisted of 10 flies (n=30 per group), and results are expressed as mean ± SE.

DISCUSSION: This study demonstrates that *L. camara* extracts significantly improved olfactory perception in the para ^{bss1} *Drosophila* model of epilepsy, with flower extracts exhibiting superior efficacy compared to leaf extracts. The olfactory deficit in diseased flies was evidenced by markedly prolonged response times to both attractant and repellent stimuli compared to controls; with diseased flies requiring minutes rather than seconds to respond to odorants. Treatment with *L. camara* extracts substantially reduced response times across all concentrations tested, indicating effective amelioration of the epilepsy-associated olfactory dysfunction. The dose-dependent responses observed across low, mid, and high concentrations demonstrate that therapeutic efficacy was maintained even at lower extract concentrations. The observed enhancement in olfactory function was dose-dependent, suggesting a pharmacological basis for the effect rather than non-specific mechanisms. Olfactory dysfunction in epilepsy has been attributed to several mechanisms, including hyperexcitability in olfactory processing regions, aberrant oscillatory activity in olfactory networks, and structural changes in olfactory areas [2].

Our mixed-sex population design, while differing from traditional sex-separated approaches, provides translational advantages for evaluating therapeutic potential. X-linked epilepsy syndromes affect both hemizygous males, homozygous females (severely) and heterozygous female carriers (variably) in clinical populations. Demonstrating that plant extracts reduce seizure susceptibility and improve behavioral outcomes in mixed populations despite baseline phenotypic heterogeneity suggests robust therapeutic efficacy relevant to real-world patient populations. The consistency of dose-dependent responses across biological replicates with variable sex ratios further validates this population-level approach. The study aligns with current understanding of how insects process chemical information in their environment. Specialized taste and olfactory receptors in insects detect chemicals signaling food, mates, or dangers, with research on fruit flies revealing the chemoreceptor's function ecologically across different life stages [7]. The improved olfactory response in treated para $^{bss\ 1}$ flies suggests that *L. camara* compounds may help normalize the function of these specialized chemoreceptors, which are essential for insect survival. *Drosophila* exhibits robust chemo tactic behaviors in response to aromatic substances, which can elicit either attraction or aversion [32]. Larvae are attracted to odors associated with food sources, such as yeast paste and short-chain fatty acids like propionic acid. These attractive behaviors are mediated by specific olfactory receptors (ORs), such as Or30a and Or94b [12]. *Drosophila* spp. rely on yeasts for food, development, and reproduction [33], making yeast-sugar mixtures containing baker's yeast (*Saccharomyces cerevisiae*) attractive and reliable fermentation baits [34, 35].

Conversely, adults and larvae avoid aversive odors, such as allyl isothiocyanate (AITC), which are toxic to non-specialized insects. The receptor Or42a is necessary for detecting AITC and triggering aversive behavior [11]. Similarly, *Drosophila* flies detect and avoid citronellal, an insect repellent produced by plants, through olfactory receptors in the antenna. The TRPA1 (Transient Receptor Potential Ankyrin 1) channel is required for this avoidance behavior, and in *Anopheles gambiae* mosquitoes, the TRPA1 ortholog responds directly to citronellal [37].

The selection of yeast and citronella as specific olfactory stimuli in this study was based on their ecological relevance to *Drosophila*. The yeast stimulus represents a natural attractant critical for the fly's lifecycle, while citronella oil serves as an ecologically relevant repellent that activates specific sensory pathways. In fruit flies, hunger activates parallel neural circuits that enhance food odor detection, while specific sensory mechanisms control both attraction to preferred fruits and repulsion from natural deterrents like citronellal [31-36], thus making them ideal choices for assessing olfactory function. The 24-hour starvation period in the experiment makes the flies even more attracted or repelled towards the odorants used [31]. Our results further support observations that animal behavior provides valuable insights for understanding sensory processing mechanisms.

The neural pathways underlying chemotaxis involve the central complex and mushroom bodies in the *Drosophila* brain [36]. These regions process olfactory information and integrate it with other sensory inputs to guide behavior. The central complex is critical for spatial orientation and locomotor responses to odorants [38], while the mushroom bodies are involved in learning and memory, enabling flies to associate specific odors with food sources or threats [40]. The tracking and quantitative analysis of chemotaxis behaviors reveals underlying neural processes that must account for environmental noise, experimental limitations, internal motivational states, and cross-modal sensory interactions. The improvements we observed in treated flies likely reflect modulation of these complex sensory integration pathways.

The superior efficacy of flower extracts compared to leaf extracts can be attributed to their higher content of flavonoids and other bioactive compounds [41, 42]. However, the precise mechanisms by which these compounds improve olfactory function remain to be experimentally validated. We hypothesize that these phytochemicals may operate through multiple potential pathways: they could directly modulate ion channel function involved in olfactory signal transduction, or they might indirectly influence olfactory perception through anti-inflammatory and antioxidative mechanisms that protect olfactory neurons from oxidative damage associated with epileptic activity. Additionally, potential interactions between *L. camara* compounds and specific olfactory receptors, including TRPA1 channels and GABA receptors, represent promising avenues for future investigation. Structure-activity relationships between specific flavonoid structures and their neuromodulatory effects also warrant systematic exploration. Our findings align with previous studies demonstrating the neuromodulatory effects of plant-derived compounds on sensory functions in *Drosophila* [43, 44].

Similarly, studies by Ghisalberti [24] and Sousa & Costa [39] have documented the diverse bioactive properties of *L. camara* constituents. The restoration of olfactory function by *L. camara* extracts in our epileptic *Drosophila* model suggests potential therapeutic applications for addressing olfactory dysfunction in epilepsy patients.

These findings may contribute to the development of plant-based interventions for sensory deficits associated with neurological disorders. The limitations of this study include: First, while the para [bss1] *Drosophila* model shares mechanistic similarities with human epilepsy, extrapolation to clinical settings requires caution. Second, although we identified key phytochemicals in the extracts, the specific compounds responsible for the observed effects and their mechanisms of action remain to be elucidated. Future studies should focus on isolating and testing individual compounds from *L. camara* extracts, employing electrophysiological techniques to elucidate underlying mechanisms, investigating potential interactions between *L. camara* compounds and specific olfactory receptors and ion channels (including TRPA1 and GABA receptors), exploring structure-activity relationships of flavonoids and other bioactive constituents, and investigating the translational potential through preclinical mammalian models. These approaches would provide deeper insights into the underlying mechanisms and therapeutic potential of *L. camara* constituents for olfactory dysfunction in epilepsy and other neurological disorders.

CONCLUSION: *Lantana camara* extracts, particularly flower extracts at high dose, can significantly improve olfactory perception in the para [bss1] *Drosophila* model of epilepsy. The underlying mechanism seems to involve bioactive plant-derived chemicals, with flavonoids and additional phytochemical compounds serving as the primary active agents. Flavonoids, such as kaempferol and myricetin, have been shown to modulate neural pathways involved in chemotaxis. These compounds interact with GABA receptors and influence the activity of olfactory sensory neurons, potentially enhancing or protecting against chemotoxicity [41, 45, 46].

The artificial nature of laboratory settings, where flies don't face natural challenges like selecting food, choosing oviposition locations, or avoiding toxic compounds, might not provide an appropriate framework for studying the connection between attractant and repellent odor response variations and fitness outcomes. Additionally, the use of *Drosophila* as a translational model system provides a cost-effective platform for screening and

evaluating the efficacy of phytochemicals [47]. Flavonoids, with their diverse biological activities, offer promising avenues for understanding and addressing neurodegenerative diseases. Our findings contribute to the growing body of evidence suggesting that natural products may offer therapeutic benefits for sensory dysfunctions associated with neurological disorders. These results suggest potential therapeutic applications for addressing olfactory dysfunction in epilepsy and warrant further investigation in mammalian models and clinical settings.

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Author's Contribution: Both the Author's Contributed Equally.

CONFLICT OF INTEREST: The authors declare that there is no conflict of interest.

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