
Evaluation of the efficacy of botanical extracts and pesticides against *Podagrica decolorata* (Coleoptera: Chrysomelidae) found on okra *Abelmonchus esculentus*

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Abstract *Podagrica decolorata* (Coleoptera : Chrysomelidae) is a serious pest of okra *Abelmonchus esculentus*. It is responsible for a significant yield losses of okra. The efficacy of four ethanol plant extracts and pesticides on *Podagrica decolorata* adults were collected on okra cultivation in Man, Côte d'Ivoire. Repellency and toxicity effects of ethanolic extracts were compared to the pesticides by contact and ingestion. Pesticides and 50 g/l of each ethanolic plant extracts were tested on ten *Podagrica decolorata* adults, respectively. The ethanolic extracts of the plants (*Hyptis suaveolens*, *Carica papaya*, *Calotropis procera* and *Tithonia diversifolia*) and pesticides (BioElit® and K-OPTIMAL35EC®) exerted repellent effects and induced mortality on *Podagrica decolorata* adults by ingestion and by contact. The pesticides BioElit® and K-OPTIMAL35EC® were on repellency class III with a value of 48.33% and 55.00%, respectively. They are followed by *Carica papaya* and *Hyptis suaveolens*, which were on repellent class II, with a value of 35.00% and 38.33%, respectively. The ethanolic extracts of *Calotropis procera* and *Tithonia diversifolia* were on repellency class I with a value of 18.33% and 6.66%. *Hyptis suaveolens* leaves extract can be used as a pesticide against *Podagrica decolorata*. This botanic extracts are eco-friendly, the plant is locally available and it efficacy is similar to the pesticides used in the bioassay.

Keywords: BioElit®, Repellency effect, K-OPTIMAL 35EC®, *Podagrica decolorata*, Toxicity

Introduction

Podagrica decolorata Duvivier (Coleoptera : Chrysomelidae) is an important pest of okra, *Abelmonchus esculentus*. This insect pest consumes and make holes on okra fruits and leaves (Soro *et al.*, 2016). Then, okra plants are unable to make photosynthesize properly and, yield and fruits market value were decreased. This has adverse effects on food security (Birlouez, 2020).

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Indeed, okra represents around 1.5% of total vegetable production (Sathish *et al.*, 2013). In West of Africa, okra cultivation is second only to tomato cultivation (Birlouez, 2020). In Côte d'Ivoire, okra production is estimated at around 185,800 tonnes per year (Soro *et al.*, 2016). In the Tonkpi region, all parts of the okra plant except the roots are consumed. This crop supplements the population's nutritional needs, which consist exclusively of carbohydrates (Diabaté, 2016). The fruit contained calcium, iron, carbohydrates, proteins and vitamins (Khomsug *et al.*, 2010). In addition, okra is used in traditional medicine and in the industry (Marius *et al.*, 1997). This crop is widely consumed in Côte d'Ivoire, particularly in the Tonkpi region. Okra cultivation is therefore of vital importance to the population of the Tonkpi region, Man, Côte d'Ivoire. However, *P. decolorata* adults and the okra mosaic virus (OMV) transmitted by them to okra plants (Ugwoke and Onyishi, 2009 ; Asare-Bediako *et al.*, 2014) were difficult to control with the pesticides commonly used by farmers. This has led to an increase in the use of both registered and unregistered pesticides and the pesticide doses and pesticides sprayed times were not well done. Consequently, harmful substances were accumulated in food, in the environment, in humans and in non-target organisms. The overuse of these pesticides leads to the emergence of resistance of insects, particularly *P. decolorata*. Several studies showed that insects become tolerant to some insecticides such as organophosphates, carbamates, pyrethroids, benzoates and spinosad (Diabaté, 2016; Bade and Bhamare, 2023) and to toxins derived from *Bacillus thuringiensis* (Zhang *et al.*, 2011). This resistance to insecticides was thought to be linked to the insecticide's inability to bind to acetylcholinesterase and render it inactive (Srinivas *et al.*, 2004). Botanic extracts are eco-friendly, easily decomposed, avoid pesticide resistance in insects and their efficacy are comparable to the pesticides (Nath *et al.*, 2020; Yah *et al.*, 2022; Arsensi *et al.*, 2025). Thus, the objective was to evaluate the efficacy of ethanolic extracts of four local plant extracts on *P. decolorata* harvested on the okra crop established in Man locality, Côte d'Ivoire. The aim of this research was to determine the toxic, antiappetant and repellency effects of plant ethanolic extracts compared to two pesticides used by the farmers against *P. decolorata* in the laboratory conditions.

Materials and methods

Study site

Okra grains, variety Clemson spineless, were sown on 2nd March, 2024 on beds established in the entomological farm of Man University, located in the Tonkpi region, west of Côte d'Ivoire (7°21'09"N and 7°36'57"W). Three okra

seeds were sown per cluster with a distance of 60 cm between rows and 60 cm between plants in a quarter hectare. After germination, weeding was carried out to obtain two plants per cluster. The climate of this region is characterized by two seasons, dry and rainy seasons. The average annual temperature was 25.0°C. The average annual rainfall was 1,632 mm, with relative humidity of 82% (Tiessé, 2020).

Preparation of the various treatments

Preparation of ethanolic extracts from plant leaf powders

Ethanolic extracts were prepared from leaf powders of four plant species [*Carica papaya* (Caricaceae); *Calotropis procera* (Asclepiadaceae); *Tithonia diversifolia* (Asteraceae) and *Hyptis suaveolens* (Lamiaceae)] harvested, during the month of February 2024, between 7 and 8 a.m. around Man University, Côte d'Ivoire. These plants were locally available and were used in traditional medicine.

Grindings of identified harvested leaves were dried in the shade for 1 week, were sieved, then weighed and mixed in a 10% ethanol solution (1g for 20 mL of ethanol). The mixtures were stirred on a magnetic stirrer for 6 hours. Then, the mixtures were filtered through cloth and filter paper. The filtrates obtained were poured into jars and stored in the refrigerator (Gnago *et al.*, 2010).

Pesticides preparation

Pesticides were purchased from the market and prepared at the manufacturer's recommended dosage. In fact, 0.5 mL of K-OPTIMAL 35EC® was mixed in 400 mL of water, and for BioElit®, 1mL was mixed in 230 mL of water.

Sampling and identification of *P. decolorata* adults (Figure 1) were captured and identified using a binocular loupe, literature and dichotomous keys (Roth, 1974).

Evaluation of the efficacy of the different treatments

Based on the preliminary test by contact and by ingestion with 20, 30, 50 and 80 g of plant ethanol extracts with 20 adults of *P. decolorata*, the 50 g/L and 80 g/L concentrations proved to be the most effective. To maintain biodiversity, the bioassays were conducted with 50 g/L of ethanolic extracts of plants powders (i.e. 50 g of powder in one liter of 10% ethanol). The doses recommended by the manufacturer were used for the pesticides.



Figure 1. Attack of *P. decolorata* Adult on okra leaf

Repellency test of plant ethanol extracts and pesticides

The repellency effect of ethanolic plant extracts was evaluated using the preferential zone method on whatman paper (Donald *et al.*, 1970). Half a 9 cm diameter Whatman paper was treated with 1 ml of ethanolic extract and the other half with 1 ml of distilled water. These treated half-discs were dried for 15 minutes, taped and placed in Petri dishes. A batch of ten *P. decolorata* adults was placed in the center of the petri dish. The number of insects present on each part was counted every two hours for 8 hours. The percentage of repulsion (PR) for each treatment was then calculated using the following formula :

$$PR (\%) = \frac{(Nc - Nt) * 100}{Nc + Nt} \quad (1)$$

PR= percentage of repulsion ; Nc= number of insects present on the area treated with distilled water ; Nt= number of insects present on the area treated with insecticides or biopesticides.

Toxicity effect of plant ethanol extracts and pesticides

Toxicity tests were performed to evaluate the toxicity of ethanolic extracts of *Hyptis suaveolens*, *Carica papaya*, *Calotropis procera*, *Tithonia diversifolia* and the two pesticides on *P. decolorata* adults by contact and ingestion.

Contact toxicity test

Batches of ten *P. decolorata* adults were impregnated with 100 µl each of the different treatments for 2 minutes. The treated insects were then dried on

Whatman paper and placed in Petri dishes containing a 5 cm diameter disc of untreated okra leaf. Observations were made every 24 hours for 72 hours (Diabaté *et al.*, 2020).

Ingestion toxicity test

Insects were fasted for 8 hours. The bioassays were performed using the leaf dip method (Shi *et al.*, 2004 ; Diabaté *et al.*, 2014). Ten *P. decolorata* adults were placed in a Petri dish containing 9 cm okra leaf discs, which were previously immersed for 1 minute in a solution of plant extracts or pesticides and then dried at room temperature for 10 minutes, respectively. The number of dead *P. decolorata* adults was recorded every 24 h for 72 h. The contact and ingestion, corrected mortality (MC) was calculated using the following formula:

$$MC (\%) = \frac{(M0 - Me)}{100 - Me} * 100 \quad (2)$$

With :

- MC= corrected mortality
- M0= average mortality per treatment
- Me= average mortality in the control (distilled water)

Data analysis

Data from the different treatments were processed using two types of software : SPSS Statistic version 2.0 and XLSTAT 2016. The mortality rate of *P. decolorata* and the percentage of repulsion for the different treatments were subjected to an analysis of variance (ANOVA main effect) at the 5% threshold using SPSS software. The means obtained were discriminated using XLSTAT 2016 software, Fisher's LSD test.

Results

Repellency effect of plant ethanolic extracts and pesticides

At 2 hours, the ethanolic extract of *T. diversifolia* had no repellent effect on *P. decolorata* adults. However, ethanolic extracts of *H. suaveolens* and *C. procera* were in repellency class I, with values of 20% and 6.66%, respectively. The ethanolic extract of *C. papaya* was in repellency class II (33.33%) and the pesticides BioElit ® and K-OPTIMAL 35EC ® were in repellency class III repellents, with values of 46.66% and 60%, respectively (F=21.00 ; p< 0.0001). After 4 hours of the bioassay, the ethanolic extract of *T. diversifolia* still had no repellent effect on *P. decolorata* adults. Ethanolic extracts of *C. papaya* and *C.*

procera were in repellency class I after 4 hours, with values of 20% and 13.33%, respectively. The ethanolic extract of *H. suaveolens* was in repellency class II (33.33%) and the pesticides BioElit® and K-OPTIMAL 35EC® were in repellency class II with values of 46.66% and 53.33%, respectively ($F = 8.028$; $p = 0.001$). At 6 hours of the bioassay, all treatments caused a repellent effect on *P. decolorata* adults. Ethanolic extracts of *C. procera* and of *T. diversifolia* were in repellency class I, with values of 13.33% and 20%, respectively while the ethanolic extracts of *C. papaya* and *H. suaveolens* were in repellency class II, with repellency percentages of 33.33% and 40%, respectively. The pesticides BioElit® and K-OPTIMAL 35EC® have higher repellency effect (repellency class III) on *P. decolorata*, with the values of 60% and 53.33, respectively ($F = 7.500$; $p = 0.002$). After 8 hours, only the ethanolic extract of *T. diversifolia* was in repellency class I (13.33%). Ethanolic extracts of *C. procera* (40%) and the pesticide BioElit® (40%) were in repellency class II. Ethanolic extracts of *C. papaya* (53.33%) and *H. suaveolens* (60.00%), and the pesticide K-OPTIMAL 35EC® (53.33%) were on repellency class III ($F = 4.20$; $p = 0.019$) (Figure 2).

At the end of the bioassay, the highest repellency effect was obtained with the pesticides BioElit® and K-OPTIMAL 35EC®. They were in repellency class III, with the values of 48.33% and 55.00%, respectively. They were followed by *C. papaya* and *H. suaveolens*, which were in repellency class II, with repellency percentages of 35.00% and 38.33%, respectively. The lowest repellent effects were induced by the ethanolic extracts of *C. procera* and *T. diversifolia* on *P. decolorata* adults. These botanical extracts were in repellency class I with values of 18.33% and 6.66%, respectively ($F = 55.092$; $p < 0.0001$) (Table 1).

Table 1. Repellency effects of pesticides and plants ethanolic extracts

Treatment	PR (%)	Class
<i>Hyptis suaveolens</i>	38,33±2,88 ^b	II
<i>Calotropis procera</i>	18,33±2,88 ^c	I
<i>Carica papaya</i>	35,0±5,0 ^b	II
<i>Tithonia diversifolia</i>	6,66±5,77 ^d	I
BioElit®	48,33±2,88 ^a	III
K-OPTIMAL 35EC®	55,0±5,0 ^a	III
F	55.092	-
p	< 0,0001	-

Means assigned to the same letter within the same column are not significantly different (Fisher LSD test, $p < 5\%$).

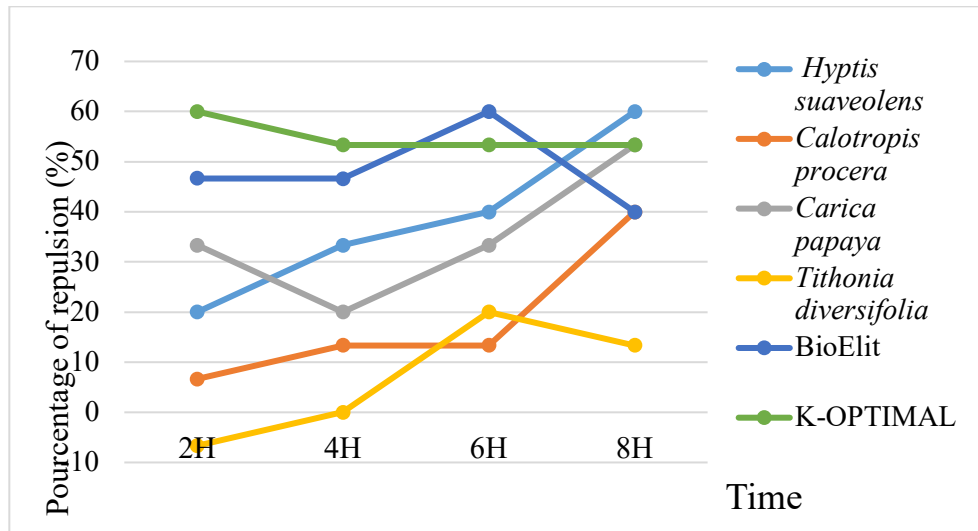


Figure 2. Percentage of repulsion induced by the different treatments on *Podagrica decolorata* adults

Contact efficacy of ethanolic extracts and pesticides

The ethanolic extracts from the leaves of local plants (*H. Suaveolens*, *C. procera*, *T. diversifolia* and *C. papaya*) induced mortality of *P. decolorata* by contact. The mortality rates ranged from 23.33% to 80.00% for the botanical extracts and were between 66.66% and 100% for the pesticides BioElit® and K-OPTIMAL 35EC®. After 24 hours of bioassay, the mortality rates caused by the different treatments in *P. decolorata* adults ranged from 23.33% to 100%. The highest mortality of *P. decolorata* were obtained by the two pesticides BioElit® and K-OPTIMAL 35EC® with a values of 66.66% and 100%, respectively. While, After 24 hours of bioassay, the percentage of *P. decolorata* adults mortality induced by the ethanolic extracts were lower than 50%. Ethanolic extracts of *C. procera* and *H. suaveolens* have similarly effective, with mortality rates of 43.33% and 36.66%, respectively. The lowest mortalities were recorded with the ethanolic extracts of *C. papaya* and *T. diversifolia* with a same value of 23.33% ($F=95.360$; $p < 0.0001$). After 48 hours, the pesticides BioElit® and K-OPTIMAL 35EC® showed similar efficacy, with mortality rates of 86.66% and 100%, respectively. Ethanolic extracts of *C. procera*, *H. Suaveolens* and *C. papaya* showed similar efficacy, with mortality rates of 60%, 63.33% and 50%, respectively. These ethanolic extracts were more effective than that of *T. diversifolia*, which induced a mortality rate of 43.33% ($F=42.967$; $p < 0.0001$). After 72 hours of bioassay, mortality rates of *P. decolorata* adults varied between 50% and 100% for the different treatments.

The lowest mortality rates were obtained with the ethanolic extracts of *T. diversifolia* and *C. papaya*, at 50% and 56.66%, respectively. The pesticides BioElit® and K-OPTIMAL 35EC® were more effective on *P. decolorata* adults with mortality rates of 96.66% and 100%, respectively. Ethanolic extracts of *C. procera* and *H. Suaveolens* were moderately effective compared with pesticides, but more effective than ethanolic extracts of *T. diversifolia* and *C. papaya*. Their mortality rates after 72 hours were 66.66% and 80%, respectively (F=25.800; p< 0.0001) (Table 2).

Table 2. Contact mortality rate of *Podagrica decolorata* adults

Traitment	Corrected mortality 24 h	Corrected mortality 48h	Corrected mortality 72h
<i>Hyptis suaveolens</i>	36,66±5,77 ^{cd}	63,33±11,54 ^b	80,00±10,0 ^{bc}
<i>Calotropis procera</i>	43,33±5,77 ^c	60,00±0,00 ^b	66,66±5,77 ^{cd}
<i>Carica papaya</i>	23,33±5,77 ^d	50,00±0,00 ^{bc}	56,66±5,77 ^d
<i>Tithonia diversifolia</i>	23,33±5,77 ^d	43,33±5,77 ^c	50,00±10,0 ^d
BioElit®	66,66±5,77 ^b	86,66±5,77 ^a	96,66±5,77 ^{ab}
K-OPTIMAL 35EC®	100±0,00 ^a	100±0,00 ^a	100±0,00 ^a
F	95.360	42.967	25.800
P	< 0,0001	< 0,0001	< 0,0001

Means assigned to the same letter within the same column are not significantly different (Fisher LSD test, p < 5%).

Efficacy of ethanolic extracts by ingestion

The botanical extracts and the pesticides BioElit® and K-OPTIMAL 35EC® induced mortality of *P. decolorata* by ingestion of treated okra leaf discs. After 24 hours, the mortality rates of *P. decolorata* adults after consumption of okra discs impregnated with ethanolic extracts of *H. suaveolens*, *C. procera*, *C. papaya*, *T. diversifolia*, and the pesticides BioElit® and K-OPTIMAL 35EC® were 46.66; 26.66; 26.66; 33.33; 66.66 and 100%, respectively. The pesticides K-OPTIMAL 35EC® and BioElit® were the most effective and were followed by the ethanolic extracts of *H. suaveolens* and *T. diversifolia*. The highest mortality at 24 h of *P. decolorata* by the ethanolic extracts were induced by *H. suaveolens* (46.66%) and *T. diversifolia* (33.33%) and the lowest mortality was recorded in the bioassay by *C. procera* (26.66%) and *C. papaya* (26.66%). However, *P. decolorata* mortality induced by the ethanolic extracts of *H. suaveolens*, *C. procera*, *C. papaya* and *T. diversifolia* were lower than 50% after 24 hours of bioassay (F = 89.76 ; p< 0.0001). After 48 hours, mortality rates were higher than 50% for all treatments. The pesticides BioElit® and K-OPTIMAL 35EC® were most effective on *P.*

decolorata adults at 48 hours, with mortality rates of 96.66% and 100%, respectively. The ethanolic extract of *H. suaveolens* (76.66%) was more effective than the other ethanolic extracts of *C. procera* (53.33%), *T. diversifolia* (53.33%) and *C. papaya* (53.33%), which were similarly effective ($F = 53.120$; $p < 0.0001$). After 72 hours of bioassay, the pesticides BioElit® (100%) and K-OPTIMAL 35EC® (100%), and the ethanolic extract of *H. suaveolens* (80.00%) induced similar mortality rates. They were followed by *C. procera* (66.66%), which was moderately effective against *P. decolorata* adults. Ethanolic extracts of *T. diversifolia* (50.00%) and *C. papaya* (56.66%) induced the lowest ingestion mortality rates after 72 hours ($F=21.54$; $p < 0.0001$) (Table 3).

Table 3. Mortality rate of *Podagrica decolorata* adults by ingestion

Treatment	Corrected mortality 24 h	Corrected mortality 48h	Corrected mortality 72h
<i>Hyptis suaveolens</i>	46,66 ± 5,77 ^c	76,66 ± 5,77 ^b	86,66 ± 5,77 ^{ab}
<i>Calotropis procera</i>	26,66 ± 5,77 ^d	53,33 ± 5,77 ^c	66,66 ± 15,27 ^{bc}
<i>Carica papaya</i>	26,66 ± 5,77 ^d	53,33 ± 5,77 ^c	63,33 ± 5,77 ^c
<i>Tithonia diversifolia</i>	33,33 ± 5,77 ^{cd}	53,33 ± 5,77 ^c	53,33 ± 5,77 ^c
BioElit®	66,66 ± 5,77 ^b	96,66 ± 5,77 ^a	100,00 ± 0,00 ^a
K-OPTIMAL 35EC®	100,0 ± 0,00 ^a	100,0 ± 0,00 ^a	100,00 ± 0,00 ^a
F	89.760	53.120	21.540
p	< 0,0001	< 0,0001	< 0,0001

Means assigned to the same letter within the same column are not significantly different (Fisher LSD test, $p < 5\%$).

Discussion

Insecticidal effect of ethanolic extracts on Podagrica decolorata adults

Ethanolic extracts of *H. suaveolens*, *C. papaya*, *C. procera* and *T. diversifolia* leaves, and the pesticides K-OPTIMAL 35EC® and BioElit® showed insecticidal activity against *P. decolorata* adults by contact and ingestion. These treatments caused significant mortality of *P. decolorata* adults. *P. decolorata* mortality by the ethanolic extracts of *H. suaveolens*, *C. papaya*, *C. procera* and *T. diversifolia* by contact and ingestion was related to the presence of secondary metabolites in their ethanolic extracts, especially alkaloids, terpenoids and phenolic compounds (Diabaté *et al.*, 2020; Diabate *et al.*, 2022; Teh *et al.*, 2022; Tchumkam *et al.*, 2023; Arsensi *et al.*, 2025). These secondary metabolites exert insecticidal effects on *P. decolorata* adults, leading to their death by contact and ingestion. According to Gnago *et al.* (2010), Diby *et al.* (2015), Diabate *et al.* (2022), Tchumkam *et al.* (2023), Able *et al.* (2025) and Kato-Noguchi and Kato (2025), the secondary metabolites of the leave

extracts of *H. suaveolens*, *C. papaya*, *C. procera* and *T. diversifolia* are toxic to herbivorous insects, especially *P. decolorata*. The lowest efficacy of some extracts could be explained by the lowest concentration of secondary metabolites in the extracts. In addition, Boeke *et al.* (2004) has shown that terpenoids, phenolic compounds and flavonoids affect the life or development cycle of insects. However, their efficacy was lower than those of the pesticides BioElit® and K-OPTIMAL by contact and ingestion. According to Tounou *et al.* (2012), chemical pesticides have a higher insecticidal effects than botanical extracts. The efficacy of the pesticides K-OPTIMAL 35EC® and BioElit® compared with ethanolic plant extracts on *P. decolorata* adults is related to their insecticidal and neurotoxic activity, resulting in the death of insects, especially *P. decolorata* (Tounou *et al.*, 2012 ; Diabaté *et al.*, 2014 ; Yah *et al.*, 2022). Indeed, pyrethroids cause prolonged membrane depolarization, leading to repetitive nerve activation by binding to sodium channels and keeping the channel open, resulting in insect death (Riba and Silvy, 1993).

Repellent effects of ethanolic extracts on Podagrica decolorata adults

This study showed that ethanolic extracts of *H. suaveolens*, *C. papaya*, *C. procera* and *T. diversifolia* leaves and the pesticides K-OPTIMAL 35EC® and BioElit® exerted repellent activity on *P. decolorata* adults. The ethanolic extracts of *C. papaya* and *H. suaveolens* had a similar repellency effect to that of the pesticides K-OPTIMAL 35EC® and BioElit® after 8 hours. The repellent activity of the plant ethanolic extracts is linked to the presence of secondary metabolites such as alkaloids, terpenoids and phenolic compounds. Casida (1990) and Tchumkam *et al.* (2023) have shown that the repellent effects of plants may depend on their chemical composition and the insect's sensitivity level. Furthermore, Nerio *et al.* (2010) have shown that the repellent activities of essential oils against insects are generally linked to the presence of monoterpenes and sesquiterpenes. In some cases, these compounds can act synergistically to enhance their efficacy. The effects induced by these botanical extracts are due to the bioactive compounds that act on the insects, causing their death or inducing antifeedant effects. According to Trematerra and Sciarretta (2002) and Nath *et al.* (2020), alkaloids, terpenoids and phenolic compounds caused repellent effects, insect death by acting on insect chemoreceptors and food intake.

Conflicts of interest

The authors declare no conflict of interest.

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