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EFFICIENCY OF HANDMADE ATTRACTANTS IN FRUIT FLY CONTROL

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ABSTRACT

Fruit flies (Diptera: Tephritidae) are considered the main pests of fruit crops worldwide, and using traps and attractants are useful tools for their effective monitoring and control. The study's main objective was to evaluate the capacity to capture fruit flies with non-commercially produced attractants and to use the Lin and Binns method to evaluate their performance. Five commercial food attractants were evaluated to capture the genera *Anastrepha* and *Ceratitis*. The study was carried out in five municipalities of Táchira State, Venezuela, during two semesters, using a completely randomized design with four replications. The experimental unit was represented by a JD EuGo 97 trap, baited with 300 mL of the respective attractant solution. The attractants did not perform equally in all environments, while no variation was observed in the level of trap capture between the two semesters studied. *Anastrepha fraterculus* was the only species collected at all altitudinal levels, suggesting an adequate capacity to adapt to different environments. The commercial product PedGo plus was the most effective attractant for fly trapping, and it may be an appropriate alternative for use by fruit growers in the control of this pest. Although it was the most efficient attractant in most of the environments studied, molasses + urea proved to be an alternative to replace PedGo plus and Nulure.
Additional Keywords: *Anastrepha*, artisanal baits, *Ceratitis capitata*, Lin and Binns index, traps

RESUMEN

Eficiencia de atrayentes artesanales en el control de moscas de las frutas

Las moscas de la fruta (Diptera: Tephritidae) son consideradas las principales plagas de los cultivos frutícolas a nivel mundial, siendo el uso de trampas y atrayentes herramientas de gran utilidad para su efectivo monitoreo y control. El objetivo principal del estudio fue evaluar la capacidad de captura de moscas de las frutas con atrayentes de producción nacional y el uso del método de Lin y Binns para evaluar su comportamiento. Se evaluaron cinco atrayentes alimenticios comerciales para la captura de los géneros *Anastrepha* y *Ceratitis*. El estudio se llevó a cabo en cinco municipios del estado Táchira, Venezuela, durante dos semestres, utilizando un diseño completamente al azar con cuatro repeticiones. La unidad experimental estuvo representada por una trampa JD EuGo 97, cebada con 300 mL de solución del atrayente respectivo. El desempeño de los atrayentes no funcionó igual en todos los ambientes, mientras que no se observó variación en el nivel de captura de las trampas entre los dos semestres estudiados. *Anastrepha fraterculus* fue la única especie colectada en todos los pisos altitudinales, sugiriendo una adecuada capacidad para adaptarse a diferentes ambientes. El producto comercial PedGo plus fue el atrayente más efectivo para la captura de moscas, por lo que puede ser una alternativa apropiada para uso por los productores frutícolas en el control de esta plaga. Aunque este producto resultó ser el atrayente más eficiente en la mayoría de los ambientes estudiados, el atrayente construido a base de melaza + urea demostró ser una alternativa para reemplazar a PedGo plus y Nulure.
Palabras clave adicionales: *Anastrepha, Ceratitis capitata*, cebos artesanales, índice de Lin y Binns, trampas

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INTRODUCTION

The genus *Anastrepha* Schiner (Diptera: Tephritidae) and the Mediterranean fruit fly *Ceratitis capitata* Wiedemann (Diptera: Tephritidae) are recognized worldwide as the main pests affecting fruit production (Sarmento et

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al., 2017; Oliveira et al., 2019). These species represent a significant threat due to the considerable economic losses they cause by the direct damage they inflict on fruits. In addition, their presence constitutes a hindrance to the commercialization of fruit products destined for export. Both the Resolutions of the Ministry for Productive Agriculture and Lands of Venezuela (MPAL, 2017) and the Plant Health Committee of the Southern Cone (COSAVE, 2021) classify them as pests of quarantine importance.

The use of attractants and traps is an essential tool for effective pest monitoring in fruit crops, allowing early detection and timely implementation of control measures (Morales et al., 2016; Vázquez et al., 2022). Among the attractant systems developed for this purpose, Biolure stands out, which is widely used in Mediterranean fruit fly (*C. capitata*) control programs. Biolure combines three synthetic foodstuffs: ammonium acetate, putrescine, and trimethylamine, and has been adopted worldwide as an effective strategy in the control of this pest (FAO, 2005; Bali et al., 2021; Kouloussis et al, 2022). According to Dukas (2020), Pinto et al. (2022), and Francis et al. (2023), it has been observed that the use of fly trapping systems specifically designed to attract females allows early detection of fly populations, which in turn improves control and erradication measures. In areas where sterile male flies are released, baited traps containing an attractant that is particularly attractive to wild females are used to detect their presence. Likewise, with the attractant known as Trimedlure, used to entice and monitor populations of released sterile male flies, fewer baited traps are used than those used with synthetic attractants. This strategy makes it possible to distinguish and monitor more efficiently the populations of wild females and the sterile male flies used in the traps.

Various synthetic artificial traps and bait stations have been used for monitoring and control of fruit fly populations, such as McPhail traps, hydrolyzed Torula yeast, Bio Anastrepha and other biological attractants, with effective results (OIEA, 2019; Mirez, 2020; Lopes et al., 2023). These alternatives demonstrated their efficacy in monitoring and controlling Mediterranean fruit fly populations. Several alternatives for fruit fly monitoring and control have been implemented in different regions of the world. Some examples include the use of traps such as Tephri Trap, along with other traps used in mass trapping, such as Fly Trap, Cera Trap, and Moskisan in Tunisia, Africa (Boulahia et al., 2015).

In Asia, the use of bait traps with methyl eugenol to control the fruit fly *Bactrocera zonata* in mango crops was reported (Bagheri, 2017), and the use of traps with methyl eugenol and cue-lure for trapping *B. zonata* in mango (Ullah et al., 2015). In Europe (Greece), McPhail-type traps with Biodelear, which consists of a mixture of attractant compounds such as pyrazines, pyranones, and amorphous nitrogen-based polymers, have been employed (Kouloussis et al., 2022). In South America, Jackson-type traps with Trimedlure and McPhail-type traps with hydrolyzed protein have been used for monitoring fruit fly population fluctuation (Conde et al., 2018) and baits for *Anastrepha fraterculus* (Wiedemann) with hydrolyzed protein from agro-industrial by-products pretreated with gamma radiation (Sinche et al. 2023) and CeraTrap (Cristóbal 2021). These diverse strategies demonstrate the adaptability and importance of finding specific solutions for fruit fly control in different geographical contexts.

However, using mixed attractants and food traps in fruit fly control can present challenges. Several authors have reported that these alternatives can be costly and require the importation of specific products (Montoya, et al., 2020; López et al., 2021; Sinche et al., 2023). This hinders homogeneity in the construction of homemade bait stations and the use of different food attractants. As a result, farmers with limited resources often choose not to carry out monitoring and control activities, which negatively affects the phytosanitary requirements necessary for fruit movement and marketing (Valenzuela, 2021; Lopes et al., 2023). Given this situation, the evaluation of other natural substances of animal and plant origin that may have potential as attractants for fruit flies has been considered (Piñero et al., 2003; Rodríguez et al., 2015; Kouloussis, 2022). The objective is to find more accessible and economical alternatives that allow farmers to effectively carry out pest monitoring and control activities.

It is of utmost importance to have an effective and reliable methodology to evaluate the efficacy of the traps used to capture adults of different fruit fly species. This ensures adequate monitoring of pest populations in fruit plantations. In experiments conducted for this purpose, analysis of variance and mean separation tests have been employed to determine the effectiveness of traps and baits (Arcila et al., 2022; Francis et al., 2023). While these statistical tools are useful for analyzing results in these types of studies, they need to provide a clear visual representation of the efficiency of one trap compared to another. Therefore, this study proposes the use of the Lin and Binns (1988) index as a tool to evaluate the efficiency of traps in trapping different fruit fly species. Although originally designed to evaluate the superiority of different cultivars in different environments, it has been adapted in this study to evaluate the superiority of different traps used in trapping fruit flies in different areas of Táchira State, Venezuela, where these insects represent pests of economic importance in fruit crops, due to the damage they cause in fruits, which affects their economic value. In addition, there is a phytosanitary concern due to the geographical proximity to the Republic of Colombia (Clavijo et al., 2018; Santos et al., 2020; Machado et al. 2021). Consequently, it is necessary to employ traps and attractants that allow timely and effective detection of native and invasive species of fruit flies from the neighboring country. The method proposed by Lin and Binns (1988) was originally used to determine the superiority of a genotype in different environments (González et al., 2019). However, it is possible to apply it to evaluate the superiority of a trap compared to other traps used, including a reference trap. By applying this approach, the overall superiority of a trap evaluated in different environments can be defined as the mean square of the distance between the number of flies caught by the trap and the maximum catch averaged over all environments. This parameter, which behaves as a measure of variance, allows us to evaluate the response of a trap concerning the best trap in each environment. Considering that the maximum catch represents the upper limit in each locality, a trap with a small mean square would indicate its overall superiority. In addition, it is possible to plot the generated indices to facilitate the visualization of the best-performing traps.

In Venezuela, most of the food attractants used in fruit fly trapping are imported, which entails high costs for monitoring and hinders the rapid and timely acquisition of the necessary products. In this context, the main objective of this study was to evaluate the capacity to capture fruit flies using national products, to recommend their use in the monitoring and control of these insect pests by fruit producers, and to use the Lin and Binns method to efficiently evaluate the superiority of the attractants used in comparison with the attractant Nulure, which has been widely recognized for its effectiveness in capturing *C. capitata* females in Central America (Vázquez, 2000; Borrero et al., 2019).

MATERIALS AND METHODS

Evaluation environments, traps, and fly collection. The study was carried out in six environments located in five municipalities of Táchira State, for 11 months (Table 1). JD Eugo 97 traps were manufactured using 2 L plastic soft drink containers, with the measurements indicated in Figure 1. The traps were distributed evenly in the experimental area, placing them on the plants at a height of 2 m, with the treatments and their respective repetitions distributed randomly. The collection of the contents of each trap was taken out every 15 days, followed by the reloading of baits in each trap. In each evaluation, the suspension was poured onto a sieve and the captured insects were rinsed with running water and then transferred to a glass jar with 75 % alcohol. The flies captured in each trap were transferred to the laboratory of the Instituto de Salud Agrícola Integral (INSAI) of Táchira State, where they were counted, sexed, identified using taxonomic keys, and preserved.

Experimental design and statistical analysis. A completely randomized experimental design with four replicates and five treatments (attractants, including natural and commercial products) was used: T1 = molasses + urea, T2 = molasses, T3 = PedGo, T4 = PedGo Plus and T5 = Nulure (control). JD EuGo 97 handmade plastic traps were used, each of which was baited with 300 mL of the corresponding attractant solution. In this way, a total of 20 traps were settled down for each location.

For statistical analysis, data were grouped by season (dry and rainy season) and an arrangement of treatments in subdivided plots was used. The main plot corresponded to the locality, the subplot represented the semesters (to detect seasonal differences in the populations) and the sub-subplot was assigned to the treatments.

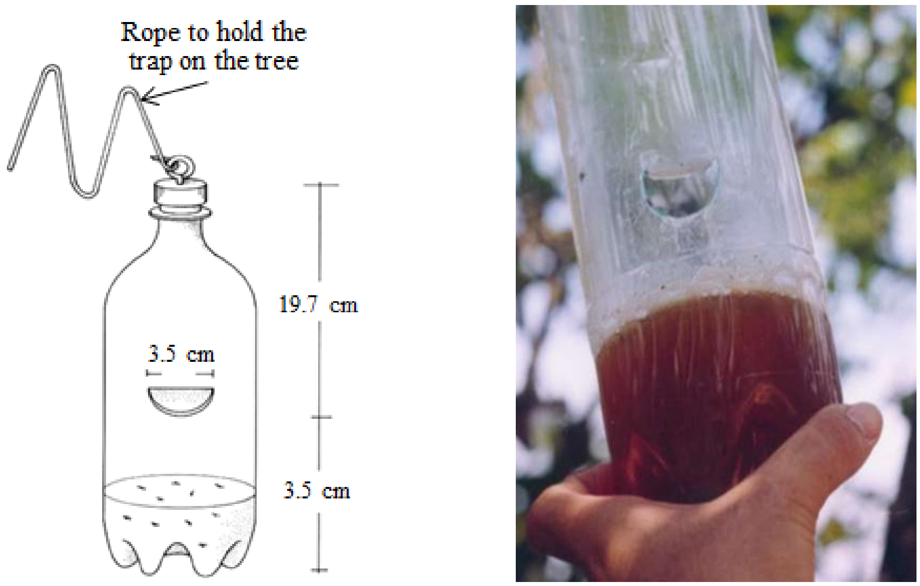

Figure 1. JD Eugo 97 traps manufactured using 2 L plastic soft drink containers.

The mathematical model used for the analysis, according to Steel and Torrie (1988), was as follows:

$$Y_{ijk} = \mu + Loc_i + S_j + S/Loc_{ij} + A_k + LocxA_{ik} + SxA_{jk} + \epsilon_{ijk}$$

Where: Y_{ijk}, represents the catch made in the *i-th* location, in the *j-th* semester of the year by the *k-th* trap; μ is the overall mean; Loc_i represents the random effect of the *i-th* location; S_j represents the random effect of the *j-th* semester of the evaluation period.; S/Loc_{ij} represents the random effect of semesters within locations, error “a”; A_k represents the fixed effect of the *k-th* trap; $LocxA_{ik}$, represents the interaction effect between the *i-th* locality by the *k-th* trap; SxA_{jk} represents the interaction effect between the *j-th* semester by the *k-th* trap and ϵ_{ijk} is the effect of the error associated with the observation Y_{ijk}, or error “b”.

Simple interaction effects $LocxS_{ij}$ and triple interaction $LocxSxA_{ijk}$ were found to be non-significant and therefore included in the error effect "b".

Before performing the analysis of variance (ANOVA), all basic assumptions were checked. To perform the analysis and determine the interactions between the factors analyzed, the data were transformed using the square root of the variable plus 1 ($DT = \sqrt{X+1}$), where DT represents the transformed data. To evaluate the relative efficiency of attractants in capturing fruit flies, the Lin and Binns (1988) model was used as a statistical tool. Following the logic of this model, the measure of test trap superiority (Pi) is defined as the mean square (MS) of the distance between the *i-th* test trap and the maximum catches. The MS behaves as a measure of variance and the graphical representation of the generated indices facilitates the visualization of the best-performing traps. Therefore, Pi is calculated using the following formula:

$$P_i = \sum_{j=1}^{n} \frac{\left(X_{ij} - M_j\right)^2}{2n}$$

where X_{ij}, represents the catch of the *i-th* trap in the *j-th* location, M_j is the maximum catch among all traps at the *j-th* location and n is the number of evaluation locations or environments.

It is important to note that the standard test statistics calculated, considering M*i* as an ordinary trap, can serve as a reference for critical values. However, they should not be considered standard significance tests (Lin and Binns, 1988).

Table 1. Political and geographic location, climatic variables, and crops present in the study localities in Táchira State, Venezuela

Political and geographic location			Climatic variables and crops			
Township	Location	Coordinates	Altitude (masl)	Tmean (°C)	Yearly rainfall (mm)	Crops
Junín	Bramón	N 07°39'36'' W 72°23'32''	1105	22.7	1474	Coffee, mango, citrus, guava, guamo
Samuel Darío Maldonado	La Tendida	N 08°25'71'' W 71°48'26''	637	25.6	1872	Citrus, mango, guava, passionfruit
Rafael Urdaneta	Las Lajas	N 07°32'28'' W 72°27'23''	1950	17.8	1175	Peach
Fernández Feo	Caño de Tigre	N 07°30'55'' W 71°51'55''	224	26.9	2560	Passionfruit, bananas, grasses
Jáuregui	Pueblo Hondo	N 08°14'98'' W 71°54'74''	2500	14.5	856	Pear, plum, and blackberry
	Ventorrillo	N 08°18'01'' W 71°53'51''	1876	17.1	973	Blackberry

Tmean: mean temperature. Coffee (*Coffea arabica*), mango (*Mangifera inidca* L.), citruses (*Citrus sp*.), guava (*Psidium guajava* L.), guamo (*Inga edulis* Mart), peach (*Prunus persica*, L.), passionfruit (*Passiflora edulis* Sims), bananas (*Musa* spp), pear (*Pyrus communis* L.), plum (*Prunus domestica* L.), blackberry (*Rubus ulmifolius* Schott.)

RESULTS

The ANOVA revealed high effects ($P\leq0.01$) for the interaction between location and attractant for all fly species captured, except for *C. capitata*, where no significant differences were found. These results indicate that the performance of the selected attractants was not consistent across all environments evaluated during the study (Table 2).

On the other hand, the ANOVA showed that the effect of the semester by attractant was not significant for the four fly species captured in the traps. On the other hand, both the main effect of attractants and locations were highly significant for all species studied, except for *C. capitata*. This shows that at least two of the attractants and at least two of the locations presented different capture levels for the species *Anastrepha fraterculus*, *A. striata,* and *A. obliqua* (Table 2).

The coefficients of determination (R^2), which ranged from 0.71 to 0.98, demonstrated that a high proportion of the variability observed can be explained by the model. In addition, appropriate coefficients of variation (CV %), from 18.449 to 30.425, indicated adequate management of the field data (Table 2).

Adult fly populations collected by the attractants. Table 3 shows that the highest populations of adult flies (mean of 245 of *Anastrepha* spp and *C. capitata*) were collected using the PedGo plus attractant ($P\leq0.05$), followed by PedGo, Nulure, molasses + urea, and molasses. No significant differences were found between the captures recorded with the PedGo, Nulure, and molasses + urea traps, showing significant differences with the other attractants. In contrast, molasses registered the lowest average.

Table 3 also shows that the Bramón and La Tendida locations generated highly significant differences in the interaction between location and attractant, as well as for location and attractant fixed effects.

The Bramón locality recorded the highest average number of adult fruit flies during the trial, with a value of 429 ($P\leq0.05$), followed by Caño de Tigre, La Tendida, Las Lajas, Ventorrillo, and Pueblo Hondo with 16, 51, 14, 3 and 3 flies, respectively. The differences among these last five locations were not significant. This average differs significantly from the averages of the other localities, which had lower populations (Table 3), and according to Table 1, range from 224 masl with an average temperature of 26.9 °C (Fernández Feo) to 2500 masl with an average temperature of 14.5 °C (Pueblo Hondo).

It is important to note that the attractants PedGo, molasses + urea, and Nulure showed average values of fruit fly captures that did not differ significantly (p > 0.05) in all the locations studied (Table 3). This suggests that the molasses + urea-based attractant could be an alternative to replace PedGo and Nulure. However, it would be necessary to improve its capacity as an attractant to perform at the same level as PedGo Plus.

Table 2. Analysis of variance to determine the efficiency of five attractants in the capture of fruit flies in six locations in Táchira State

Source of variation	df	*Anastrepha fraterculus*	*Anastrepha striata*	*Anastrepha obliqua*	*Ceratitis capitata*	Total
Localities (Loc)	5	278.56 **	28.74 **	10.19 **	0.44	340.40 **
Semester (Sem)	1	10.09	0.36	0.72	0.43	8.79
Sem /(Loc)	5	9.91 *	0.40	0.37	0.41	12.41 *
Atractants (Atr)	4	73.25 **	5.67 **	4.04 **	0.39	98.34 **
Loc x Atr	20	35.14 **	3.72 **	1.97 **	0.25	38.72 **
Sem x Atr	4	7.49	0.77	0.15	0.27	8.53
Error	20	3.00	0.57	0.27	0.25	3.68
Total	59					
R^2		0.976	0.956	0.953	0.71	0.976
CV (%)		30.425	23.761	18.449	20.73	30.261
Mean		69.73	9.37	4.85	2.42	85.97

*, **: $P \leq 0.05$ or 0.01, respectively. R^2 and CV are mean coefficient of determination and variation, respectively

Table 3. Average values of adult fruit flies of *Anastrepha* spp and *C. capitata* collected by five attractants in the six localities of Táchira State during the period under study

Attractant	Localities						Attractant average
	Bramón	Caño de Tigre	La Tendida	Las Lajas	Ventorrillo	Pueblo Hondo	
Molasses + urea	219 b	0 a	19 ab	18 a	4 a	4 a	44 B
Molasses	9 c	0 a	0 b	2 a	1 a	0 a	2 C
PedGo	327 b	18 a	64 ab	17 a	0 a	4 a	71 B
PedGo plus	1267 a	37 a	143 a	19 a	2 a	4 a	245 A
Nulure (c)	323 b	28 a	28 ab	15 a	8 a	6 a	68 B
Localities (average)	429 A	16 B	51 B	14 B	3 B	3 B	85.97

Different lowercase letters in each column indicate differences between average catches per attractant at each location. Different capital letters indicate differences between average catch values per attractant, and per location, according to Tukey's test ($P \leq 0.05$)

Total fruit fly species collected by the attractants. Table 4 shows that the PedGo Plus attractant registered the highest capture of fruit fly specimens, with a total of 2942, which differs significantly ($P \leq 0.05$) from the rest of the attractants used. PedGo and Nulure are in second place with 857 and 813 flies, respectively; meanwhile, molasses + urea and molasses are in third and fourth place with 524 and 22 flies, respectively. The behavior pattern of the attractants was similar for the species *A. fraterculus*, *A. striata* and *A. obliqua*, showing the highest captures with the PedGo Plus attractant, which differed significantly from the rest of the attractants, except in the case of *A. striata*, where the PedGo Plus and Nulure attractants presented statistically equal capture levels (p >0.05).

On the other hand, the species *A. serpentina* and *A. dryas* showed low populations in general, and no significant differences were found between the populations collected with the different attractants. The same situation was observed in the

Mediterranean fruit fly, *C. capitata*, where low populations were also recorded in the localities studied, with no significant differences between the treatments evaluated.

The species *A. fraterculus* recorded the highest number of specimens collected in the study, with 4184 individuals ($P\leq0.05$). On the other hand, *A. serpentina* was the species with the lowest number of specimens recorded, with only 4 individuals. Both species differed significantly in terms of the number of specimens collected compared to the rest of the identified species.

The species *A. obliqua* (291), *A. dryas* (50) and *C. capitata* (67) had relatively low populations compared to *A. fraterculus* and *A. striata*, which recorded a total of 4184 and 562 individuals, respectively (Table 4).

In summary, the results show that the PedGo Plus attractant was the most effective in capturing fruit flies in general, although some species showed low populations in all locations studied.

Overage catches of *A. fraterculus* with five attractants in six localities. The dominant species, *A. fraterculus*, showed the highest fly capture at the Bramón location using the PedGo Plus attractant (Table 5). This difference was statistically significant compared to the other locations studied. However, in La Tendida, similar capture levels were observed between PedGo and Nulure. It is noteworthy that this species was collected at all altitudinal levels studied, from Caño de Tigre at 224 masl to Pueblo Hondo at 2500 masl (Table 1), which suggests its ability to adapt to different environmental conditions in the region studied.

Table 4. Total values of six fruit fly species collected by five attractants in the six localities of Táchira State during the period under study (*A.:Anastrepha*; *C.: Ceratitis*)

Attractant	Fruit fly species collected						Total
	A. fraterculus	*A. obliqua*	*A. striata*	*A. serpentina*	*A. dryas*	*C. capitata*	
Molasses + urea	396 d	26 b	93 b	0 a	8 a	1 a	524 C
Molasses	21 e	0 bc	0 c	0 a	0 a	1 a	22 D
PedGo	729 b	50 b	51 b	1 a	12 a	14 a	857 B
PedGo plus	2490 a	186 a	206 a	3 a	16 a	41 a	2942 A
Nulure (c)	548 c	29 b	212 a	0 a	14 a	10 a	813 B
Total	4184 A	291 C	562 B	4 D	50 C	67 C	

Different lowercase letters indicate differences between total catches per attractant for each species. Different capital letters indicate differences between the values of total catches per attractant, and per species, according to Tukey's test ($P\leq0.05$)

Lin and Binns model to evaluate trap efficiency. Table 6 shows the results of the Lin and Binns (1988) model used to estimate the average performance of each attractant. The PedGo Plus attractant showed the lowest value of superiority indexes (Pi), indicating a higher efficiency compared to the other attractants evaluated. In addition, PedGo Plus also obtained the highest superiority index concerning the control attractant, being approximately 3.6 times more efficient in terms of capture. These results highlight that PedGo Plus was significantly superior to the Nulure attractant, used as a control, and was significantly different from the other attractants evaluated.

The Lin and Binns superiority index (Pi) is defined as the mean square of the distance between the *i-th* test trap and the maximum catches at each location. A lower value of Pi indicates higher trap efficiency. For example, PedGo Plus achieved the highest captures in the locations of Bramón, La Tendida, Caño de Tigre, and Las Lajas, which resulted in a low value of Pi for this attractant. In contrast, the lures evaluated in Ventorrillo and Pueblo Hondo obtained higher Pi values, indicating a lower efficiency in terms of capture.

These results are visualized in Figure 2, where the PedGo Plus is close to the X-axis, while the molasses-based attractant is close to the Y-axis. In addition, the efficiency of PedGo and Nulure is quite similar, and the molasses + urea attractant is located close to PedGo and Nulure.

Table 5. Average catch values obtained per attractant for the species *A. fraterculus* in the six localities of the state of Táchira during the period under study.

Attractant	Localities						Average
	Bramón	Caño de Tigre	La Tendida	Las Lajas	Ventorrillo	Pueblo Hondo	
Molasses + urea	165 b	0 a	13 b	17 a	4 a	0 a	33 B
Molasses	9 c	0 a	0 b	1 a	1 a	0 a	2 C
PedGo	291 b	6 a	54 ab	15 a	0 a	0 a	61 B
PedGo plus	1095 a	12 a	122 a	15 a	2 a	1 a	208 A
Nulure (c)	207 b	20 a	25 ab	14 a	8 a	1 a	46 B
Localities average	353 A	7 B	43 B	12 B	3 B	0 B	69.73

Different lowercase letters indicate differences between average catches per attractant at each location. Different capital letters indicate differences between average catch values per attractant, and per location, according to Tukey's test ($P \leq 0.05$)

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DISCUSSION

The use of bait traps with suitable attractants is an effective alternative for the integrated management of fruit fly populations in different fruit crops. Therefore, it is of great importance to evaluate the efficacy of these attractants in trapping fruit flies.

In the present study, a low incidence of the species *C. capitata* was observed in comparison with the collected populations of species of the genus *Anastrepha.* Studies carried out by Valenzuela (2021) support the results obtained regarding the low incidence of *C. capitata* in comparison with species of the genus *Anastrepha* in different crops. Segura et al. (2006). compared the relative abundance of these fruit pests in 26 fruit species sampled from 62 localities of Argentina in regions where *C. capitata* and *A. fraterculus* coexist and they founded that in general, *C. capitata* was predominant over *A. fraterculus*, but not always.

In this study, *A. fraterculus* was the most frequent species, regardless of the host type, and those areas with the greatest diversity of crops, such as Bramon and La Tendida, were those that recorded the highest incidence of fruit flies. However, in a study by Katiyar et al. (2000), the presence of *C. capitata* was found incidentally when examining fruits of plants of the Myrtaceae family in the states of Mérida, Táchira, Trujillo, and Zulia, where most of the records corresponded to species of the genus *Anastrepha*. These findings support the idea that *C. capitata* shows a lower incidence compared to *Anastrepha* species in different crops and regions studied.

The abundance of species of the genus *Anastrepha* in Venezuela varies according to the crops and host plants in each area and locality. In all altitudinal zones studied, *A. fraterculus* was the only species collected, suggesting a greater ability to adapt to different environmental conditions. This is evidence that *A. fraterculus* is dominant or shows a preference for elevated areas in Venezuela, which coincides with the findings of Katiyar et al. (2000), who observed a greater abundance of this species in various plants of the Myrtaceae family at altitudes between 1250 and 1750 meters above sea level compared to other species. In addition, Hernández et al. (2012) and (2015) demonstrated the existence of two morphotypes of *A. fraterculus* within the cryptic species complex in the country. These studies identified the "Venezuelan" morphotypes in the lowlands of the Caribbean and the "Andean" morphotypes corresponding to the highlands of Colombia and Venezuela.

The use of food traps and attractants represents a good option for fruit fly control if it is integrated with other methods. However, this alternative is only viable if it is easy to apply and, at the same time, competes favorably with other control methods.

Table 6. Total fruit fly catch values by location and the average catch per trap and superiority parameters of Lin and Binns (1988)

Attractant	Ventorrillo	Pueblo Hondo	Las Lajas	Caño de Tigre	La Tendida	Bramón	Trap average	SD	CV (%)	SI(c)	Pi
Molasses+urea	7	7	35	0	37	438	87	172	198	64	371.73
Molasses	1	0	3	0	0	18	4	7	194	3	534.92
PedGo	0	8	34	35	127	653	143	254	178	105	297.10
PedGo plus	4	7	37	74	286	2534	490	1007	205	362	0.01
Nulure (c)	16	11	30	55	56	645	136	250	185	100	301.80
Localities average	6	7	28	33	101	858	172	480	279	127	

SD, CV, SI(c) and Pi mean, respectively, standard deviation, coefficient of variation, superiority index regarding the control (c) and superiority index of Lin and Binns.

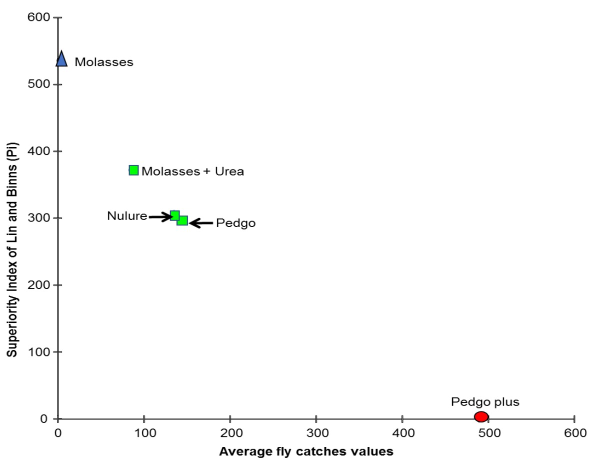

Figure 2. Lin and Binns superiority index for measuring fruit fly capture efficiency with five different attractants.

Barba and Tablizo (2014) emphasize the importance of seeking national options for homemade traps and attractants that are more economical, environmentally friendly, and represent products safely for the health of farmers, as opposed to using chemical insecticides. To achieve this, it is essential to have easy-to-apply methodologies that allow accurate evaluation of the efficacy of homemade attractants in trapping insect pests and that provide a graphical representation of the performance of all alternatives used.

Luque et al. (2007) conducted a study in Venezuela using PedGo Plus attractant with successful results in capturing fruit flies. In the present study, it was found that the use of JD EuGo 97 handmade plastic traps, baited with 300 ml of PedGo plus attractant solution, is a preferable alternative to imported McPhail traps because the attractant used is low-cost and domestically produced.

The PedGo plus attractant showed the highest capture results in all locations studied, except in those with low fly populations, where no significant differences were observed among the attractants evaluated. Therefore, it may be a suitable option as an attractant bait in handmade traps for the detection or capture of fruit flies, in combination with appropriate crop management practices. In addition, PedGo plus presented the lowest Lin and Binns superiority index (Pi) and the highest value in terms of superiority index compared to the control attractant, demonstrating its higher efficacy for fruit fly trapping in the environments evaluated. The attractant made with molasses + urea showed a similar capture response to PedGo and Nulure, which shows that it can be an alternative to replace these two attractants commonly used in different fruit fields.

CONCLUSIONS

In general, the performance of the attractants showed variations in different environments, while the capture level of the different traps did not vary between the two analyzed seasons.

A. fraterculus was the only species collected in all altitudinal zones studied, suggesting a greater ability to adapt to different environmental conditions.

PedGo plus presented the lowest Lin and Binns superiority index (Pi) and the highest value in terms of superiority index compared to the control attractant, demonstrating its higher efficacy for fruit fly trapping.

Although PedGo plus was the most efficient attractant in most of the environments studied, molasses + urea proved to be an alternative to replace PedGo and Nulure.

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