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Original Article

Oviposition performance of tephritid polyphagous *Anastrepha fraterculus* and *Ceratitis capitata* during three periods of exposure to fruit

Performasse de oviposição dos tefritídeos polífagos *Anastrepha fraterculus* e *Ceratitis capitata* durante três períodos de exposição da fruta

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Abstract

Our study evaluated the oviposition behaviour of *Anastrepha fraterculus* (Wiedemann, 1830) and *Ceratitis capitata* (Wiedemann, 1824) in five fruit species. Apples, guavas, mangoes, peaches and tangerines were exposed to infestation for 6, 12 and 24 hours. *Anastrepha fraterculus* and *C. capitata* showed different oviposition behaviour in apples and tangerines and similar oviposition behaviour in guavas, mangoes and peaches. There was a positive correlation between infestation time and pupae/kg, as well as between pupae/fruit and the survival rate of the immature (pupal viability). In this study, we present discussions about the oviposition behaviour of flies and the host infestation index. This index can reflect the reproductive capacity that each fruit species offers for each fly species. Here, we see an adult recovery rate greater than 89% in the highest infestation index observed in guava (185 *A. fraterculus* per unit fruit) and peach (220 *C. capitata* per unit fruit). Understanding the reproductive capacity of each host can help with risk analysis and the management of fruit flies.

Keywords: Tephritidae, fruit flies, infestation index.

Resumo

Nosso estudo avaliou o comportamento de oviposição de *Anastrepha fraterculus* (Wiedemann, 1830) e *Ceratitis capitata* (Wiedemann, 1824) em cinco espécies frutíferas. Maçãs, goiabas, mangas, pêssegos e tangerinas foram expostos à infestação por 6, 12 e 24 horas. *Anastrepha fraterculus* e *C. capitata* apresentaram comportamento de oviposição diferente em maçãs e tangerinas e comportamentos de oviposição semelhante em goiabas, mangas e pêssegos. Houve correlação positiva entre tempo de infestação e pupas/kg, bem como entre pupas/fruta e taxa de sobrevivência dos imaturos. Neste estudo, apresentamos discussões sobre o comportamento de oviposição de moscas e o índice reprodutivo do hospedeiro. Esse índice pode refletir a capacidade reprodutiva que cada espécie frutífera oferece para cada espécie de mosca. Nesse caso, a taxa de recuperação de adultos foi superior a 89% no maior índice de infestação observado em goiaba (185 *A. fraterculus* por unidade de fruta) e pêssego (220 *C. capitata* por unidade de fruta). Compreender a capacidade reprodutiva de cada hospedeiro pode ajudar na análise de risco e no manejo das moscas-das-frutas.

Palavras-chave: Tephritidae, moscas-das-frutas, índice de infestação.

1. Introduction

Tephritidae is the most economically important family in the order Diptera (White and Elson-Harris, 1994). The importance of these insects is mainly associated with the relationship between flies and host fruit. The relationship begins when the female oviposits inside the fruit, where the frugivorous larvae later develop. This relationship causes serious injuries to the structure of the fruit. The oviposition of the females leaves openings in the peel that favour infection by microorganisms, which contributes to the accelerated rotting of the fruit. The feeding larvae cause rotten galleries in the pulp, in addition to softening and physicochemical changes in the fruit (Machota-Junior et al., 2013; Omoloye et al., 2016; Louzeiro et al., 2020).

The oviposition behaviour and insect development rate are mainly influenced by the host preference (Thompson, 1988; Joachim-Bravo et al., 2001), competition between females and the physicochemical composition of the host, which includes the nutritional value for the larvae (Fontellas-Brandalha and Zucoloto, 2004) and fruit defence mechanisms (Greany et al., 1983; Guillén et al., 2017). Additionally, climatic conditions, the incidence

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of natural enemies, host availability and maturation and oviposition stimuli are relevant (Price et al., 1980; Prokopy and Roitberg, 1984; Vayssières et al., 2009; Bisognin et al., 2015; Dias et al., 2017; Sivinski et al., 2004). *Anastrepha fraterculus* (Wiedemann, 1830) and *Ceratitis capitata* (Wiedemann, 1824) are polyphagous and holometabolic insects whose immature stages develop inside fruit. However, the relationship between fly and host, as well as, the life cycles of these insects, may be different for each species of host fruit.

Due to the importance of fruit flies for the production and distribution of fresh fruit worldwide, several studies have been conducted to understand the relationship between flies and their fruit hosts. However, since the relationship between flies and their hosts is variable, their hosts are often classified as primary or secondary based on the fly oviposition preference (Freeman and Carey, 1990; Joachim-Bravo et al., 2001). Some of the criteria used in the classification of hosts include the infestation indices pupae per fruit, pupae per kg and the survival rate of the immature (e.g., pupal viability). This study presents the infestation index and pupal viability of *A. fraterculus* and *C. capitata* in five fruit species during three periods of exposure to the fruit. We also discuss the relationship between flies and hosts based on the infestation index and host reproductive index, which may represent a measure of reproductive risk that each species of fruit offers for each tephritid species.

2. Material and Methods

2.1. Insects

The present study used females of *A. fraterculus* and *C. capitata* reared in the Economic Entomology Laboratory, Instituto Biológico, São Paulo, Brazil. The population of *C. capitata* was reared on an artificial diet (Raga et al., 1996; Sousa et al., 2020), while *A. fraterculus* was replicated in papaya (*Carica papaya* L.). The adults of both species were raised in cages and provided with water and an artificial diet (Raga et al., 2018). Females (sexually mature) aged 12 to 14 days were tested for *C. capitata* and females between 13 and 16 days were tested for *A. fraterculus*. These ages were chosen based on previous studies (Raga et al., 2020; Sousa et al., 2020).

2.2. Fruit

In this study, we used the following ripe fruits: apples cv. Gala (*Malus domestica* Borkh.), guavas cv. Tailandesa (*Psidium guajava* L.), mangoes cv. Tommy Atkins (*Mangifera indica* L.), peaches cv. Chiripá [*Prunus persica* (L.) Batsch] and tangerines cv. Tangor Murcott (*Citrus reticulata* Blanco). Apples, mangoes, peaches and tangerines were purchased from a food supply centre. Guavas were purchased directly from a bagged guava (paper) orchard. Fruits were chosen that showed similarity in terms of peel colour, length, diameter and weight (as shown in Table 1). Fruits of each species with similar characteristics were used. In the laboratory, the fruits were washed with a solution of water plus sodium hypochloride (0.5% v/v) and allowed to dry at room temperature.

2.3. Infestation bioassay

The experiment was conducted in a room (3.5 x 2.9 x 2.1 m) with 25 ± 2ºC and 70 ± 5% of relative humidity. The fruits were infested individually. The infestation took place in 6000 cm^3 glass cages with an upper opening of 9 cm and a lower opening of 15 cm in diameter. The openings were sealed with an aluminium foil tray (bottom of the cages) and a plastic cover with micro-holes (top opening of the cages). Inside the cages, the fruit was suspended from the base. For this, the fruit was placed on a glass tube.

Each fruit was individually exposed to infestation by 10 females of *A. fraterculus* and *C. capitata*, separately, for 6, 12 and 24 hours. Different groups of females were used for each period of exposure to oviposition. Five individual fruits of each species were used at each period of exposure to oviposition, with each fruit being considered a replicate.

2.4. Fruit storage

After the infestation period, the fruits were individually stored in containers (1 L) with approximately 40 g of vermiculite at the base. The containers were identified and sealed with sheer fabric bound by an elastic. Up to 30 days after infestation, the pupae were separated and counted. The pupae were kept in 500 mL disposable cups with moistened vermiculite. The containers with infested fruits and pupae were stored under the conditions of 25 ± 2ºC and 70 ± 5% of RH. The number of pupae and adults were used to calculate infestation indices and percentage of pupal viability (Monteiro et al., 2023).

2.5. Data analysis

The variables used were infestation indices (pupae/fruit and pupae/kg of fruit), and the percentage of pupal viability. Data from infestation indices were subjected to an analysis of variance (two-way ANOVA) and the comparison of means by Tukey´s test. Before ANOVA, the normal distribution of data was verified by the Shapiro-Wilk test ($p > 0.05$). The number of pupae and adults recovered at each period of exposure to the fruit (6, 12 and 24h) were the sources of variation. Correlation analysis was performed with data on infestation indices and pupal viability, separately for each fruit species and fly species. We used Pearson's correlation to estimate the relationship between fruit exposure period versus pupae/kg and between the pupae/fruit versus pupal viability. Statistical analyses were performed using SAS University Edition software (Version 3.8) (SAS Enterprise Miner 13.1. SAS Institute Inc., Cary, NC.).

3. Results

3.1. Infestation bioassay

The infestation indices and pupal viability of *A. fraterculus* and *C. capitata* varied between exposure to infestation period and fruit species (as shown in Table 2).

Table 1. Characteristics of the fruit used in the infestation of *A. fraterculus* and *C. capitata*.

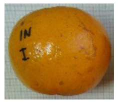
Plant species	Peel colour	Picture	Length (cm)			Diameter (cm)			Weight (g)		
			6h	12h	24h	6h	12h	24h	6h	12h	24h
			Average (range)	Average (range)	Average (range)	Average (range)	Average (range)	Average (range)	Average (range)	Average (range)	Average (range)
Citrus reticulata	Yellow		5.5 (5.2-5.8)	5.6 (5.1-6.1)	5.6 (5.3-5.9)	7.1 (6.7-7.7)	7.0 (6.5-7.5)	7.1 (6.9-7.3)	192.2 (152.0-252.0)	178.2 (152.0-218.0)	184.2 (156.0-244.0)
Malus domestica	Red-yellow		6.7 (6.3-7.4)	6.7 (6.2-7.6)	6.5 (6.1-7.0)	7.0 (6.7-7.5)	7.1 (6.9-7.4)	7.0 (6.8-7.4)	150.6 (124.0-180.0)	155.4 (132.0-184.0)	149.8 (132.0-178.0)
Mangifera indica	Green-red		12.1 (10.6-14.1)	11.6 (8.9-13.8)	11.7 (9.7-14.0)	10.0 (7.8-12.8)	10.0 (7.8-12.5)	10.1 (7.8-12.6)	455.8 (264.0-7.42.0)	433.4 (310.0-700.0)	449.8 (314.0-682.0)
Prunus persica	Red-yellow		5.6 (5.2-5.9)	5.7 (5.4-5.9)	5.7 (5.4-6.1)	5.8 (5.6-6.1)	5.9 (5.7-6.4)	5.9 (5.8-6.1)	98.4 (90.0-104.0)	101.8 (96.0-108.0)	96.8 (92.0-104.0)
Psidium guajava	Green		7.8 (7.4-8.5)	7.7 (7.3-8.2)	7.8 (7.0-8.3)	7.1 (6.0-8.2)	7.2 (6.5-7.8)	7.2 (6.6-8.1)	194.2 (158.0-228.0)	193.4 (158.0-224.0)	197.8 (168.0-240.0)

Table 2. Means of infestation indices and pupal viability of *A. fraterculus* and *C. capitata* in five fruit species during three infestation periods. Lowercase letters in the column and uppercase letters in the row (within each index) represent statistically significant differences ($p < 0.05$).

Plant species	Tephritid fly	Pupae/fruit (range)			Pupae/kg (range)			Pupal viability % (range)		
		6h	12h	24h	6h	12h	24h	6h	12h	24h
Citrus reticulata	*A. fraterculus*	1.2 bA (0-4)	2.0 cA (0-8)	8.8 dA (0-17)	6.7 cA (0-21.9)	12.2 cA (0-48.8)	53.9 cA (0-102.4)	35.0 (0-100)	40.0 (0-100)	55.1 (0-100)
	C. capitata	0.0 bA (0)	2.2 cA (0-11)	32.8 bcdA (0-100)	0.0 cA (0)	14.4 cA (0-72.4)	165.3 cA (0-543.5)	0.0 (0)	18.1 (0-91)	38.8 (0-100)
Malus domestica	*A. fraterculus*	6.4 abA (0-21)	16.0 cA (5-38)	12.2 cdA (0-35)	37.8 cA (0-126.5)	89.9 bcA (31.1-206.5)	74.3 cA (0-216.1)	68.5 (0-100)	83.0 (65-100)	60.5 (0-100)
	C. capitata	56.8 abA (23-114)	56.6 bcA (17-150)	38.4 bcdA (0-89)	431.4 abcA (185.5-850.7)	417.1 bcA (119.7-1102.9)	289.4 bcA (0-674.2)	95.2 (87-100)	92.7 (88-97)	69.8 (0-100)
Mangifera indica.	*A. fraterculus*	19.4 abB (0-84)	47.2 bcAB (0-108)	81.2 abcA (37-131)	71.0 bcA (0-318.2)	141.5 bcA (0-312.1)	241.9 cA (93.9-417.2)	63.5 (0-100)	75.4 (0-100)	93.0 (84-99)
	C. capitata	0.2 bA (0-1)	24.6 bcA (0-123)	11.2 cdA (0-32)	0.3 cA (0-1.7)	35.1 cA (0-175.7)	18.3 cA (0-46.9)	20.0 (0-100)	16.4 (0-82)	79.3 (0-100)
Prunus persica	*A. fraterculus*	50.6 abA (0-78)	41.4 bcA (0-103)	67.8 bcdA (28-112)	493.7 abA (0-764.7)	408.7 bcA (0-1009.8)	708.5 bA (269.2-1191.5)	78.6 (0-100)	77.6 (0-100)	95.7 (89-100)
	C. capitata	73.8 aB (56-115)	162.4 aA (126-220)	147.8 aA (95-186)	762.6 aB (614.6-1127.4)	1567.1 aA (1259.6-2037.1)	1533.5 aA (950.0-1978.7)	99.7 (98-100)	95.5 (89-100)	95.6 (86-100)
Psidium guajava	*A. fraterculus*	47.4 abA (6-163)	94.4 abA (35-185)	86.2 abA (55-144)	238.6 bcA (27.5-815.0)	502.1 bA (180.4-872.6)	446.0 bcA (272.3-782.6)	80.3 (50-100)	86.6 (51-100)	91.5 (59-100)
	C. capitata	54.2 abA (7-86)	18.8 cA (0-50)	59.6 bcdA (0-117)	305.1 bcA (31.2-457.4)	97.9 bcA (0-284.1)	280.9 bcA (0-531.8)	95.3 (92-100)	72.8 (0-100)	75.8 (0-100)

Anastrepha fraterculus and *C. capitata* showed different infestation indices in apples and mangoes, and similar infestation indices in guavas, peaches and tangerines. The highest infestation index of *A. fraterculus* occurred in a guava unit (185 pupae/fruit, 872.6 pupae/kg) a mango unit (131 pupae/fruit, 417.2 pupae/kg). For these infestation indices, the pupal viability was above 98%. In *C. capitata*, apples and peaches presented maximum values of 150 and 220 pupae/fruit, respectively, equivalent to 1102.9 and 2037.1 pupae/kg and 90.6 and 89.1% pupal viability, respectively.

Up to 6h after fruit exposure, the peaches stimulated strong oviposition by *C. capitata*, while the same species laid no eggs in tangerines. Up to 12h after fruit exposure, peaches and guavas stimulated oviposition in *C. capitata* and *A. fraterculus*, respectively. The same oviposition behaviour was observed at 24h after fruit exposure when *A. fraterculus* showed similar oviposition behaviour in mangoes (as shown in Table 2).

At 24h after fruit exposure, *C. capitata* showed higher infestation (pupae/fruit) than *A. fraterculus* in peaches and similar infestations were observed between fly species in the remaining fruits. In terms of pupae/kg, peach exposure to *C. capitata* exhibited the highest infestation among the fruits (average 1257 pupae/kg).

3.2. Relationship between length of exposure to oviposition and pupae/kg

We observed that *A. fraterculus* and *C. capitata* increased and/or decreased their infestation over the exposure period for each fruit species (see Figure 1). The infestation index pupae/kg was directly proportional to the exposure period of mango and tangerine to *A. fraterculus* oviposition. The same behaviour occurred in peaches exposed to *C. capitata* (as shown in Table 3) when the infestation index at 12h was double that observed at 6h. The oviposition behaviour of *A. fraterculus* increased over time in guavas, apples, mangoes, peaches and tangerines. The infestation of *C. capitata* also increased over time in guavas and tangerines and decreased in apples and mangoes.

3.3. Relationship between pupae/fruit and pupal viability

Generally, the pupal viability of both fruit fly species in each fruit species was similar among the three exposure periods, except for *C. capitata* in mangoes. Pupal viability was directly proportional to pupae/fruit in guavas, mangoes, peaches and tangerines infested by *A. fraterculus*, as well as in guavas, peaches and tangerines infested by *C. capitata* (as shown in Table 4). The positive relationship between pupae/fruit and pupal viability of *A. fraterculus* was mainly observed in guavas and peaches (see Figure 2). The positive relationship of *C. capitata* was mainly observed in peaches. In guavas and apples, the pupal viability of *C. capitata* increased and decreased proportionally to the pupae/fruit values (see Figure 2).

4. Discussion

Anastrepha fraterculus and *C. capitata* exhibited different oviposition behaviour for each fruit species.

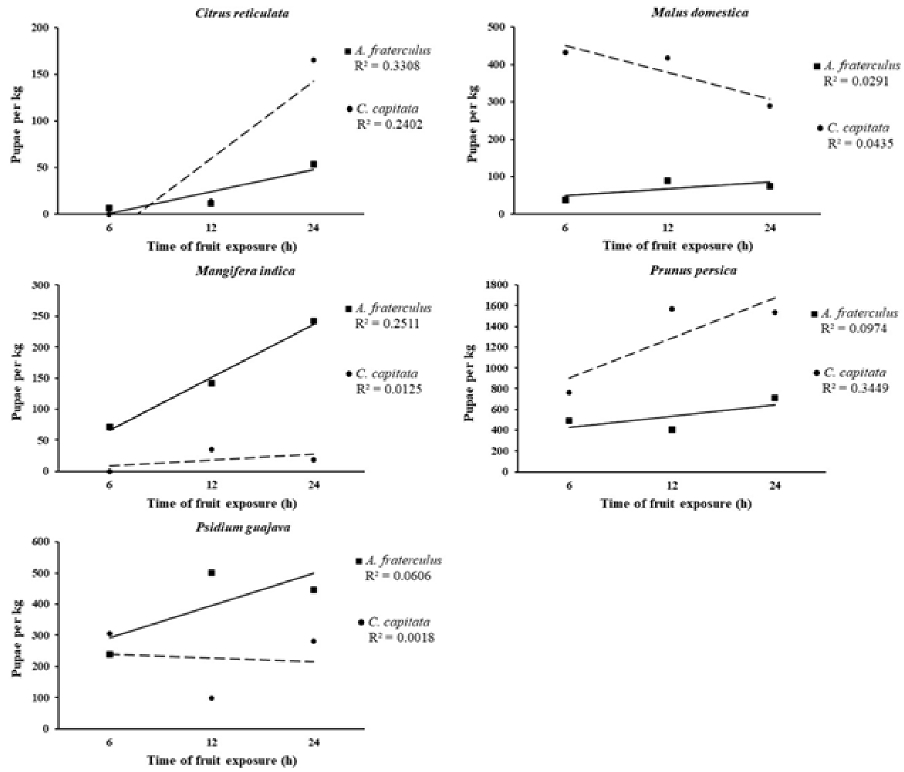


Figure 1. Oviposition behaviour of *A. fraterculus* and *C. capitata* during three infestation periods of fruit.

Table 3. Relationships between the infestation period and pupae/kg of *A. fraterculus* and *C. capitata* in five fruit species. When not significant at $p \leq 0.05$, the regression equation was not shown.

Plant species	Tephritid fly	Regression equation	*r*	*F*-value	d.f.	*p*-value
Citrus reticulata	*A. fraterculus*	y = 11.07800x + 0.12048	0.575	6.41	2; 13	0.0249
	C. capitata	-	0.490	4.11	2; 13	0.0636
Malus domestica	*A. fraterculus*	-	0.170	0.39	2; 13	0.5436
	C. capitata	-	0.208	0.59	2; 13	0.4558
Mangifera indica	*A. fraterculus*	y = 9.92659x + 0.02689	0.501	4.36	2; 13	0.0571
	C. capitata	-	0.111	0.16	2; 13	0.6916
Prunus persica	*A. fraterculus*	-	0.312	1.40	2; 13	0.2574
	C. capitata	y = 1.76764x + 0.00950	0.587	6.85	2; 13	0.0213
Psidium guajava	*A. fraterculus*	-	0.246	0.84	2; 13	0.3764
	C. capitata	-	0.042	0.02	2; 13	0.8808

Table 4. Relationships between the pupae/fruit and pupal viability of *A. fraterculus* and *C. capitata* in five fruit species. When not significant at $p \leq 0.05$, the regression equation was not shown.

Plant species	Tephritid fly	Regression equation	*r*	*F*-value	d.f.	*p*-value
Citrus reticulata	*A. fraterculus*	y = 20.83837x + 5.63541	0.705	12.85	2; 13	0.0033
	C. capitata	y = 6.08028x + 1.10683	0.829	28.63	2; 13	0.0001
Malus domestica	*A. fraterculus*	-	0.120	0.19	2; 13	0.6676
	C. capitata	-	0.357	1.91	2; 13	0.1903
Mangifera indica	*A. fraterculus*	y = 56.80131x + 0.41608	0.555	5.81	2; 13	0.0315
	C. capitata	-	0.398	2.45	2; 13	0.1416
Prunus persica	*A. fraterculus*	y = 49.44790x + 0.64816	0.630	8.59	2; 13	0.0117
	C. capitata	y = 103.72871x - 0.05312	0.638	5.93	2; 13	0.0105
Psidium guajava	*A. fraterculus*	y = 69.98668x + 0.21263	0.615	7.92	2; 13	0.0146
	C. capitata	y = 61.81108x + 0.44153	0.503	4.41	2; 13	0.0558

These differences were observed based on infestation indices and pupal viability. The relationship between insects and their hosts is variable and influenced by several factors (Price et al., 1980; Danks, 2007). Our laboratory experiments attempted to minimise the influence of biotic and abiotic factors. However, in infestation bioassay, we must consider the strong influence of the preference of the fly, the physicochemical composition of the host and the female fly age.

The polyphagia behaviour found in *A. fraterculus* and *C. capitata* is certainly another relevant factor in the relationship between insect and host (Ali and Agrawal, 2012). In some polyphagous tephritids it is common to choose inappropriate hosts for the development of offspring due to the lack of discrimination in the choice of hosts, in addition to the adaptive factors of the insect (Krainacker et al., 1987). This may partially explain the oviposition of *A. fraterculus* and *C. capitata* in tangerines, even when this fruit provides a low rate of pupal viability, as noted in this study.

The oviposition stimuli for both *A. fraterculus* and *C. capitata* were considerably fast. The exposure time of 6h was enough to consistently infest the five fruit species. However, our first hypothesis, 'the infestation index pupae/kg is directly related to the exposure period to infestation', was only positive for mangoes and tangerines infested by *A. fraterculus* and peaches infested by *C. capitata*. Notably, the study of ovipositional behaviour can be partial evidence to validate our hypothesis. In relation to oviposition behaviour, Tephritidae exhibit a hierarchy of preferences to oviposit (Petitinga et al., 2021), whose females presented specialized receptors that respond differently to the kairomones from appropriate hosts (Metcalf, 1990; Diaz-Fleischer and Aluja, 2003). Additionally, applied studies on the evolution of oviposition can help to better understand the oviposition behaviour of tephritid flies (Díaz-Fleischer et al., 2000). Among other factors, these studies should consider the marking of females (attraction or deterrent effect), the proof test of females, the physicochemical characteristics of the host (e.g., colour, maturation status and nutritional value for the larvae) and the specialisation of the ovipositor (Díaz-Fleischer et al., 2000).

Ceratitis capitata is an r-strategist (Gomulski et al., 2012) and lays an average of between 3 to 50 eggs per clutch in

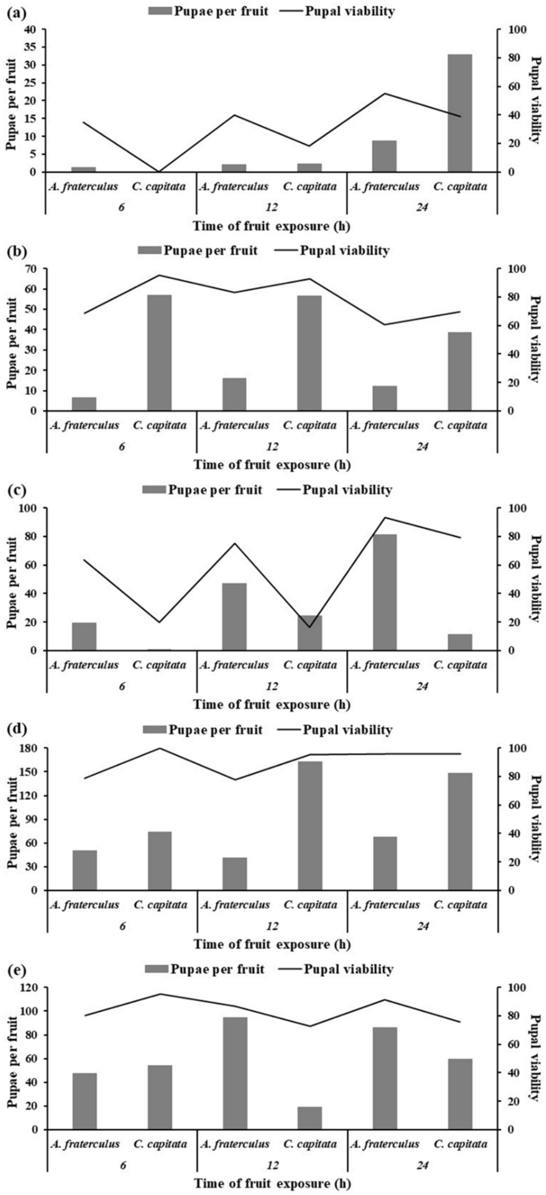


Figure 2. Comparison between infestation index pupae/fruit and pupal viability of *A. fraterculus* and *C. capitata* in *C. reticulata* (a), *M. domestica* (b), *M. indica* (c), *P. persica* (d) and *P. guajava* (e).

laboratory, depending on the fruit host; for *A. fraterculus* this average is 4 (Sousa et al., 2020). Host conditions can cause variation in the number of eggs laid over space and time. Consequently, the infestation index observed over time in the laboratory also may vary in fly species with a large number of eggs per clutch, distributed in a greater or lesser number of punctures. Probably, *A. fraterculus* spent much more time to oviposit the same egg density per fruit than *C. capitata*. This behaviour partly explains the increase of oviposition by *A. fraterculus* over exposure times in apples, guavas, mangoes, peaches and tangerines.

There is a relationship between infestation and metabolic changes and/or accelerated ripening of the fruit (Keck, 1934; Oroño et al., 2019). Our results can assist in the search for an infestation interval pupae/kg that guarantees the recovery of immatures and partially prevents that the fruit have been submitted to high infestation index and suffer collapsing. Therefore, we recommend the individualized guava and peach be exposed to fruit fly infestation for up to 6 hours, while apple, mango and tangerine be kept for up to 12 hours.

Our second hypothesis, 'pupal viability is directly related to the infestation index pupae/fruit' was positive for guavas, mangoes, peaches and tangerines. Here, we expected an inverse relationship. We expected that a high infestation index pupae/fruit (in individual fruit) would result in nutritionally deprived immatures mainly due to the competition of the larvae for resources and accelerated decay or collapse of the fruit. Consequently, malnourished larvae would not develop in adults (Jang, 1986; Awmack and Leather, 2002). Masselière et al. (2017) showed a positive relationship between adult preference and larval performance for specialist species, but no such relationship was found for generalist in Tephritidae species. However, studies have shown that there is a positive relationship between host preference and the development and survival of progeny (Thompson, 1988; Costa et al., 2011). This partially explains the high adult recovery rates (> 89%) in guavas and peaches when there was the highest infestation index for pupae/fruit. High pupal viability for both fruit fly species was reported for guavas and peaches (Raga et al., 2017, 2020). No significant differences were detected in emergence rates of *Anastrepha ludens* (Loew 1873) reared in different degree of ripe of mangoes, but ripe fruits showed significantly more pupae than unripe fruits (Diaz-Fleischer and Aluja, 2003). Thus, the choice of ripe fruits for the present study favored the oviposition and provided high pupal viability for many fruits exposed to both fruit fly species.

Guavas and peaches were the fruits with the highest host infestation index values. Host infestation index data is valuable in the risk analysis of frugivorous flies (Bellamy et al., 2013). This infestation index can show the reproductive capacity that each fruit species provides for specific fly species. In our study, a single guava was able to support 185 pupae of *A. fraterculus* at 99% pupal viability, while a single peach provided 220 pupae of *C. capitata* with 89% pupal viability. In terms of nutrition and oviposition activity, guavas and peaches can support and sustain large populations of tephritid flies (Costa et al., 2011).

The evaluation of the infestation index pupae/kg in relation to the infestation period aimed to contribute to laboratory infestation studies. The host suitability of these fruits can impact their production in isolated or mixed orchards. Consequently, large populations can negatively impact the management of fruit flies. Additionally, beyond the spread of the pest to other regions, they can increase the risk of damage in fruit production (Vayssières et al., 2009).

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