Influence Of Feeding On Three Stored Product Pests On Rearing Of The Predatory Mite *Cheyletus Malaccensis* (Acari: Cheyletidae) In Hail, Saudi Arabia

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Abstract: Survey study of stored-product was conducted in hail region during 2013. Predatory mite species were found associated with insect and mite pests, among those *Cheyletus malaccensis* Oudemans was the most abundant species. This mite was provided with three acarid mite pest, *Tyrophagus putrescentiae* (Schrank), *Caloglyphus rodrigeuzi* Samsinak, *Acarus siro* L. in addition to the insect *Ephestia kuehinella* (Keller) and incubated at 26°C and 65% RH. Development and reproduction of *C. malaccensis* were faster and females produced more eggs when they were provided with *T. putrescentiae* and followed by *C. rodrigeuzi* while *A. siro* was the last. *Cheyletus malaccensis* successfully doubled its population in a shorter time and had the highest rates of net reproduction, natural increase in addition to finite rate of increase when it fed on *T. putrescentiae*. The cheyletid mite *C. malaccensis* proved to be effective and can play a role in biological control of stored-product insect and mite pests.
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Key words: *Cheyletus malaccensis*, *Tyrophagus putrescentiae, Caloglyphus rodrigeuzi, Acarus siro,* biology and life tables.

1. Introduction

Food products become heavily infested with pest arthropods including mites. Storage mite communities are formed by herbivorous and fungivorous species. Among them, *Tyrophagous putrescentiae* (Schrank), *Caloglyphus rodrigeuzi* Samsinak, *Acarus siro* L. in the family Acaridae (Armitage and Stables, 1984). Their infestation decreases food quality due to contamination with metabolic wastes and microorganisms resulting in changes in odour and taste of food (Sinha and Paul, 1972).

Natural enemies of family Cheyletidae, are found on fruit trees feeding on phytophagous mites and scale insects, where they hide under their armours; in flour mills, granaries and store houses. They usually associated with stored product pests; in soil and debris and feeding on collembolan, housefly eggs and larvae and other small soil arthropods (Yousef et al. 1982; Zaher, 1986; Hagen et al. 1999 and Fouly and Al-Rehiayani, 2011). Some species of cheyletidae are considered parasites inhabiting nests of birds and wasps or in burrows of small mammals (Yousef et al. 1982 and Zaher, et al. 1986).

Different biological aspects of cheyletid mites have been studied by several authors (Wafa et al., 1970, 1971; Summers, 1973; Mohamed et al., 1982; Cebolla et al. 2009).

Several researchers designed biological control programs using different species of cheyletid mites and achieved considerable reduction percentages of insect and mite pests (Zdarkova 1986; Zdarkova and Horak 1990; Pekar and Hubert 2008).

In Saudi Arabia, Al Youssif and Soliman (1978) and Rostom (1993) collected some cheyletid mites from samples of wheat, maize, wheat bran and dust. They found *Acaropsis sollers* Rohd., *Cheyletus malaccensis* Oudemans and *Acaropsella volgini* (Gerson). Moreover, Fouly and Al-Rehiayani (2011) identified two cheyletid mite species, *C. malaccensis* and *Cheyletogenes ornatus* (C. & F.) in a survey study in Qassim region. Thus, very little data were found with regard the biological aspects of cheyletid mites under Saudi Arabia conditions. Therefore the present investigation aims to get some knowledge about the food range and the effect of diets consisting of three acarid mites, *T. putrescentiae*, *C.* rodriguezi and *A. siro* (Acari: Acaridae) on duration and feeding capacity as well as life table parameters of the cheyletid predatory mite *C. malaccensis* under laboratory conditions.

2. Material and Methods

Stock culture of mite and insect species

Individuals of the three stored food mite pests *T. putrescentiae* and *C. rodriguezi* as well as *A. siro* were chosen because their frequent occurrence in food stores in hail region. Mite individuals were collected by using the modified Tullgern's funnels (Krantz, 1986). A pure culture of the acarid mites was maintained in laboratory on mould cheese and bread. Mite cultures were kept in a plastic rearing unit, which was previously described by Fouly (1997). A culture of *A. siro* was maintained on grounded flour in glass jar of one kg. Samples were collected during spring and summer 2013 in Hail region, Saudi Arabia.

Rearing of Predatory Mite in Laboratory

The cheyletid predatory mite *C. malaccensis* was collected from stored flour samples by using the modified Tullgern's funnels at hail region in September 2012. Mite individuals were identified and transferred into small plastic rearing units (10cm in diameter) which were previously mentioned by Fouly (1997). Newly deposited eggs of *C. malaccensis* had been daily collected for ten days and singly placed in smaller rearing units (2 cm in diameter). Predatory mite eggs were divided into three groups of approximately 50 eggs each. Newly hatched larvae were provided with a surplus amount of one of the prey species, the developing stages of the acarid mites *T. putrescentiae* and *C. rodriguezi* as well as eggs of *A. siro* during their entire life span. A fourth group of larvae were subjected to eggs of *Ephestia kuehinella* (Keller) ((Lepidoptera: Pyralidae) as insect food source. All rearing units were kept in an incubator at 26±1C^{o} and 65%±5 RH. In all cases, incubation period, duration of developmental stages (in days), number of surviving mite individuals and egg production were recorded daily until the death of the last surviving predator female.

Statistical analyses

Data was statistically analyzed by ANOVA test to compare means of each treatment (LSD test, where P<0.05) using Duncan's Multiple Range Test and CoStat Software program (1990). Duration of immature stages, mortality, sex ratio and total number of deposited eggs/females of *C. malaccensis* were counted daily and used in calculation of life table parameters.

Life table parameters of *C. malaccensis* were calculated according to Birch (1948), Anderwartha and Birch (1954). After that the Basic Computer Program of Abou Setta *et al*., (1986) was applied, where the intrinsic rate of natural increase, r_m was estimated from the equation: $\Sigma e^{-r_m} l_x m_x = 1$, where: **x** is the age in days, l_x the age-specific survival rate (proportion of females alive at age **x**) x (survival rate during the immature stage) X (hatchability%), and m_x the oviposition rate at age **x** {(age-specific oviposition) x (proportion of females)}. The net reproductive rate (R_o), is given as $R_o = \Sigma l_x m_x$. The mean generation time (T), in days, is given by $T = \ln R_o / r_m$. The hatchability and developmental rate at lab conditions of 26^{o}C and 65% RH were used for l_x. The proportions of females (number of females/females + males) were used for calculating the m_x values. Moreover, the doubling time (DT) was determined according to Laughlin (1965); May (1976) and Carey (1993).

3. Results

Data in Table (1) indicated that there were no significant differences between the incubation period of eggs of *C. malaccensis* which ranged from 4.87 to 5.18 days. After that, hatched larvae showed significant difference in their duration according to the offered prey species. Predatory individuals didn't feed on eggs of *E. kuehinella* for about three days. The acarid mite *T. putrescentiae* shortened the duration period of male and female larvae by an average of 4.37 and 5.16, respectively. A longer larval development was achieved when larvae fed on *C. rodriguezi* and *A. siro* (LSD 0.31 – 0.26, P<0.05) for male and female larvae, respectively. The same trend was observed during the first nymphal stage, where *T. putrescentiae* caused the shortest duration and followed by *C. rodriguezi* and then *A. siro* for both male and female mite. After that, data showed that female passed through a second nymphal stage while males didn't. a diet of *T. putrescentiae* significantly accelerated the duration of female deutonymph by an average of 8.16 days while, there were no significant differences between female deutonymphs when predatory mites were subjected to *C. rodriguezi* and *A. siro* as food source. Accordingly, life cycle was the shortest when *C. malaccensis* fed on *T. putrescentiae*, while there were no significant differences between the total duration in case of *C. rodriguezi* and *A. siro* (Table 1).

Table 1. Duration in days (Mean ± SE) of incubation period, immature stages of *Cheyletus malaccensis* fed on *Tyrophagous putresenctiae*, *Caloglyphus rodriguzei* and *Acarus siro* and kept at 26^{o}C and 65% RH.

Stage	Sex	*Tyrophagous putresenctiae*	*Caloglyphus rodriguzei*	*Acarus siro*	L.S.D
Egg	♀	5.24±0.62 ^{a}	5.18±0.60 ^{a}	5.06±0.58 ^{a}	---
	♂	5.07±0.72 ^{A}	4.92±0.56 ^{A}	4.87±0.52 ^{A}	---
Larva	♀	5.16±0.62 ^{a}	6.20±0.74 ^{b}	6.77±0.82 ^{c}	0.26
	♂	4.37±0.46 ^{A}	5.83±0.64 ^{B}	6.68±0.74 ^{C}	0.31
Protonymph	♀	6.86± 0.78 ^{a}	7.48±0.48 ^{b}	8.18± 0.92 ^{c}	0.42
	♂	6.72±0.68 ^{A}	7.76±0.69 ^{B}	8.30±0.78 ^{C}	0.39
Deutonymph	♀	8.16±0.90 ^{a}	9.38±0.94 ^{b}	9.60±0.88 ^{b}	0.45
	♂	----	----	----	---
Life cycle	♀	26.12±3.24 ^{a}	28.24±3.62 ^{b}	29.61±3.88 ^{b}	2.24
	♂	16.16±2.02 ^{A}	18.51±2.64 ^{B}	19.85±2.82 ^{B}	1.15

Means followed by the same letter (lowercase for female-uppercase for males) in the same raw are not significantly different, Duncan Multiple Range Test (P=0.05)

Data in Table (2) showed that 92, 86 and 82% of the immature stages of *C. malaccensis* succeeded to reach maturity. That means a diet of *T. putrescentiae* caused the highest rate of immature survivorship and followed by *C. rodriguezi,* while *A. siro* eggs occupied the last rank. On the other hand, males showed two different shapes, heteromormphic and homomorphic. Male of *C. malaccensis* fed on *T. putrescentiae* completed its development before female and lived for only 23.11 days while female completed its longevity in 28.44 days. Longevity of both sexes was significantly differed when they were fed on *C. rodriguezi* and *A. siro*. In other words, male mite lived for 24.24 and 27.43 days, while female lived for 30.78 and 33.98 days when both sexes were fed on the aforementioned preys, respectively (Table 2).

Adult female of *C. malaccensis* took an average of 6.44, 7.42 and 8.78 days before laying its first egg when it was fed on *T. putrescentiae, C. rodriguezi* and *A. siro*, respectively. During an oviposition period of 18.45, 16.80 and 16.21 days, this female laid an average of 41.33, 28.22 and 20.08 eggs with a daily rate 2.24, 1.68 and 1.24 egg/female when predatory mite was fed on the same previous preys, respectively (Table 3). All differences were significant. These results showed that *T. putrescentiae* was the most efficient food source, where it gave the longest oviposition period and the highest rate of fecundity of *C. malaccensis*. After finishing the egg production, female of *C. malaccensis* fed on *T. putrescentiae, C. rodriguezi* and *A. siro* lived for an average of 3.55, 6.56 and 8.99 days before it died (Table 2).

Table 2. Survivorship % (egg to adult), duration of male and female, female oviposition period (in days) of *Cheyletus malaccensis* fed on *Tyrophagous putrescentiae*, *Caloglyphus rodriguzei* and *Acarus siro* and kept at 26°C and 65% RH.

Prey species	Survival rate %	Duration (in days)						
		Female			Longevity		Life span	
		Preoviposition	Oviposition	Postoviposition	♀	♂	♀	♂
Tyrophagous putresenctiae	92	6.44± 0.68 ^{a}	18.45± 1.82 ^{c}	3.55± 0.42 ^{a}	28.44± 2.82 ^{a}	23.11± 2.44 ^{A}	54.56± 5.82 ^{a}	42.96± 4.86 ^{A}
Caloglyphus rodriguzei	86	7.42± 0.74 ^{b}	16.80± 1.48 ^{b}	6.56± 0.72 ^{b}	30.78± 3.02 ^{b}	24.24± 2.16 ^{B}	59.02± 5.88 ^{b}	42.75± 4.22 ^{A}
Acarus siro	82	8.78± 0.82 ^{c}	16.21± 1.44 ^{b}	8.99± 0.88 ^{c}	33.98± 3.24 ^{c}	27.43± 2.68 ^{C}	63.59± 7.24 ^{c}	43.59± 4.64 ^{A}
L.S.D.		0.87	1.56	0.68	1.66	1.09	4.12	---

Values are represented as Mean± SE. Means followed by the same letter (lowercase for female-uppercase for males) in the same column are not significantly different, Duncan Multiple Range Test (P= 0.05)

Table 3. Total and daily rate of deposited eggs/female (Mean± SE) of *Cheyletus malaccensis* fed on *Tyrophagous putrescentiae*, *Caloglyphus rodriguzei* and *Acarus siro* and kept at 26°C and 70% RH.

No. deposited eggs/♀	Constant temperatures °C			L.S.D
	Tyrophagous putresenctiae	*Caloglyphus rodriguzei*	*Acarus siro*	
Total No.	41.33± 4.22 a	28.22±3.46 b	20.08±2.08 c	0.981
Daily rate	2.24±0.84	1.68±0.78	1.24±0.64	----

Means followed by the same letter in the same row are not significantly different, Duncan Multiple Range Test (P= 0.05)

Life table parameters of *C. malaccensis*

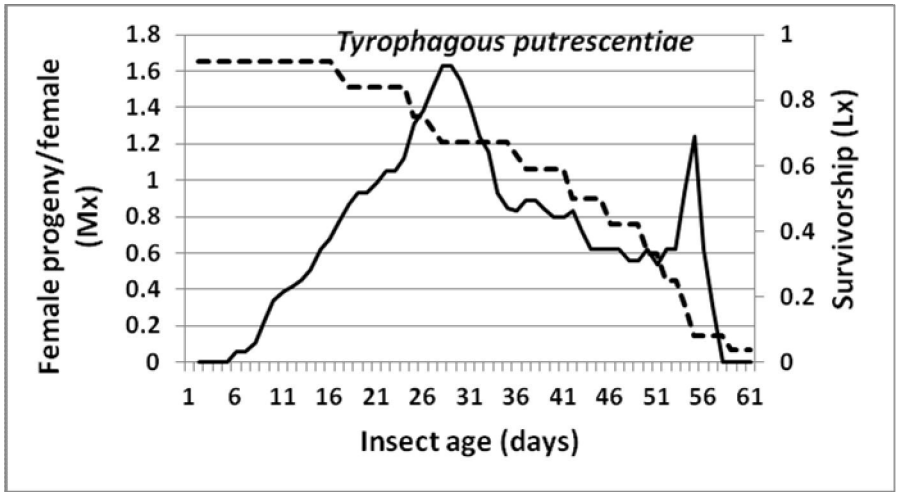
Table (4) showed that sex ratio of *C. malaccensis* was slightly affected by food source, where females percentages (females/females + males) averaged 62%, 58% and 56% when predatory mites were provided with *T. putrescentiae, C. rodriguezi* and *A. siro*, respectively. These values were subsequently used in calculation the specific rate of fecundity (Mx). Survival curves (Lx) of *C. malaccensis* showed that most eggs developed to maturity (92%, 86% and 82% when they fed the aforementioned preys, respectively) and most female death occurred gradually after extended ovipositional period (Figure 1). Table (4) also showed that *T. putrescentiae* was the most preferable food source because it caused a mean generation time (*T*) of only 55.27 days, while it prolonged to 70.17 and 72.03 days when the predatory mite was subjected to *C. rodriguezi* and *A. siro*, respectively. Also, *C.*

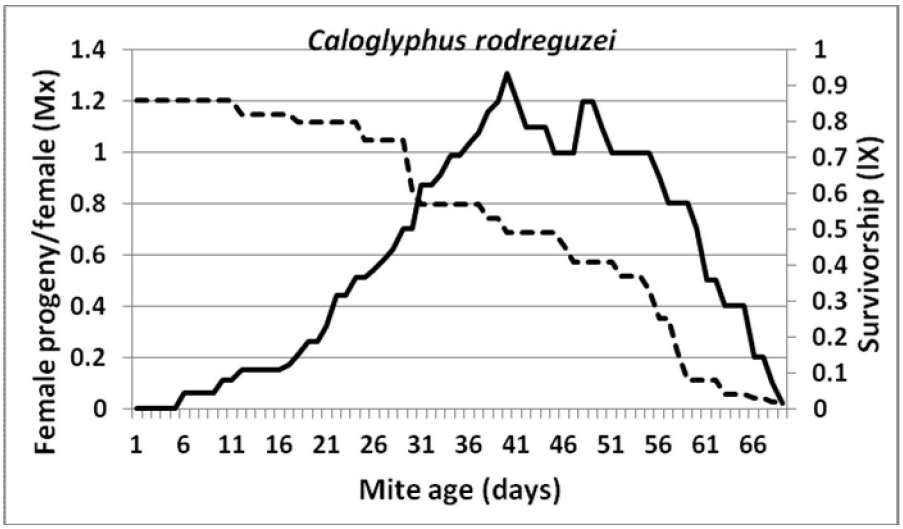
malaccensis needs to 11.75, 15.75 and 21.66 days to double its population (*DT*).

From Table (4) and Figure (1), it was clear that *T. putrescentiae* caused the highest value of reproductive rates ($Ro = \Sigma Lx\ Mx$) of 26.47 expected female daughters per female. These values slightly declined by feeding on *C. rodriguezi* (24.63) and then sharply decreased to 14.33 females|female when the predatory mite fed on *A. siro*, respectively.

Table 4. Life table parameters of *Cheyletus malaccensis* fed on *Tyrophagous putrescentiae*, *Caloglyphus rodriguzei* and *Acarus siro* and kept at 26°C and 70% RH.

Prey species	Proportion of Females (sex ratio)	Mean generation time (days) *T*	Doubling time *DT*	Net reproductive rate (female egg/female) (*Ro*)	Intrinsic rate of natural increase (r_m)	Finite rate of increase e^{rm} (λ)
Tyrophagous putrescentiae	0.62	55.27	11.75	26.47	0.059	1.062
Caloglyphus rodriguzei	0.58	70.16	15.75	24.63	0.044	1.046
Acarus siro	0.56	72.03	21.66	14.53	0.032	1.032





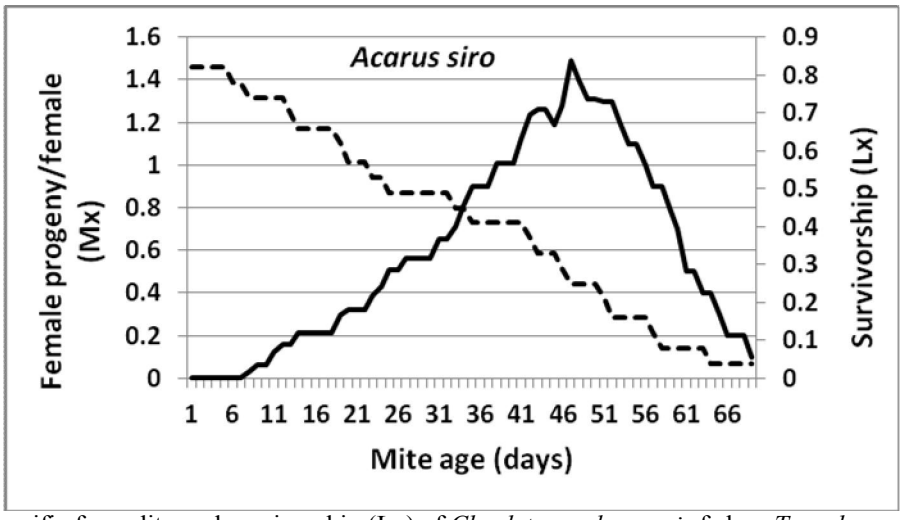


Figure 1. Age specific fecundity and survivorship (Lx) of *Cheyletus malaccensis* fed on *Tyrophagous putrescentiae*, *Caloglyphus rodriguzei* and *Acarus siro* and kept at 26°C and 65% RH.

Regarding the intrinsic rate of increase (r_m) (No. females/female/day), the present results showed that prey species obviously affected r_m value of *C. malaccensis* where it was 0.059 females progeny/female/day when predatory mite fed on *T. putrescentiae* and then declined to 0.044 and 0.032 when mites were fed on *C. rodriguezi* and *A. siro*, respectively (Table 4).

It was also noticed that the finite rate of increase e^{rm} (λ) (population multiplications in a unit of time, Birch 1948) was at its highest level (1.062) when *C. malaccensis* individuals fed on *T. putrescentiae* and slightly declined to 1.1.046 and 1.032 after feeding on *C. rodriguezi* and *A. siro*, respectively.

4. Discussion

Predatory mite individuals didn't accept eggs of *E. kuehinella* as food but they successfully developed and reproduced on other acarid mites. These observations were previously noticed by Cebolla, et al. (2009) who suggested that *C. malaccensis* has a strictly acarophagous predatory habit.

The present investigations showed that *T. putrescentiae* proved to be the most preferable prey because it caused the shortest development and adult longevity of *C. malaccensis* and followed by *C. rodriguezi*, while eggs of *A. siro* was the least efficient food source. Also, *T. putrescentiae* caused the highest rate of immature survivorship and followed by *C. rodriguezi,* while *A. siro* eggs occupied the last rank. Males of *C. malaccensis* had two dissimilar heteromorphic and homomorphic forms. Similar observations were obtained by Palyvos and Emmanouel (2006) in laboratory colonies of *C. malaccensis*. During adulthood, *T. putrescentiae* shortened the preoviposition period of *C. malaccensis* by 13.20% and 26.65% as compared with those fed on *C. rodriguezi* and *A. siro*, respectively. A diet of *T. putrescentiae* positively prolonged the duration of egg laying period by an average of 8.94% and 12.14 days longer than that of *C. rodriguezi* and *A. siro*, respectively. That directly resulted in a total number of deposited eggs 41.33 eggs which decreased by 31.72% and 51.41% when the predatory mite fed on *C. rodriguezi* and *A. siro*, respectively. These results clearly arranged the suitability of prey species as *T. putrescentiae* and followed by *C. rodriguezi* and *A. siro*. These results agree with the findings of Zaher, et al. (1986); Zdarkova (1986) and Pekar and Hubert (2008). Contradictory, Cebolla et al. (2009) showed that *Aleuroglyphus ovatus* and *C. redickorzev* were more preferable to *C. malaccensis* in comparison with *T. putrescentiae.*

Feeding on *A. siro eggs* resulted in *Ro* about 54.89% – 58.99% of that obtained by feeding on *T. putrescentiae* and *C. rodriguezi*, respectively. That means a diet of *A. siro* caused a lower numbers of expected female offspring as compared with other acarid mites. These findings agree with those of Yousef et al. (1982) who found that *T. putrescentiae*, especially immature stages, was the most preferable food source of *C. malaccensis*.

Concerning the intrinsic rate of increase (r_m) (female/female/day), Birch (1948) stated that r_m is the rate of increase of an insect species under specific physical conditions, in unlimited environment where the effects of increasing density don't need to be considered. Accordingly, *T. putrescentiae* proved

again its suitability as food source to obtain the highest rates of female offspring every day. On the other hand, the cheyletid mite needed for 11.75 days to double its population when it fed on *T. putrescentiae* but it had to spend 34.04 and 84.34% longer time when the food was *C. rodriguezi* and *A. siro* to do the same activity, respectively. That means *T. putrescentiae* helped the predatory mite to build up new generations in shorter time as compared with the two tested prey species. Similar results were obtained by Pekar and Hubert (2008) who found that rising temperature accelerated the natural increase of *C. malaccensis* provided with acarid mites and caused its ability to double its numbers in a shorter time.

From the previous results it can be concluded that *C. malaccensis* as acariphagous predator can be used as biological control agent to suppress populations of acarid mite pests infesting stored-product foods in Hail, Saudi Arabia.

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