

**Longevity and oviposition of Mediterranean fruit fly  
(*Ceratitis capitata*) (Diptera : Tephritidae) fed on a  
predominantly sugar and a predominantly protein diet**

**CORNELIA VAN DER MERWE**

Assignment presented in partial fulfillment of the requirements for the degree of Master of  
Science at the University of Stellenbosch.



Study leader: Dr. K.L. Pringle

March 2001

## **DECLARATION**

I, the undersigned, hereby declare that the work contained in this assignment is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

## OPSOMMING

Proewe met die Mediterreense vrugtevlieg, *Ceratitits capitata* (Wiedemann), is uitgevoer om die mortaliteit van die mannetjies en wyfies, asook eierlegging van wyfies wat met twee verskillende diëte voorsien is, te bepaal. Die onderskeie diëte het uit 'n mengsel van proteïen en suiker (5 dele suiker en 1 deel proteïen) en (5 dele proteïen en 1 deel suiker) bestaan. Verdunnings van 80%, 60%, 40%, 20% en 10% is van die onderskeie diëte gemaak en aan die vlieë voorsien. Daar was geen verskil in die lewensduur van wyfies wat op die twee diëte gevoed is nie. Mannetjies wat op die oorwegende suiker dieët gevoed is, het langer as dié wat op die proteïen dieët gevoed is, geleef. Vlieë wat op die suiker dieët gevoed het, het regdeur 'n hoër gemiddelde daaglikse eierlegging per wyfie as dié wat op die proteïen dieët gevoed het, getoon. Geen noemenswaardige verskil in eierlegging vir vlieë wat op verskillende konsentrasies van die twee diëte gevoed het, is gevind nie.

## ABSTRACT

Experiments using the Mediterranean fruit fly, *Ceratitidis capitata* (Wiedemann), were conducted to determine the mortality of males and females and the ovipositing ability of females fed on two diets. The sugar diet consisted of 5:1 sugar:protein and the protein diet consisted of 5:1 protein:sugar. Dilutions of 80%, 60%, 40%, 20% and 10% with water of both diets were also provided to the flies. Female longevity was shorter than male longevity. There was no difference in female longevity between fruit flies fed on the two diets. However, males fed on the sugar diet lived longer than those fed on the protein diet. More eggs per female per day were laid by those fed the sugar diet than by those fed the protein diet. There were no differences in oviposition between flies fed on the different concentrations of the two diets.

## **ACKNOWLEDGEMENTS**

I would like to thank my promoter, Dr. Ken L. Pringle, for all the advice and assistance that I received from him. I also thank INFRUITEC for providing flies for this study. The Deciduous Fruit Producer's trust contributed towards the funding of this project.

Thanks also to my fiancé, Christie, my parents, family and friends for support throughout my studies.

## **CONTENTS**

1.	Introduction	1
2.	Materials and Methods	2
3.	Results	3
4.	Discussion	11
5.	References	12

# **Longevity and oviposition of Mediterranean fruit fly (*Ceratitis capitata*) (Diptera : Tephritidae) fed on a predominantly sugar and a predominantly protein diet**

## **INTRODUCTION**

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), feeds on more than 200 plant species and causes serious losses to world fruit industries. This insect is seen as one of the most destructive and widely distributed fruit pests in the world (Fischer-Colbrie & Busch-Peterson, 1989).

The presence of *C. capitata* in fruit producing countries results in export barriers, as some of the important importing countries, such as the U.S.A, Canada, Japan and some European countries, do not have this pest. To overcome these market barriers, fruit fly free areas in infested countries have to be established. This can be achieved using the sterile insect technique (SIT). In the initial stages of a SIT programme, toxic bait sprays are usually applied to reduce the wild population. Fruit fly nutrients are used as the attractant in these bait sprays (Steiner, 1952). The most commonly used nutrients are some form of protein hydrolysate, as protein is required for egg production by the females, and mating success by the males (Warburg & Yuval, 1997). However, sugar is also required by adult fruit flies.

The nutritional behaviour of insects often reflects their physiological needs for survival and reproduction (Warburg & Yuval, 1996). Fruit flies are self-selective (*sensu* Cangussu & Zucoloto, 1995). Adult fruit flies can discriminate between diets containing different proportions of carbohydrate and protein (Teran 1978). Müller *et al.* (1997) have found that females maintained on a normal diet (sugar and protein) had a longer life expectancy than males maintained on the same diet, but they also showed that, with protein deprivation, this sex differential reversed in favour of males. Male mortality and life expectancy was only mildly affected by protein deprivation.

The aim of the present study was to determine the effects of different concentrations of a predominantly sugar diet and predominantly protein diet on oviposition and longevity of a South African strain of *C. capitata*.

## **MATERIALS AND METHODS**

### **Fruit flies**

The fruit flies used in this study originated from a population that was collected from fruit trees in gardens at Riebeek-Kasteel and Riebeek-West, near Malmesbury (South Africa). They were reared in the laboratory of INFRUITEC, Stellenbosch, since 1997 (about 34 generations) using the methods described by Barnes (1976). The flies were between 24 and 48 hours old when the experiments were initiated.

### **Diets**

The predominantly sugar diet (subsequently referred to as the sugar diet) was sugar : protein in a ratio of 5:1. This is a standard adult diet (Barnes, 1976). The predominantly protein diet (subsequently referred to as the protein diet) was protein : sugar in a 5:1 ratio. The sugar used was Hulett's sugar (sucrose) and the protein was a hygroscopic, enzymatic, autolyzed brewer's yeast. Six concentrations of these diets were prepared by diluting with distilled water to 80%, 60%, 40%, 20% and 10% solutions. The 100% diets were the solid, undiluted mixture of sugar and protein. The standard adult diet (sugar : protein, 5:1) also served as the control for both the predominantly sugar diet and the predominantly protein diet. The experiments were repeated three times for each trial and continued until either all the females or all the males were dead.

One ml of the food solution was placed in glass containers 20 mm high and 25 mm in diameter. Glass beads (diameter 2 mm) were placed in the glass containers to prevent the flies from drowning in the food solution. Food was replaced every second day, and clean distilled water on cotton wool was provided daily.

### **Experimental conditions**

Experiments were conducted in 30cm x 30cm x 38cm and 25cm x 25cm x 18cm perspex cages in an air conditioned room maintained at an average temperature of 24.96 °C (maximum 28 °C; minimum 22 °C), with 14 hrs light per day. Twenty females and twenty males were kept in each cage.

### **Mortality**

Dead flies were counted every 24 hrs at night when activity had ceased. They were removed and their sex was noted. The longevity of the flies was expressed as the time to 50%



mortality. This measure was used in favour of the average life span, because the latter can be greatly influenced by individual flies, living for exceptionally long periods. The time to 50% mortality was analyzed in a factorial design with gender, diet and concentration as main effects.

## Oviposition

The ovipositing site was a cylindrical sieve 6 cm high and 6 cm in diameter with a mesh size of 200  $\mu\text{m}$ . Petri dishes, six cm in diameter, were placed on the top and bottom of the cylindrical sieve. The bottom petri dish was filled with water and the top petri dish had a hole in it of  $\pm 5$  mm in diameter through which a piece of cotton wool was drawn. The cotton wool was wetted with 1ml of pure guava juice to attract the females and stimulate oviposition through the sieve. The eggs on the inside of the sieve and in the water in the bottom petri dish, were then counted daily. Data pertaining to the average number of eggs laid per female per day and total number of eggs laid, were analyzed as a factorial experiment with diet (sugar diet and protein diet) and concentrations (100%, 80%, 60%, 40%, 20% and 10%) as main effects. However, the variances were not homogeneous (Bartlett's  $\chi_{11}^2 = 31.93$ ;  $P = 0.00078$ ) therefore data were log-transformed. This successfully stabilized the variances (Bartlett's  $\chi_{11}^2 = 14.19$ ;  $P = 0.22$ ).

## RESULTS

### Longevity

*C. capitata* males fed on the standard diet lived longer than the females (Fig. 1). The time to 50% mortality was affected by diet and gender, but not by concentration (Table 1). However, there were interactions between diet and gender (Table 1). The interaction was due to the fact that diet appeared to have a marked effect on the time to 50% mortality of the males, but not of the females (Fig. 2). Therefore, data for male and female flies were analyzed separately. Diet had a significant effect on the time to 50% mortality of the males (Table 2) but not on that of the females (Table 3). The time to 50% mortality of males fed on the sugar diet was longer than for those fed the protein diet (Fig. 3A). In the case of females the time to 50% mortality was similar for both diets (Fig. 3B). The concentration of the diets did not affect survival of either male or female fruit flies (Tables 2 and 3).

**Table 1.** Factorial analysis of variance of time to 50% mortality of *Ceratitits capitata* with diet, concentration of diet and gender as main effects.

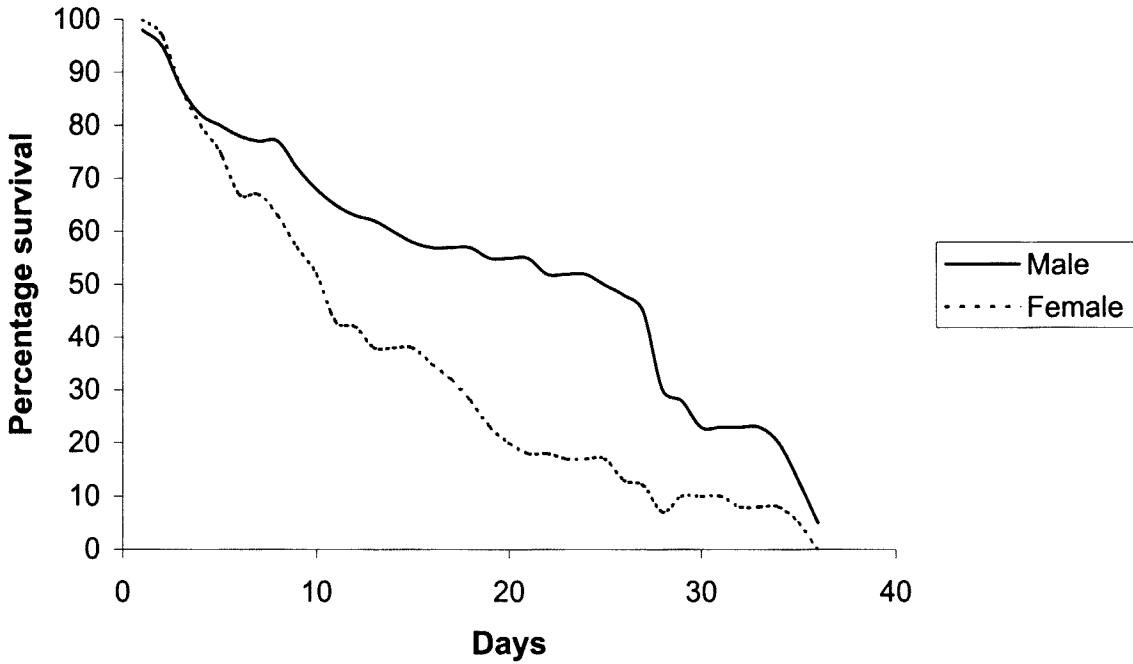
Source	df	SS	MS	F	p-level
Diet (D)	1	636.06	636.06	27.87	<0.001
Concentration (C)	5	220.11	44.02	1.93	0.107
Gender (G)	1	840.5	840.5	36.83	<0.001
DxC	5	114.11	22.82	1.00	0.428
DxG	1	420.5	420.5	18.43	<0.001
CxG	5	35.33	7.07	0.310	0.905
DxCxG	5	42.00	8.4	0.368	0.868
Error	48	1095.33	22.82		

**Table 2.** Factorial analysis of variance of the time to 50% mortality of male *Ceratitits capitata* with diet and concentration as main effects.

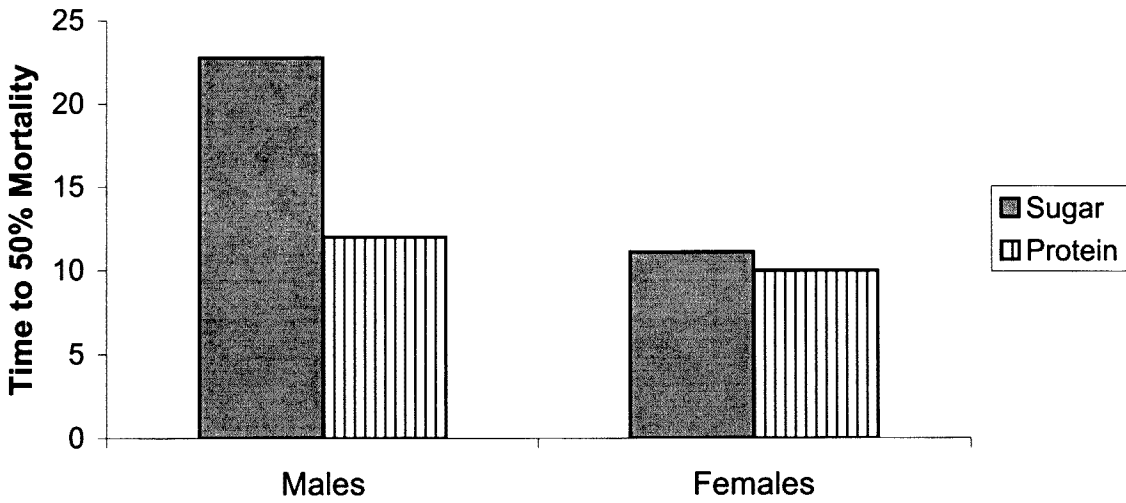
Source	df	SS	MS	F	p-level
Diet (D)	1	1045.44	1045.44	44.17	<0.001
Concentration (C)	5	190.56	38.11	1.61	0.195
DxC	5	76.56	15.31	0.647	0.666
Error	24	568.00	23.67		

**Table 3.** Factorial analysis of variance of the time to 50% mortality of female *Ceratitits capitata* with diet and concentration as main effects.

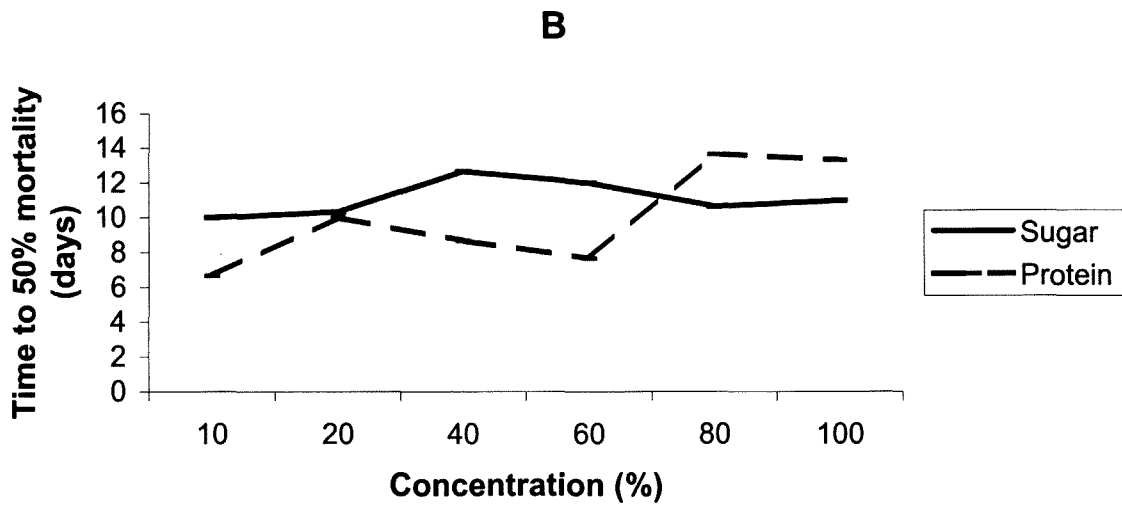
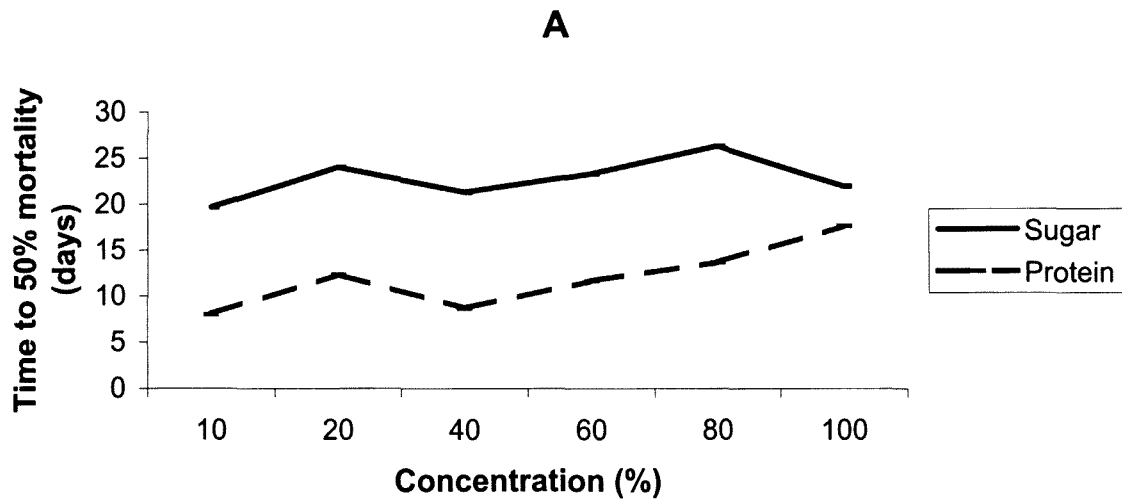
Source	df	SS	MS	F	p-level
Diet (D)	1	11.11	11.11	0.506	0.484
Concentration (C)	5	64.89	12.98	0.591	0.707
DxC	5	79.56	15.91	0.724	0.612
Error	24	527.33	21.97		



**Fig 1.** Percent survival of male and female *Ceratitis capitata* fed the standard sugar:protein, 5:1 diet



**Fig 2.** Time to 50% mortality in days for male and female *Ceratitis capitata* fed the sugar and protein diets.



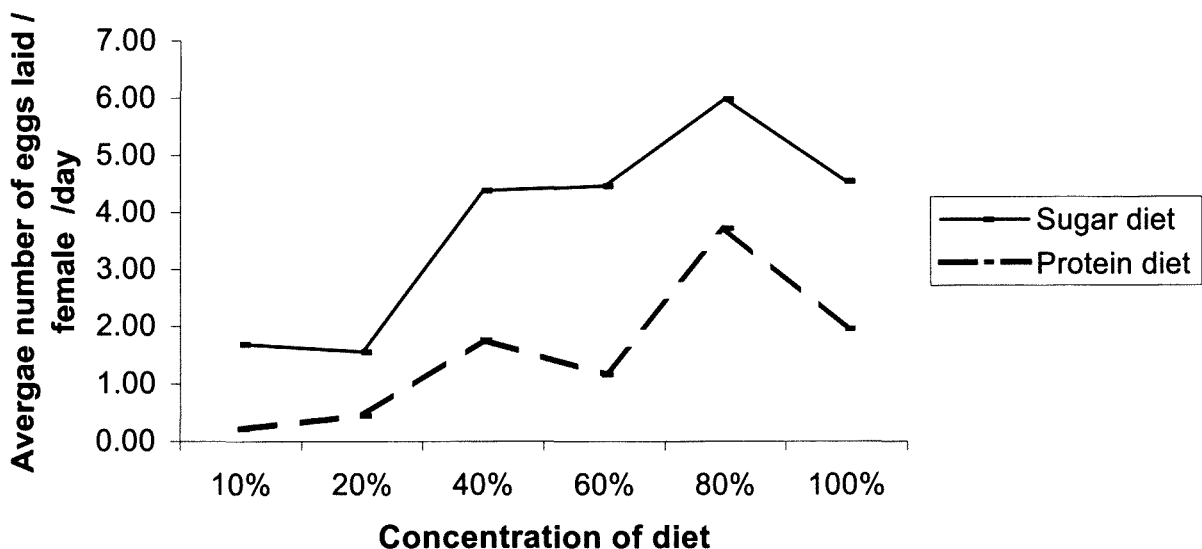
**Fig 3.** Time to 50% mortality (days) of *Ceratitidis capitata* fed different concentrations of the protein and sugar diets for A males; B females.

## Oviposition

More eggs/female/day were laid by females fed on the sugar diet (3.77 eggs/female/day) than by those fed the protein diet (1.54 eggs/female/day). This difference was significant (Table 4). There were no differences in oviposition at the different concentrations of the diets (Table 4). However, there appeared to be a trend of decreasing numbers of eggs/female/day as the concentration decreased (Fig. 4), although females fed on the 80% dilution diet produced more eggs than those fed the 100% diet. This could have been because the solution (80%) was easier to imbibe than the solid (100%) diet.

**Table 4.** Analysis of variance of the average number of eggs laid per female per day by *Ceratitis capitata* with diet and concentration as main effect.

Source	Df	SS	MS	F	p-level
Diet (D)	1	44.64	44.64	5.53	0.027
Concentration (C)	5	66.33	13.27	1.64	0.187
DxC	5	4.92	0.983	0.122	0.986
Error	24	193.93	8.08		

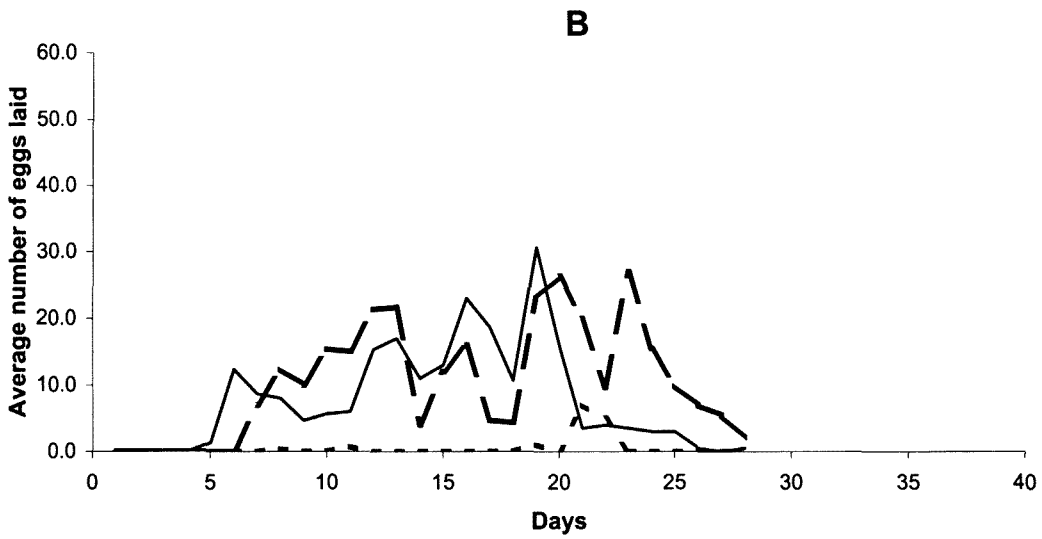
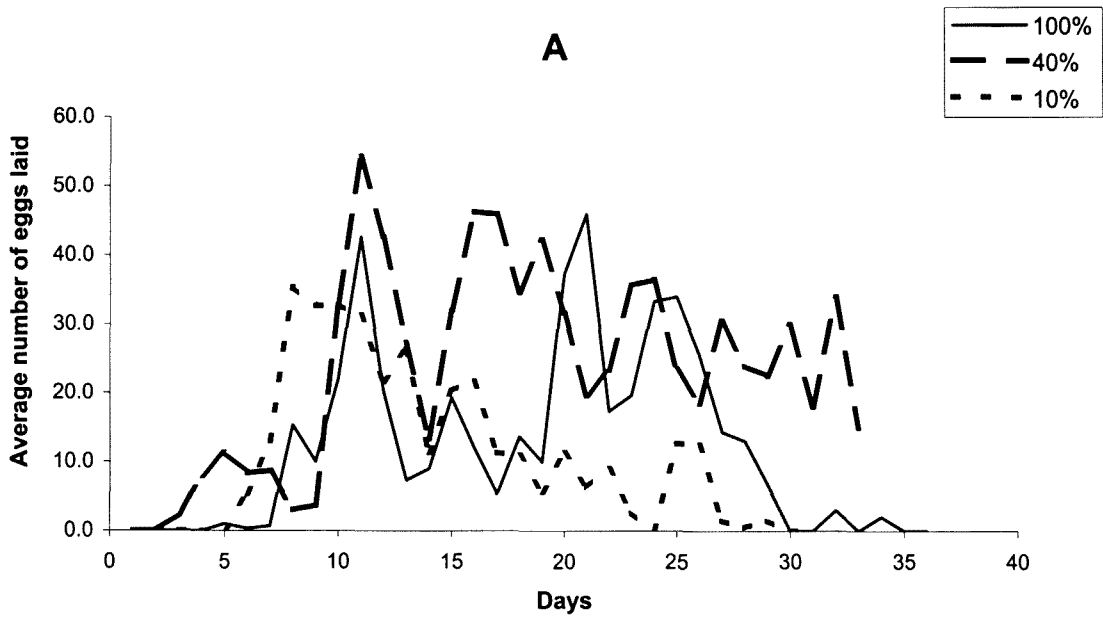


**Fig. 4.** Average number of eggs laid per female per day by *Ceratitis capitata* versus the different concentrations of the sugar and protein diets.

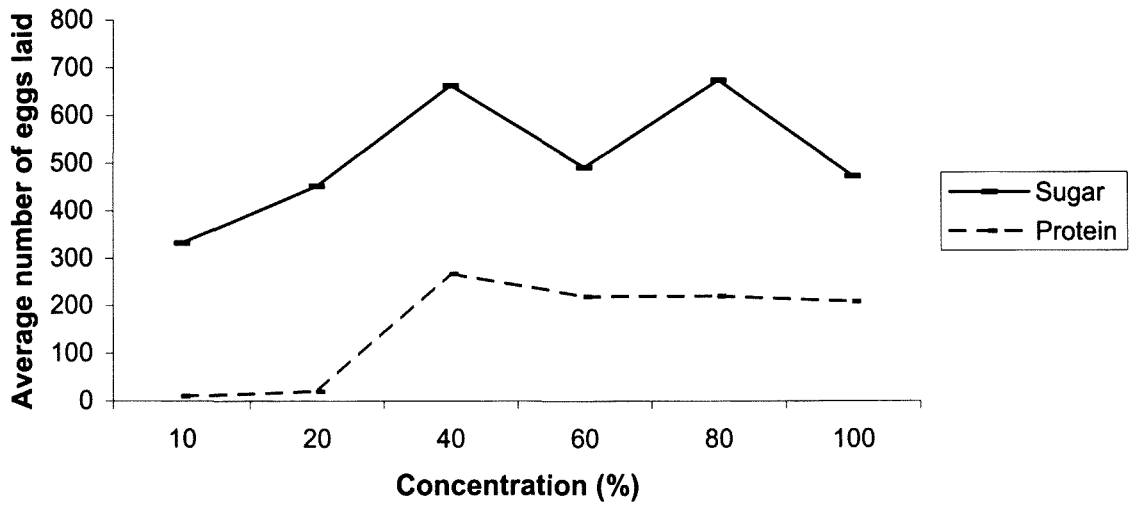
Oviposition started between days two and seven (Fig. 5). For clarity, data for only three concentrations are shown in Fig 5. More eggs were laid by flies supplied with the sugar diet than by those fed with the protein diet (Fig. 6). The differences were significant (Table 5). Differences in concentrations of the diets bordered on significance (Table 5). However, it appeared as if fewer eggs were laid by flies fed on the low concentration of diet than by those fed with the higher concentration (Fig. 6), especially in the case of the protein diet.

**Table 5.** Analysis of variance of the total number of eggs laid by female *Ceratitis capitata* with diet and concentration as main effect.

Source	Df	SS	MS	F	p-level
Diet (D)	1	5.03	5.03	7.78	0.010
Concentration (C)	5	7.78	1.56	2.41	0.066
DxC	5	1.50	0.301	0.465	0.798
Error	24	15.50	0.646		



**Fig 5.** Average number of eggs laid over time by *Ceratitidis capitata* supplied with three concentrations of the sugar diet (A) and by flies supplied with three concentrations of the protein diet (B).



**Fig. 6.** Total number of eggs laid by *Ceratitis capitata* fed different concentrations of the sugar and protein diets



## DISCUSSION

### Longevity

The average life span of *C. capitata* fed on the sugar diet was longer than that of the flies fed on the protein diet. Regardless of diet, males lived longer than the females. This contradicts the results of Müller *et al.* (1997) who found that females maintained on a normal diet (our sugar diet) had a longer life expectancy than males maintained on the same diet, although this was reversed under protein deprivation. No explanation could be found for the lower female than male longevity of flies fed the protein diet in our experiments.

### Oviposition

The sugar diet was more suitable for oviposition by *C. capitata* than the protein diet. In the case of both diets, fruit flies fed the 80% dilution laid more eggs/female/day than those fed the other concentrations, including the 100% diet (Fig. 4). This was also the case for the total number of eggs produced (Fig. 6).

Blay & Yuval (1997) found that males fed on yeast only, emitted less pheromones than males fed on yeast and sucrose, or sucrose alone. The protein diet used in this study consisted of 5 parts protein and 1 part sugar. Therefore, the sugar levels in the protein diet may have been too low for sufficient pheromone production by the males, which could have a direct effect on mating and thus egg production by females.

### General

Fruit flies fed on the predominantly sugar diet had an overall better performance, measured in terms of longevity and oviposition, than those fed on the predominantly protein diet. This, combined with the self-selective ability of *C. capitata* (Cangussa & Zucoloto, 1995) and its ability to discriminate between different diets (Teran, 1978), suggests that sugar as an ingredient in baits should be investigated.

**REFERENCES**

- BARNES, B.N. 1976. Mass rearing the Natal fruit fly *Pterandrus rosa* (Ksh.) (Diptera: Trypetidae). *Journal of the Entomological Society of South Africa* **39** : 121-124
- BLAY, S. & YUVAL, B. 1997. Nutritional correlates of reproductive success of male Mediterranean fruit flies (Diptera: Tephritidae). *Animal Behavior* **54** : 59-66.
- CANGUSSU, J.A. & ZUCOLOTO, F.S. 1992. Nutritional value and selection of different diets by adult *Ceratitis capitata* flies (Diptera: Tephritidae). *Journal of Insect Physiology* **38** : 485-491
- CANGUSSU, J.A. & ZUCOLOTO, F.S. 1995. Self-selection and perception threshold in adult females of *Ceratitis capitata* (Diptera: Tephritidae). *Journal of Insect Physiology* **41** : 223-227.
- FISCHER-COLBRIE, P & BUSCH-PETERSON, E. 1989. Pest Status: Temperate Europe and West Asia Chapter 2.8 in: *World Crop Pests: Fruit Flies – Their Biology, Natural Enemies and Control. Volume 3A*. A.S. Robinson and G. Hooper (Eds). Elsevier Science Publishing Company Inc., New York.
- MÜLLER, H.; WANG, J.; CAPRA, W.B.; LIEDO, P.; CAREY, J.R. 1997. Early mortality surge in protein-deprived females causes reversal of sex differential of life expectancy in Mediterranean fruit flies. *Proceedings of the National Academy of Science of the United States of America*. **94** : 2762-2765.
- STEINER, L.F. 1952. Fruit fly control in Hawaii with poison bait sprays containing protein hydrolizates. *Journal of Economic Entomology* **45** : 838 - 843.
- TERAN, H.R. 1978. Seleccion de alimentos por los machos e influencia de estos y del espacio vital sobre el compartamiento reproductivo de las hembras de *Ceratitis capitata*. *Revisita Agronomica Noroeste Argentino* **15** : 59-66
- WARBURG, M.S. & YUVAL, B. 1996. Effects of diet and activity on lipid levels of Mediterranean fruit flies. *Physiological Entomology*. **21** : 151-158.

WARBURG, M.S. & YUVAL, B. 1997. Circadian patterns of feeding and reproductive activities of Mediterranean fruit flies (Diptera: Tephritidae) on various hosts in Israel. *Annals of the Entomological Society of America*. **90** : 487-495.