

Flight and Oviposition Behavior of *Ephestia cautella* and *Plodia interpunctella* in Response to Odors of Different Chocolate Products

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*The present study is included in a project with the aim to develop attractants from food odors for trapping female moths. Males and mated, but not unmated, females of *Ephestia cautella* and *Plodia interpunctella* were attracted by odors of three different chocolate products in flight tunnel experiments. Chocolate containing nut or rum elicited upwind flight and landing responses. Extracts of the chocolate products induced upwind flight in both species and both sexes. Larvae of the tested species survived best in plain chocolate (*E. cautella*) or nut-containing chocolate (*P. interpunctella*). The oviposition preference of *P. interpunctella* females seems to be highly adaptive, since females oviposited in the diet most suitable for larval feeding, whereas *E. cautella* females showed a less selective oviposition preference, between the diets tested.*

KEY WORDS: food odors; flight tunnel; Pyralidae; Lepidoptera; attraction; oviposition; larval survival.

INTRODUCTION

Pyralid moths (Lepidoptera) infest stored products all over the world and the need for efficient control methods is prominent. In pest management,

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methods based on pheromones have been developed to circumvent the development of resistance to pesticides and to lower the use of toxic chemicals (see e.g., McNeil, 1991; Cardé and Minks, 1995; Foster and Harris, 1997). Pheromone-based methods, such as mass trapping and mating disruption, however, only target males which could be a drawback, since untrapped males or males not affected by disruption possibly remate and are thus able to maintain the population at high densities (Lanier, 1990). To include control of females of stored product moths in management programs, utilization of food odors has been suggested (Chambers, 1991), since host volatiles may induce landing by gravid insects (Renwick, 1989). Chemicals acting as ovipositional cues have been found for some pyralid moths, e.g., almond oil for *Amyelois transitella* Walker (Phelan *et al.*, 1991) and farnesene and other terpenoids for *Ostrinia nubilalis* Hübner (Binder *et al.*, 1995; Binder and Robbins, 1997).

Two pyralid moth species typically infesting indoor habitats are the Indian meal moth, *Plodia interpunctella* Hübner and the almond moth, *Ephestia cautella* Walker. A few studies on these polyphagous species have examined the effects of laboratory diets on adult female behavior. A diet based on corn induced upwind flight and oviposition of gravid females of *P. interpunctella* (Phillips and Strand, 1994). Nuts and almonds also seem to contain odors attractive for gravid females (Hoppe, 1981), and walnut oil can act as an oviposition stimulant for *P. interpunctella* (Nansen and Phillips, 2003). A 1:1 mixture of acetic acid and isoamyl alcohol have been used for trapping female *P. interpunctella* (Toth *et al.*, 2002). Several studies have come to the conclusion that wheat odors induce flight and oviposition in gravid *E. cautella* females (Barrer, 1977; Barrer and Jay, 1980; Gothilf *et al.*, 1993). Adult *E. cautella* moths were observed flying around large bins containing a variety of chocolate products in a Swedish chocolate factory suggesting that we could find and isolate attractive odors from the various chocolate products. We also hypothesized that *P. interpunctella* would respond to the same type of products and odors, since the two moth species share the same food preferences (Benson, 1973; Levinson and Levinson, 1978).

The objectives of this study were to find products that induce flight behavior of the target species and to test how attraction differ depending on species, sex, and mating status. We also report on the possibility to extract the attractive odors from the products by using two different extraction methods, headspace collection and steam distillation. In addition, we observed if the diets were suitable for reproduction and recorded the close-range choice of gravid females between different diets.

MATERIALS AND METHODS

Insects

Laboratory cultures of *E. cautella*, originating from a Swedish chocolate factory, and *P. interpunctella*, provided by the Danish Pest Infestation Laboratory at Lyngby, were used in the experiments. The larvae were reared on a diet containing 100 g of wheat germ, 10 g of Brewer's yeast, and 20 g of glycerol, in jars placed in a climate chamber with 17:7 (L/D) photoperiod at 24°C and 60% relative humidity (r.h.). Insects were sexed at the pupal stage and the adults were kept in separate climate chambers with the same conditions.

Flight Tunnel Experiments

A 70 cm × 70 cm × 200 cm flight tunnel, earlier described by Zhu *et al.* (1999), was used. The air was pushed through the flight tunnel with a fan at 0.5 m/s. Light intensity was set to 10 lux, temperature was maintained at 23°C ± 1°C and r.h. was 30–50%. All flight tunnel experiments were conducted during the first 2 h of the scotophase, a period of which behavioral tests have been conducted before, both for females (Phillips and Strand, 1994) and males (Zhu *et al.*, 1999). One- to three-day-old moths were tested for 3 min and a total of 30 moths were tested on each stimulus. All chocolate products tested were treated and presented in the same way, 15 g of each were mashed and put in a 90-mm Petri dish and covered with a metal mesh to avoid responses to visual and contact cues. The metal mesh was cleaned with ethanol and heated at 300°C in an oven for 4 h between experiments.

In the mating status experiments 60 virgin moths of each sex were tested in the flight tunnel. Fifteen grams of the rearing diet mentioned above were used as test stimulus. After being tested in the flight tunnel, all moths were put individually in 250 mL plastic jars and half of the moths were allowed to mate with a conspecific until the onset of the scotophase the next day whereas the other half was maintained unmated. The next day the moths were tested again, the unmated moths functioning as a control group to exclude time or preexposure effects. Three females that had oviposited in the mating jar were excluded, since attraction to ovipositional cues would presumably decrease after oviposition. Females exhibiting pheromone calling behavior in the mating jar were assumed to be unmated, and were therefore not tested in the flight tunnel experiments.

Chocolate Products

In all subsequent behavioral experiments mated females and unmated males were used, based on the results from the mating status experiment. Diets tested were wheat-based rearing diet, plain chocolate, a nut-containing chocolate product and a rum-flavored chocolate product. The control was an empty Petri dish covered with a metal mesh. Upwind flight, defined as moths orienting and reaching at least halfway in the flight tunnel, and landing were observed in the flight tunnel.

Headspace Extracts

The volatiles emanating from the chocolate products were collected with a closed loop stripping analysis setup (Bestmann *et al.*, 1988). The volatiles from 15 g of a product were collected for 24 h on a charcoal filter, the filter extracted with 80 μL of dichloromethane and the extract diluted with 720 μL cyclohexane. The extracts were tested in the flight tunnel by using an ultrasonic sprayer (El-Sayed *et al.*, 1999), working at a frequency range of 290–320 kHz which was optimized to avoid disturbing effects of moths hearing the ultrasound (Skals *et al.*, 2003). The extracts were released at a rate corresponding to the sampling rate in the closed loop setup. As a control, a 9:1 mixture of cyclohexane and dichloromethane was used. Upwind flight and landing were observed in the flight tunnel.

Steam Distillation Extracts

Each of the three types of chocolate products was subjected to steam distillation. Water was boiled at elevated pressure in a separate vessel and the steam was transferred to a vessel containing 200 g of chocolate kept at 100°C. During 2 h the steam from the stirred water-chocolate mixture was collected and cooled to room temperature. The collected water layer was extracted three times with diethyl ether. The layer containing a noticeable odor of chocolate (300 mL) was dried with MgSO_4 and concentrated under reduced pressure to 2 mL. In order to release comparable concentrations of the two different extract types in the sprayer, they were quantitatively compared on a gas chromatograph. By comparing peak areas from chromatograms of the two extraction types, the concentration of volatiles in the extracts could be roughly estimated and used for subsequent dilution. A Hewlett Packard 5890 gas chromatograph with a nonpolar HP-1 column was used for the comparisons. The samples were injected splitless and the

injector temperature was 225°C. The carrier gas was hydrogen. The column temperature was kept at 40°C for 2 min then increased by 10°C/min up to 230°C. The temperature was finally kept at 230°C for 10 min.

Oviposition Experiments

The same four diets as in the flight tunnel experiments were tested. Two different experimental setups were used, a no-choice test and a four-choice test. In the no-choice test 10 g of each diet were put in a 250-mL jar with one male and one female, and the jar was put in a climate chamber with L17:D7 photoperiod at 24°C and 60% r.h. After mating, the time of three developmental stages was observed, i.e., larval hatching, start of pupation and emerging adult moths. The adult moths were counted and the sex ratio was recorded. Ten jars were observed for each diet and species.

In the four-choice test, four 90-mm Petri dishes with 10 g of each diet, respectively, were put in a 22 cm × 31 cm × 12 cm plastic box in the climate chamber as described above. One male and one female were allowed to mate for 48 h. The moths were then removed to minimize the risk that the subsequent batches of eggs were affected by the odors of the previously laid eggs, and thereby skewing the experimental outcome. The hatching larvae were observed and the diets containing larvae were considered attractive, whereas those without larvae were recorded as nonattractive. The resulting proportion for each box and diet would then be 25, 33, 50, or 100% depending on whether 4, 3, 2, or 1 diets, respectively, contained larvae. Ten boxes with each species were observed.

Both headspace and steam distillation extracts were also tested in a four-choice oviposition experiment. Petri dishes with filter paper applied with 20 μ L of extract at the same dose used in the flight tunnel experiment; plain, nut-containing and rum-flavored chocolate, were used. Twenty microliters of the 9:1 mixture of cyclohexane and dichloromethane was used as a control in the experiments with headspace extracts, whereas 20 μ L of cyclohexane only was used as a control in experiments with steam distillation extracts. All four Petri dishes were put in a 22 cm × 31 cm × 12 cm plastic box in the climate chamber as described above. One male and one female were allowed to mate and after 48 h the eggs in each Petri dish were counted. The proportion of laid eggs were calculated by dividing the number of eggs in a diet by the total number of eggs in the box. A total of 20 boxes were observed for each species and extract type. Boxes with females that had laid less than 10 eggs were excluded before data analysis to avoid biased influence of females laying extraordinary low numbers of eggs.

Statistics

The flight tunnel data were analyzed at the $p < 0.05$ level with Ryan's multiple comparison test for proportions (Ryan, 1960). Data from the oviposition experiments were tested by ANOVA followed by Tukey's post hoc test at $p < 0.05$ level in SPSS 10.0 for Macintosh. Proportions were arcsin-transformed before statistical analysis.

RESULTS

Mating Status

The mating status experiment in the flight tunnel showed, for both *E. cautella* and *P. interpunctella*, that mated females were more induced to land, whereas mating did not alter the males' response to the diet odors (Fig. 1).

Flight Towards Chocolate Products

The flight tunnel experiments with chocolate products revealed small differences in the responses of the two sexes of *E. cautella*, only responses to plain chocolate showed a significant intersexual difference, both for upwind flight and landing (Table I; Fig. 2). Males were significantly more attracted to all the products than to the control, whereas females were attracted to all products except plain chocolate, for which the responding number was not significantly different from the control (Table I; Fig. 2). For *P. interpunctella*, females were induced both to fly upwind and to land by all products tested. For males, only rearing diet was significantly better than the control (Table I; Fig. 2). All chocolate-based diets showed a significant intersexual difference in the landing response of *P. interpunctella*, but not for the upwind flight behavior. Data for upwind flight and landing are nearly identical.

Flight Towards Extracts

When analyzing upwind flight behavior in response to headspace extracts, we found that females of *E. cautella* were more induced to fly upwind to the nut-containing and rum-flavored chocolate extracts, compared to the control (Table I). More males responded to the chocolate extracts than the control but the results were not significant. Both sexes of *P. interpunctella* were induced to fly upwind by the headspace extracts, except that

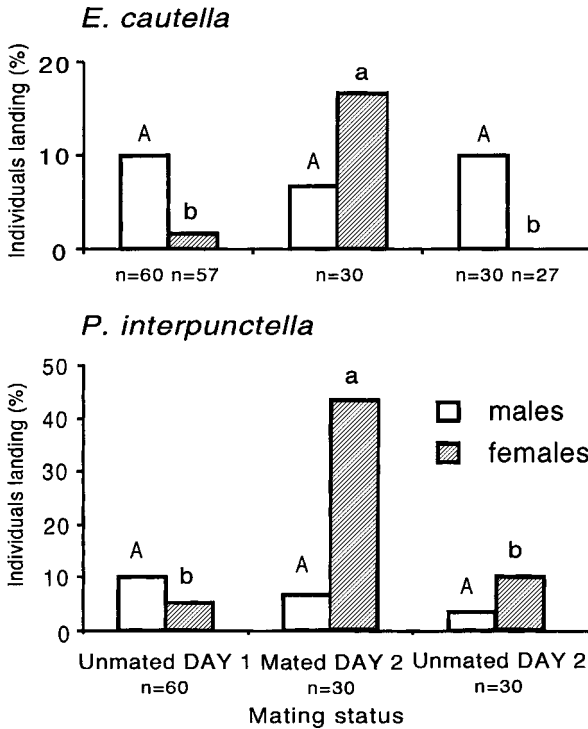


Fig. 1. Percentage of males and females of *Ephestia cautella* and *Plodia interpunctella* that were induced to land by 15 g of wheat-based rearing diet. Bars within sex with the same letters do not differ significantly at $p < 0.05$ level (Ryan's test).

of plain chocolate to which only females were attracted. The GC comparison revealed that the steam distillation extracts contained much higher concentrations of some chemicals, thus the original steam distillation extracts were diluted 100 times with cyclohexane before tested in the flight tunnel. The steam distillation extracts showed the same pattern, a higher proportion of individuals flew upwind when tested against chocolate odors, except to extract of rum-flavored chocolate to which only females were attracted (Table I). The observed proportion of landing females on the headspace extracts was not significantly different from the control in any of the species. In males, however, landing rate was higher for rum-flavored chocolate than for the control in both species and also for nut-containing chocolate in *P. interpunctella* (Fig. 3). Extracts from steam distillation induced lower rates of landing than headspace extracts for both species and both sexes, with the

Table I. Percentage of Individuals Flying Upwind When Tested in the Flight Tunnel Against Stored Products and Headspace and Steam Distillation Extracts of Chocolate Products

Control	<i>Ephestia cautella</i>		<i>Plodia interpunctella</i>	
	Males	Females	Males	Females
Flight towards stored products				
Control	17B	3d	10B	3b
Wheat rearing diet	67A	47bc	53A*	83a
Plain chocolate	73A*	23cd	27AB*	57a
Nut-containing chocolate	60A	80a	37AB*	63a
Rum-flavored chocolate	67A	73ab	40AB*	67a
Flight towards extracts of chocolate products				
Control	27C	10b	10C	0c
Headspace				
Plain chocolate	57ABC	40ab	20C	40ab
Nut-containing chocolate	60ABC	50a	60AB	73a
Rum-flavored chocolate	60ABC	47a	83A	57ab
Steam distillation				
Plain chocolate	87A*	37ab	83A*	50ab
Nut-containing chocolate	47BC	43ab	53AB	47ab
Rum-flavored chocolate	70AB*	23ab	27BC	33b

Note. Data within a column with the same letter do not differ significantly at $p < 0.05$ (Ryan's test, $n = 30$). Intersexual difference is indicated by an asterisk.

exception of plain chocolate that was significantly different from the control and induced more than 50% of *P. interpunctella* males to land (Fig. 3).

Oviposition Experiments—No-Choice

No difference in the number of emerged males and females moths was observed in either *E. cautella* or *P. interpunctella*. Therefore, in the subsequent statistical analyses the data for males and females were pooled and regarded as one group, the total number of emerged moths (Fig. 4). For both species, most moths emerged in the standard rearing diet (Fig. 4). For *E. cautella* the number of emerged moths in chocolate did not differ significantly from that in rearing diet, whereas for *P. interpunctella* nut-containing chocolate was second best to rearing diet. Very few *P. interpunctella* moths emerged in plain or rum-flavored chocolate.

The total time of development for both species was shortest in rearing diet (Table II). For *E. cautella* the time from eggs to first instar larvae being present and to the start of pupation differed significantly between the diets (Table II). The difference in total generation time for *P. interpunctella* was

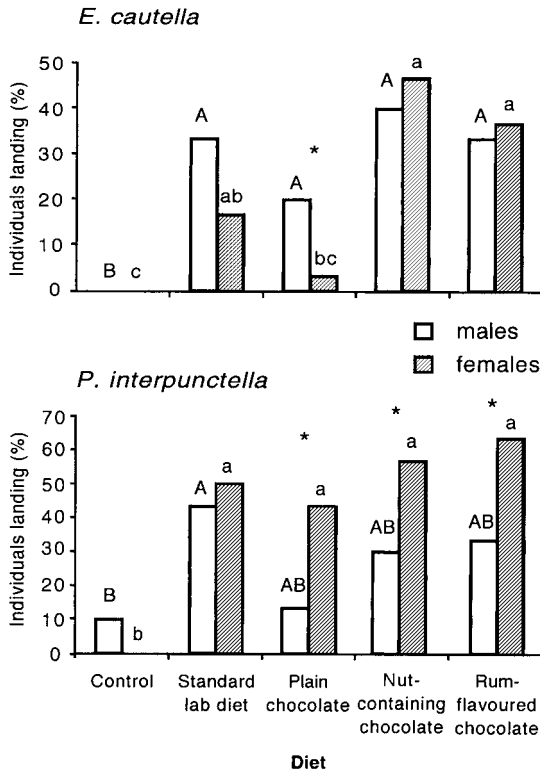


Fig. 2. Percentage of males and mated females of *E. cautella* and *P. interpunctella* that were induced to land by 15 g of four different diets, $n = 30$. Bars within sex with the same letters do not differ significantly at $p < 0.05$ level. Asterisk indicates a significant difference in attraction between sexes at $p < 0.05$ level (Ryan's test).

due to the difference in time to first instar larvae to be present (Table II), except for rum-flavored chocolate where also time of pupation was significantly different. Of the chocolate diets, the rum-flavored chocolate had the longest generation time for *P. interpunctella*. For *E. cautella* there was no difference between the chocolate diets.

Oviposition Experiments—Four-Choice

Larval presence indicates that there was no difference in oviposition preference of gravid *E. cautella* in a four-choice situation (Fig. 5).

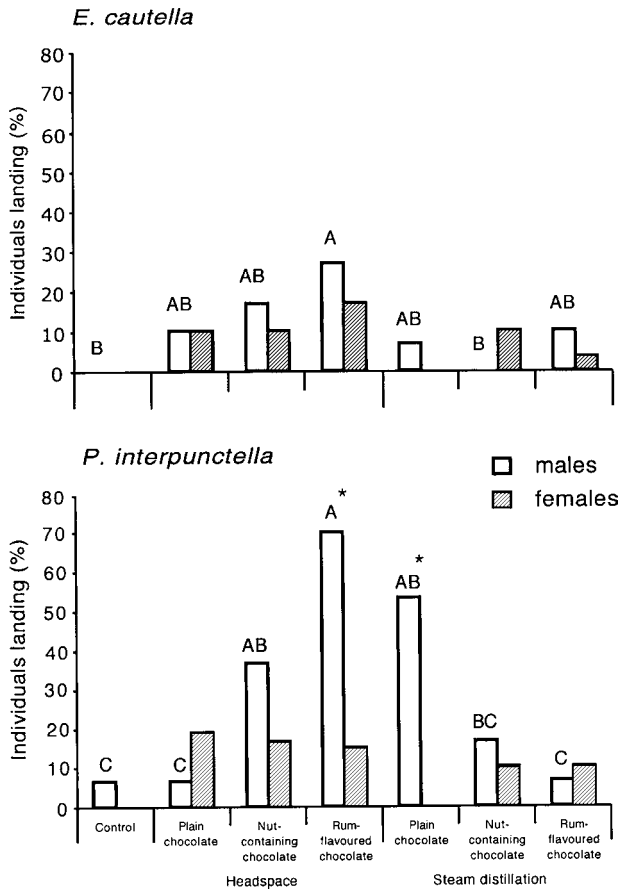


Fig. 3. Percentage of males and females of *E. cautella* and *P. interpunctella* induced to land by volatiles in headspace and steam distillation extracts from a variety of chocolate products, $n = 30$. Bars within sex with the same letters do not differ significantly at $p < 0.05$ level. Landing responses of females were not significantly different. Asterisk indicates a significant difference in attraction between sexes at $p < 0.05$ level (Ryan's test).

Rearing diet and nut-containing chocolate were more preferred by the gravid *P. interpunctella* females, in comparison with the other diets (Fig. 5). *Ephesia cautella* females oviposited in response to the extracts, however no significant difference between the extracts of the different diets was observed in the experiment with headspace extracts (Fig. 6). In the experiment with steam distillation extracts the proportion of eggs laid was significantly

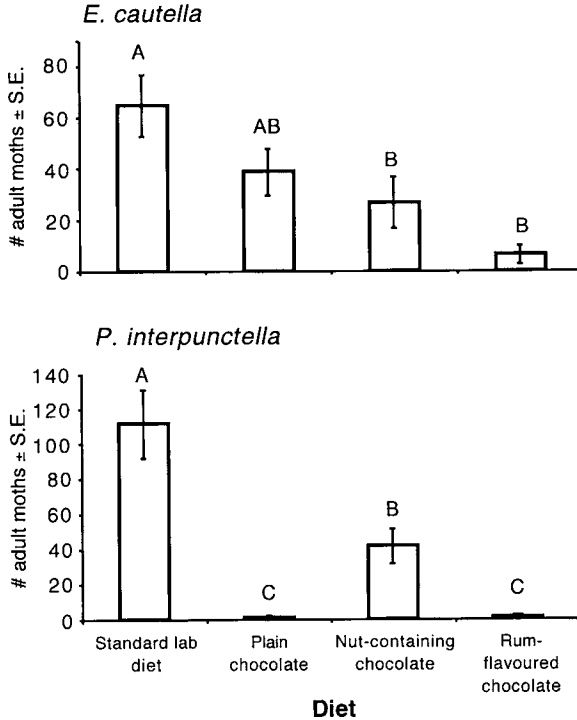


Fig. 4. Number of emerging moths depending on diet. There was no difference between sexes for either *Ephestia cautella* (two-way ANOVA, $F = 0.093$, $p > 0.05$) or *Plodia interpunctella* (two-way ANOVA, $F = 0.229$, $p > 0.05$), and the data for both sexes were pooled. Bars with the same letter do not differ significantly (*E. cautella*: one-way ANOVA, $F = 7.275$, $p < 0.001$; *P. interpunctella*: one-way ANOVA, $F = 23.909$, $p < 0.001$; $n = 7-10$). Difference between diets were tested at $p < 0.05$ level with Tukey's post hoc test.

higher in the Petri dish with extract from rum-flavored chocolate (Fig. 6). Neither headspace nor steam distillation extracts of the different diets induced any significant oviposition in *P. interpunctella*. Only in three of a total of 40 boxes observed was more than 10 eggs laid.

DISCUSSION

Both females and males of the two moth species were attracted to the chocolate products. Larvae of the two species are known to feed on

Table II. Time for Development (Days \pm SE) of *E. cautella* and *P. interpunctella* Depending on Diet, $n = 10$

	Standard lab diet			Plain chocolate			Nut-containing chocolate			Rum-flavored chocolate		
<i>E. cautella</i>												
1st instar larva present	20.5 \pm 0.5a	23.8 \pm 0.9b	23.5 \pm 0.6b	23.6 \pm 0.8b								
Start of pupation	14.1 \pm 0.7a	27.3 \pm 2.4b	25.5 \pm 5.0ab	27.7 \pm 2.5b								
Adult moth emergence	16.1 \pm 1.8a	30.0 \pm 4.5a	19.6 \pm 1.8a	29.0 \pm 15.1a								
Total Time	50.8 \pm 1.7a	81.1 \pm 6.0b	68.6 \pm 5.0ab	80.3 \pm 13.8b								
<i>P. interpunctella</i>												
1st instar larva present	18.1 \pm 0.4a	24.9 \pm 1.5b	24.0 \pm 0.7b	25.8 \pm 0.9b								
Start of pupation	13.9 \pm 0.8a	29.5 \pm 11.7a	21.2 \pm 1.9a	46.8 \pm 4.1b								
Adult moth emergence	9.5 \pm 0.5a	10.3 \pm 1.9a	13.6 \pm 2.2a	9.0 \pm 0.9a								
Total Time	41.5 \pm 0.5a	64.7 \pm 12.7b	58.8 \pm 3.1b	81.7 \pm 4.0c								

Note. Data within a row with the same letter do not differ significantly (one-way ANOVA, *E. cautella*: 1st instar larvae present: $F = 5.313, p < 0.01$, start of pupation: $F = 4.085, p < 0.05$, generation time: $F = 6.987, p < 0.01$; *P. interpunctella*: 1st instar larvae present: $F = 19.321, p < 0.001$, start of pupation: $F = 14.241, p < 0.001$, generation time: $F = 19.136, p < 0.001$). Difference between diets were tested with Tukey's post hoc test.

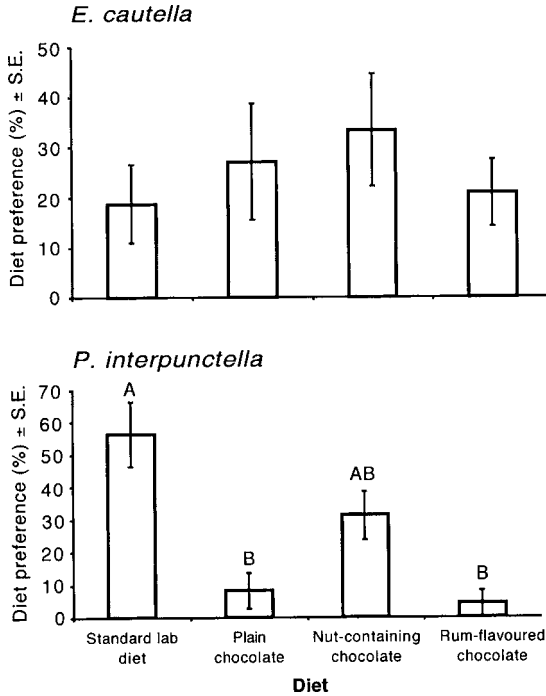


Fig. 5. Oviposition preference of gravid females of *E. cautella* and *P. interpunctella* to different diets measured as 1st instar larvae present in the diet. Bars with the same letter do not differ significantly (One-way ANOVA, *E. cautella*: $F = 0.556, p > 0.05$; *P. interpunctella*: $F = 8.217, p < 0.001$). Difference between diets were tested at $p < 0.05$ level with Tukey's post hoc test.

chocolate among other stored products, thus suggesting that the diets are suitable as oviposition sites. We used laboratory rearing diet as a positive control in the early experiments since wheat-based diets have been proven attractive in earlier studies (Barrer, 1977; Barrer and Jay, 1980; Gothilf *et al.*, 1993). Mated females were clearly more attracted than unmated females in the flight tunnel. Testing female pyralid moths in the early scotophase is suggested to increase the probability of flight activity (Phillips and Strand, 1994). However, this is also the time of day for maximum pheromone calling behavior, when unmated females are typically positioned on the wall or ceiling with the abdomen raised. While mated females are attracted to oviposition sites by food odors, unmated females are employed in calling and remain stationary (Hagstrum and Davis, 1980).

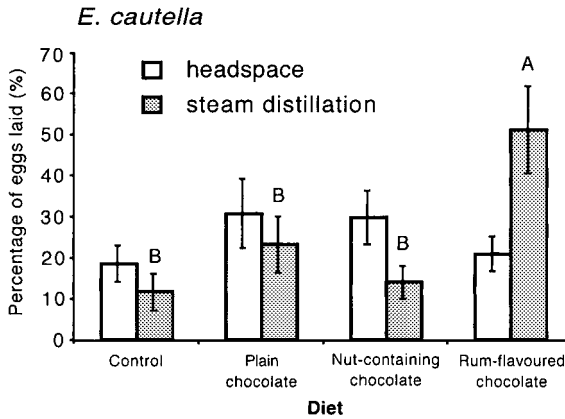


Fig. 6. Percentage of eggs laid by *E. cauttella* females in response to headspace and steam distillation extracts of chocolate. Bars with the same letter do not differ significantly (Headspace ns; Steam distillation: one-way ANOVA, $F = 6.331$, $p < 0.05$). Difference between diets were tested at $p < 0.05$ level with Tukey's post hoc test.

This difference in behavior between unmated and mated females probably explains the results. Males can be expected to associate food odors with partners for mating which may explain their attraction to the tested products. Since males have a high ability to remate (Ryne *et al.*, 2001), mating should not have any effect on their behavior which was also shown in our experiment.

We can conclude that isolation of the attractive odors is possible. When comparing induced upwind flight, the chocolate products were in most cases more attractive than the control, providing strong evidence of behavior-mediating odors in the chocolate products. The attraction to chocolate products is thus guided by volatile cues which can be isolated by closed loop collection, which is promising for future chemical identification of the behaviorally active substances. Headspace extracts obtained from closed loop collection of volatiles induced significantly more males to land than the control did. There was also a difference in female behavior when chocolate odors were presented compared to the control, with a trend of more landings, also indicating some attractivity of the extracts. Another sampling method such as SPME or different filter materials, e.g. Porapak or Super Q might be used to obtain a more complete odor bouquet, i.e. inducing responses similar to those of the chocolate products. However, the headspace extracts tested show activity, which presumably

is enough for further identification of the substances in the extracts. The level of landing response was generally lower to steam distillation extracts than to headspace extracts, but to directly compare the extraction methods, identification of the active components in the extracts is required. A speculative conclusion could be that the steam distillation extracts contain nonvolatile substances, that are released by the sprayer at short distances and perhaps mask the attractive volatile substances close to the source. At longer distances the attractive volatile odors can be perceived without the involvement of the nonvolatiles, thus explaining the high proportion of moths flying upwind, induced by the steam distillation extracts.

We found an interspecific difference in the ability to successfully reproduce in the chocolate diets. Again, laboratory rearing diet was used to compare the chocolate products to a diet that is known to be suitable for moth rearing. *Ephestia cautella* is able to reproduce in all chocolate diets, but less successfully in rum-flavored chocolate. Thus, the attraction in the flight tunnel is nonadaptive for the gravid females, but the rum-flavored chocolate probably emits chocolate-specific components from the chocolate part that attract gravid moths. The flavor additive rum contains small amounts of ethanol which can be toxic to lepidopteran larvae (Dentener *et al.*, 2000) and reduce survival in rum-flavored chocolate. This conclusion applies to *P. interpunctella* as well, which in addition obviously requires more nutritious food than mere chocolate to survive. The high ability of *P. interpunctella* to reproduce in nut-containing chocolate is in accordance with earlier reports (Hoppe, 1981), and the attraction to nut-containing chocolate is adaptive for the gravid females, since it provides a suitable substrate for feeding larvae. When it comes to development time, from mating to emergence of adult offspring, the different diets show the same pattern. Wheat-based rearing diet had the shortest generation time for both species, i.e. again being most suitable, and nut-containing chocolate was second best. For *P. interpunctella* only a few moths emerged in pure and rum-flavored chocolate making it difficult to compare the generation time of rearing diet and nut-containing chocolate with the other two diets.

The oviposition preference experiments with chocolate products show that *E. cautella* is less selective when choosing oviposition site since all four diets are equally preferred, whereas *P. interpunctella* females are more specific and prefer to lay their eggs in wheat or nut-containing diet. For *P. interpunctella* there seems to be a correlation between female oviposition preference and larval survival. The test with the collected headspace volatiles showed that *E. cautella* is still less specific in oviposition preference when both visual and contact chemoreception stimuli are absent. *Ephestia cautella* females do not discriminate between any of the odors, not even the control, indicating that the oviposition behavior for the almond moth

is not based on olfactory cues alone. In contrast, the experiment with the steam distillation extracts revealed that *E. cautella* females can discriminate between different chemical stimuli, either by olfaction or contact chemoreception, but the preference is not adaptive since only few larvae survived in the rum-flavored chocolate. Only three of the *P. interpunctella* females tested oviposited in response to the extracts. Females of *P. interpunctella* were shown to oviposit in tests with different kinds of host-related oils when applied on wheat kernels (Nansen and Phillips, 2003). When contact with the substrate was prevented in the experiments, the number of oviposited eggs was lowered, and only one oil type, walnut, was significantly better than the control. Females of *P. interpunctella* seem to base their oviposition preferences on a combination of visual, olfactory and contact chemoreception cues.

Attraction of pyralid males to food odors has been reported for *O. nubilalis* using phenylacetaldehyde (Cantelo and Jacobson, 1979; Maini and Burgio, 1990; Maini and Burgio, 1999) but for moths infesting indoor habitats, e.g. food storage facilities, no study has shown male attraction. Food-derived substances attracting females have been identified for lepidopteran pests, e.g. *Amyelois transitella* Walker, a moth infesting almonds (Phelan *et al.*, 1991) and the above-mentioned *O. nubilalis*. For indoor pyralids, field trapping experiments with food-derived substances have shown the possibility of trapping females (Toth *et al.*, 2002). Toth and coworkers found, when working with attractants for noctuids, that a 1:1 mixture of acetic acid and isoamyl alcohol also trapped females of *Ephestia kuehniella* Zeller and *P. interpunctella* in Hungary. However, their bait formulation caught only very few moths in preliminary trapping experiments in Swedish mills and stores (P.-O. C. Olsson, unpublished results). *Ephestia cautella* females can actually be lured by water as shown by Ryne *et al.* (2002). However, the purpose is probably not oviposition, but rather drinking to increase longevity and improve reproduction (Norris, 1934).

The chemicals eliciting the attraction to chocolate could be applied in pest management, mainly for detection of pest outbreaks and monitoring of females. Abundance of females in a pest population has been shown to be highly correlated with larval damage or feeding (Maini and Burgio, 1999). Trapping of females and examination of their mating status may also be used to monitor the results of mating disruption by means of pheromones. The chocolate-derived chemicals may have a future also in combination with pheromone to improve monitoring and control of males.

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