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# Survival and development of *Cadra cautella* (Walker) (Lepidoptera: Pyralidae) on cocoa bean and cocoa powder

## Kemampuan hidup dan perkembangan *Cadra cautella* (Walker) (Lepidoptera: Pyralidae) pada biji dan bubuk kakao

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**ABSTRACT**

The almond moth *Cadra cautella* (Walker) is a notable stored product pest which can cause detrimental loss on stored cocoa. Cocoa can be stored in bean and powder forms. The information about survival and development of *C. cautella* on stored cocoa is limited. This research aimed to determine the effect of cocoa powder and cocoa bean in the storage against the survival and development of *C. cautella.* This research was conducted in Plant Pests Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya. This research consisted of two treatments namely cocoa bean and cocoa powder with no choice method and repeated six times. The observed variables were number of larvae, pupae, male and female almond moth of F1 progeny, and developmental time of this insect. The t-test analysis was applied to determine the treatment effect. Results showed that the number of larvae, pupae, adult males and females of F1 progeny cultured on cocoa powder were significantly higher than on cocoa bean. The total developmental time and life cycle of almond moth were shorter on cocoa powder than on cocoa bean. Therefore, to store cocoa in powder form is riskier to the almond moth infestation rather than in bean form. Hence, it is suggested to take more concern on the cocoa powder storage better in order to minimize the almond moth infestation.

**Key words:** almond moth, cocoa form, stored cocoa

**ABSTRAK**

Ngengat almond, *Cadra cautella* (Walker), merupakan hama gudang penting yang dapat menyebabkan kerusakan yang signifikan pada penyimpanan kakao. Kakao biasanya disimpan dalam bentuk biji dan bubuk. Informasi mengenai pertumbuhan dan perkembangan ngengat almond pada penyimpanan kakao masih terbatas. Oleh sebab itu, penelitian bertujuan untuk mengetahui kemampuan hidup dan perkembangan ngengat almond pada kakao dalam bentuk butiran biji dan kakao dalam bentuk bubuk. Penelitian ini dilakukan di Laboratorium Hama Tanaman, Departemen Hama dan Penyakit Tumbuhan, Fakultas Pertanian, Universitas Brawijaya. Penelitian terdiri atas dua perlakuan, yaitu kakao dalam bentuk butiran biji dan kakao dalam bentuk bubuk dengan menggunakan metode tanpa pilihan yang diulang sebanyak enam kali. Variabel yang diamati adalah jumlah larva, pupa, imago jantan dan betina, serta lama perkembangan serangga hama tersebut. Uji t diaplikasikan

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untuk menentukan signifikansi pengaruh perlakuan. Hasil penelitian menunjukkan bahwa jumlah larva, pupa, dan imago pada kakao dalam bentuk bubuk signifikan lebih tinggi dibandingkan dengan pada kakao dalam bentuk butiran. Total waktu perkembangan dan siklus hidup ngengat almond yang dipelihara pada bubuk kakao lebih singkat dibandingkan dengan pada biji kakao. Oleh karena itu, kakao yang disimpan dalam bentuk bubuk perlu lebih diperhatikan untuk meminimalisir infestasi ngengat almond.

**Kata kunci:** bentuk kakao, kakao dalam simpanan, ngengat almond

## INTRODUCTION

The almond moth, *Cadra cautella* (Walker), is a notable stored product pest which can be as one of the limiting factors during the storage process. The almond moth is a cosmopolitan pest that has been reported in Africa, Asia, Europe, Oceania, and South America (Hagstrum & Subramanyam, 2009). In Northern Europe, almond moth is reported to be associated with dates, cocoa (Burks & Johnson 2012), dried fruits, and nuts (Hill 2003).

Infective stadia of almond moth is the larval phase by the direct feeding and production silk thread, which can contaminate the stored product. Product losses caused by almond moth is up to 64.8% on wheat (Gotyal et al. 2010), 10.1% on cocoa (Tettey et al. 2014), 10.31% and 29.05% for 1–4 months of cocoa beans storage (Oyewo & Amo 2018). Chistrian et al. (2019) reported that almond moth is one of the pests which is found on stored cocoa beans in Haut-Sassandra Region and causes losses up to 26.88% during 120 days. In addition, infestation of *C. cautella* in stored cocoa was also found in Brofoyedru Cocoa District of Ghana. Furthermore, the storage period and stored product pests infestation can affect the quality of cocoa beans (Boateng et al. 2022). The attack of stored product pests is influenced by the diet quality such as chemical properties (carbohydrate, protein, fat, vitamin, mineral content) and physical factors (hardness and diet form) (Parra et al. 2012; Cohen 2015).

Indonesia is the third largest country of the world in producing cocoa after Ghana and Ivory Coast (Marwati et al. 2020). Cocoa has a notable role in Indonesia as a source of foreign exchange, which contribute in world cocoa trade at about 10% (FAOSTAT 2022; Ibnu 2022). Cocoa is not only traded in bean form but also in other processed forms like cocoa powder, fat, and paste (Abdoellah 2021; Ibnu 2022). Almond moth is one of the key pests on stored cocoa which could cause some damages on cocoa production not only the quantity but also the quality. The percentage of weight loss in unfermented cocoa (0.14–1.22%) was higher than fermented cocoa (0.04–0.23%) during 1–6 months storage (Dharmaputra et al. 2000). Oyewo & Amo (2018) also demonstrated that infestation of almond moth first instar larvae can cause damage in cocoa by 2.95–14.64% during three months storage. The weight loss percentage caused by almond moth was about 10.14% during 120 days storage period (Tettey et al. 2014). Regarding to the serious problem with almond moth, it must take more concern in order to prevent the infestation.

Latest research about stored cocoa reported that fermentation process of cocoa bean before storage can reduce the insect damage due to its unpleasant smell affected by high content of acetic acid (Dharmaputra et al. 2000), but this research was not discuss about cocoa powder in the storage. There is no information regarding storing cocoa in powder form on the survival and development of almond moth. The cocoa powder and bean could affect the growth and development of almond moth. This research aimed to study the survival and development of *C. cautella* on cocoa bean and cocoa powder forms.

## MATERIAL AND METHOD

### Rearing of almond moth

Almond moth rearing was conducted at Plant Pests Laboratory (26.87 °C and 51.06% RH), Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya. The method for almond moth rearing was modified from Hasyim et al. (2014) and Husain et al. (2017). The almond moth used in this research was from the almond moth collection of Plant Pests Laboratory

from cashew nuts. Insect rearing was carried out by infesting 100 adults of almond moth (without considering the sexes) on 300 g of cashew nut in a rearing container (l = 27.5 cm, w: 18 cm, h = 6.5 cm) covered with gauze (Hasyim et al. 2014; Husain et al. 2017). After 14 days, the moths were removed from the container. The container was then stored in the laboratory until F1 adults emerged (Hasyim et al. 2014). Eighty of 1- or 2-day-old moths (without differentiate the sexes) were put into the mating cage until they produced eggs for one day. The new-laid eggs (0−1 day old) were used in this research (Oyewo & Amo 2020).

**Survival and development of almond moth**

This research was conducted by no choice test method, consisted of two treatments and six repetitions. This research was carried out by infesting 100 eggs on 100 g cocoa powder or 22 whole cocoa beans in a jar (Ø = 8.8 cm, h = 8 cm) covered with gauze (Oyewo & Amo 2018, 2020). The observed variables were the number of larvae, pupae, and adults (male and female). The sexes were differentiated by the abdomen shapes. The male's abdomen tip is pointed while the female's is blunt. The number of larvae was observed at 4$^{th}$ instar on 30 days after infestation (Husain et al. 2017). Larvae were observed and counted by removed the diet, while the pupae observation was carried out after adult observation. The number of pupae was observed by disassembling the aggregation of feed then counted the pupal exuviae and abortive pupae. The adults were observed and counted every day until no adults emerged (Husain et al. 2017).

For developmental observation, the eggs of F1 adult progeny laid on the same day were placed in a container (Ø = 3 cm, h = 3.5 cm) contain of 3 g cocoa powder or 1 cocoa bean and repeated four times. This experiment was carried out using 10 eggs, but each egg was placed in a different container. The transformation from eggs to larvae, larvae to pupae, and pupae to adults were observed every day. The observed variables were egg, larval, pupal phase, and total development. Adults emerged on the same day were maintained in pairs, then observed every day until the eggs laid. Life cycle of almond moth was measured by calculating the date from egg to adult firstly laid an egg (Husain et al. 2017). The sex ratio was calculated by this following formula ♂ : ♀ = 1 : x according to the proportion of females to males among the total number of adults (Wei 2008). Data were analyzed by t-test at 5% error level using R statistics program (R Core Team 2022).

## RESULTS

**Survival and development of almond moth**

The forms of cocoa significantly influenced the survival and development of almond moth. Number of larvae ($t = 3.501$; $P < 0.001$), pupa ($t = 5.457$; $P < 0.001$), and adults ($t = 4.275$; $P < 0.001$) were significantly higher when the test insects were infested on cocoa powder than on cocoa bean (Table 1).

The storage cocoa forms also influenced the number of adult males and females of almond moth, but not the sex ratio. Number of adult males and females are significantly ($P < 0.05$) higher when almond moth infested on the cocoa powder than on cocoa bean. On the other hand, the cocoa forms did not influence the almond moth sex ratio. The number of females were higher than males on bean form, while on powder, males were higher than females (Table 2).

The storage cocoa forms also influenced larval stadium, developmental time, life cycle of almond moth ($P < 0.05$) but not to egg and pupal phase ($P > 0.05$) (Table 3). Egg phase on the two cocoa forms was relatively similar. Larval phase was

**Table 1.** Mean number of larva, pupa, and adult of *Cadra cautella* on cocoa bean and powder

| Variables | n | Cocoa bean $\bar{x} \pm SD$ | Cocoa powder $\bar{x} \pm SD$ | P value |
|---|---|---|---|---|
| Larva | 7 | 38.57 ± 16.48 a | 64.71 ± 10.88 b | 0.001* |
| Pupa | 7 | 29.00 ± 8.02 a | 53.71 ± 8.90 b | 0.001* |
| Adult | 7 | 21.00 ± 9.94 a | 44.14 ± 10.30 b | 0.001* |

*Values in the same row followed by different letters indicate significantly different, $t\alpha_{0.05}$; SD: standard deviation.

significantly shorter on cocoa powder than on cocoa bean. Pupal phase on the two cocoa forms was relatively similar. The developmental time and life cycle of almond moth were significantly shorter on cocoa powder than on cocoa bean (Table 3).

## DISCUSSION

This study revealed that cocoa powder was more suitable for almond moth than cocoa bean. Insect preference, survival, and development were affected by the type and form of diet (Astuti et al. 2020). The number of eggs released per adult female of almond moth on cocoa powder were at about 155.8 eggs (Akinneye & Ashamo 2009). Oyewo & Amo (2020) also reported that female's fecundity of almond moth on corn powder was higher than on cocoa beans. This research also revealed that the number of almond moth adults on cocoa powder was higher than on cocoa bean i.e. 44.14 and 21.00 individuals, respectively. Akinneye & Ashamo (2009) also stated that cocoa powder could enhance the survival percentage of almond moth up to 73%. A diet could be recommended as a rearing diet if the insect viability is about 70–100% (Cox et al. 1981; Singh 1983). Astuti et al. (2020) also conveyed that several corn varieties (Pioneer 21, Pioneer 29, Pertiwi 3, Bisi 18, and Bisma) in powder form could enhance the number of egg and decline the mortality rate of *Tribolium castaneum* (Coleoptera: Tenebrionidae). This research was in line with those previous reports, which disclosed that cocoa powder was more suitable for survival and development of almond moth. This result was in accordance with the feeding behavior of almond moth, which is categorized as a secondary pest (Rees 2004). This results showed that the growth of almond moth in cocoa powder was better than on cocoa grain because almond moth is a secondary pest that can grow better on powder than on grain.

Insect preference was influenced by the physical (texture, hardness, and form) and biochemical characteristic or nutrient content (carbohydrate, protein, fat, vitamin, and mineral) of the diet (Astuti et al. 2013, 2020; Cohen 2015; Parra et al. 2012; Sjam 2014). Astuti et al. (2020) informed that *T. castaneum* was more preferred to lay eggs on the powder form than grain form of corn. In addition, the phenolic content and the grain hardness were positively correlated with the population growth and development of *Rhyzopertha dominica.* The higher of phenolic content and grain hardness, the lesser number of eggs of *R. dominica* laid (Astuti et al. 2013).

The survival rate of stored product pest is influenced by the genetic and ecological factors,

**Table 2.** Mean number of adult males and females, and sex ratio of *Cadra cautella* on cocoa bean and powder

| Variables | n | Cocoa bean $\bar{x} \pm SD$ | Cocoa powder $\bar{x} \pm SD$ | P value |
|---|---|---|---|---|
| Males | 7 | 9.85 ± 6.59 a | 26.42 ± 6.16 b | 0.000* |
| Females | 7 | 11.14 ± 4.33 a | 17.71 ± 4.60 b | 0.047* |
| Sex ratio (F : M) | 7 | 1.02 ± 0.43 : 1.00 ± 0.00 a | 0.69 ± 0.10 : 1.00 ± 0.00 a | 0.421 |

*Values in the same row followed by different letters indicate significantly different, $t\alpha_{0.05}$; SD: standard deviation.

**Table 3.** Development of *Cadra cautella* on cocoa bean and powder

| Variables | n | Cocoa bean $\bar{x} \pm SD$ (days) | Cocoa powder $\bar{x} \pm SD$ (days) | P value |
|---|---|---|---|---|
| Egg phase | 4 | 4.50 ± 1.00 a | 4.00 ± 0.00 a | 0.391 |
| Larval phase | 4 | 57.00 ± 6.00 a | 48.00 ± 3.82 b | 0.047* |
| Pupal phase | 4 | 7.67 ± 0.57 a | 8.00 ± 0.00 a | 0.422 |
| Total development | 4 | 68.75 ± 5.85 a | 58.75 ± 6.13 b | 0.046* |
| Life cycle | 4 | 74.33 ± 0.57 a | 64.67 ± 2.30 b | 0.012* |

*Values in the same row followed by different letters indicate significantly different, $t\alpha_{0.05}$; SD: standard deviation.

such as natural enemies, human activity, climate, and diet (Astuti 2019; Astuti et al. 2013, 2020). Cocoa is one of the host ranges of almond moth (Hagstrum et al. 2013; Hagstrum & Subramanyam 2009; Hill 2003), and several reports also showed that almond moth can develop a great association on cocoa (Dharmaputra et al. 2000; Oyewo & Amo 2020; Samsudin et al. 2016).

Oyewo & Amo (2020) reported that egg, larval, pupal stadium, and total development time of almond moth on cocoa bean was longer (42 days) than on corn powder (30 days). Akinneye & Ashamo (2009) also stated that total development time of almond moth on cocoa powder was for about 38.33 days. Another report on the secondary pest, *T. castaneum,* show the great survival and development occurring on the powder form than whole grain (Astuti et al. 2020). Besides food, another factor affecting the population growth and development of pests were temperature and relative humidity (RH) of the storage. The total development of almond moth in this research lasted for 58.75–68.75 days.

Rees (2004) informed that the developmental time of almond moth was 26 days at 30 °C and 75% RH. Larva stadium was last for 24–38 days at 27–36.5 °C and 40–80% (Oyewo & Amo 2020). Oyewo & Amo (2020) also depicted that total developmental time of almond moth on cocoa powder was 38.33 days at 28.2°C and 75,5% RH. Results of this study indicated that cocoa powder was better food for survival and development of almond moth regarding the more adults emerged and the shorter life cycle rather than in cocoa bean which was its main host.

## CONCLUSION

Survival of almond moth was higher on cocoa powder than on cocoa bean. Developmental time of almond moth on cocoa powder was shorter than on cocoa bean. Therefore, to store cocoa in powder form is riskier to the almond moth infestation than in bean form, hence, it could be suggested to take more concern on the cocoa powder storage in order to minimize the almond moth infestation.

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