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RESEARCH PAPER

The Effect of Different Nutrient Combinations on Development Time and Emergence rate of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae)

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Abstract

In this study, the effects of different nutrient combinations on the development time and emergence rate in the cultivation of the host *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae), which has an important place in biological control mass production, were investigated. Food experiments were carried out by using 200 g different food combinations in 15 x 20 x 8 cm containers and adding 1.000 Mediterranean flour moth eggs on it. Standard food and ground hazelnut shell were used. 5 different food combinations; A (200 g standard food as a control), B (50 g standard food + 150 g hazelnut shell), C (100 g standard food + 100 g ground hazelnut shell), D (150 g standard food + 50 g ground hazelnut shell) and E (200 gr ground hazelnut shell) were used for the experiments. As a result, no moth emergence was observed in the group E. The development time was 41 days in A, 48.3 days in B, 41.3 days in C, and 41 days in D. The best development time was observed in food combination D compared to food combination A (control). The development time was statistically found significant. The adult emergence rate was 91,86% in A, 18,16% in B, 82,00% in C and, 95,63% in D. As a result, D food combination is recommended in mass production of *Ephestia kuehniella*, because the development time is short and the adult emergence rate is the highest.

INTRODUCTION

Mass production of parasitoids and predatory insects has an important place in biological control. *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae), popularly known as the Mediterranean flour moth, is the most preferred laboratory host in the production of natural enemies both scientifically and commercially (Abd El-Hafez, 2001; El-Wakeil, 2007; Wang *et al.*, 2014). The reason why it is often preffered is that it has larger eggs compared to other moths and high reproductive capacity (200-300 eggs per female). Besides, it can easily and cheaply be produced on different food types. In addition to being easy to produce, a high standard of sustainable production of *E. kuehniella* with limited resources is needed to maximize the quantity and quality of natural enemies feeding on this host. Because many of Lepidoptera species do not feed especially in the adult period, the body size, phenology and egg production of *E. kuehniella* females are directly related to the larval foods. (Bauerfeind and Fischer, 2005; Gianoli *et al.*, 2007; Altermatt, 2010).

For the effective and sustainable use of biological control agents, one of the most important factors in the mass production of host *E. kuehniella* is food combination in laboratory.

Insects have to take essential nutrients necessary for their growth and development. Nutritional ecology studies aim to determine the effect of nutrition on the development of organisms. Food in insects; it affects many activities such as development time, emergence rate, adult live weight, yield, and longevity (Sönmez *et al*., 2019).

E. kuehniella is particularly harmful to flour and grains. Flour and flour types are generally used as food combination in mass production. Recently, flour prices have increased mass production costs. Alternative methods have to be developed to reduce food costs. One of the developed methods should be focus on whether the waste materials can be used as food.

Hazelnut, that cultivation dates back to ancient times, has found the most suitable growing ecology in the Black Sea Region in Türkiye and is one of the important agricultural products of Türkiye (Demir and Beyhan, 2000). 92% of Türkiye's hazelnut production is carried out in Sakarya, Ordu, Giresun, Trabzon, Samsun and Bolu, located in the Black Sea Region, Türkiye (Kılıç, 1997). Hazelnut production in Türkiye is 665 thousand tons in 2020. Considering that approximately 50% of the hazelnut is in the shell, according to the data of Turkish Statistical Institute (TÜİK). Moreover, approximately 388.000 tons of hazelnut shells are released as a result of hazelnut production (Anonymous, 2021). Hazelnut shell is used as a high calorie fuel (4100-4400 cal/g) and it is very valuable in Türkiye, especially in hazelnut-producing regions. In a nutshell; it is used in the wood products and paint industry in countries such as Germany, Italy and the USA. In addition, pentosan, which is found in woody plant tissues and used as a reserve nutrient and adding material in plants, is present in the hazelnut shell at a rate of 25-30%. During the consumption of fruit with shells, fruit peels are considered as waste and therefore not used in any industry (Dönmez *et al*., 2016). In a study conducted in Türkiye on hazelnut shells, the results of the chemical analysis of the shells are as follows; 62,76% holocellulose, 32,98% α-cellulose, 45,62% lignin and 3,57% polyphenolic substance (Dönmez *et al*., 2016). Due to the lignin and carbohydrate compositions that hazelnut shells contain, it is possible to use them as raw materials in the production of high value-added compounds with the biorefinery approach. In previous studies, there are the used of shells for different purposes. Therefore, these studies aim to make an economical and sustainable production of the appropriate food, evaluate the shell fruit wastes in Türkiye and increase the quality of the production of biological control agents. Studying cheaper and more economical applications in terms of continuity of production is an important criterion for mass production. In food-related studies aimed at reducing food costs, hazelnut shells were used in order to use agricultural product wastes as an alternative food source and to evaluate the wastes.

There are many studies on host food. Locatelli and Limonta (1998) investigated the growth of three different stored product pests, *Plodia interpunctella* (Hübner, 1813), *Corcyra cephalonica* (Stainton, 1811) and *Ephestia kuehniella* (Zeller, 1879) (Lepidoptera: Pyralidae) in different wheat varieties and wheat flours. As a result of the study, it was stated that the development of hard-shelled wheat was insufficient, a small number of individuals could reach the adult stage and the developmental period was prolonged. It was determined that the adult emergence of *E. kuehniella* was observed between 43-56 days according to the food types besides the possible reproduction rate was the highest in whole wheat flour. Safa *et al*. (2014), investigated the effects of five different foods on some biological properties of *E. kuehniella*. Egg production, the adult lifespan, larval development time, larval, pupa and adult weights, embryonic development and egg hatch rate parameters were examined in five different foods. Embryonic development and hatching rates were not affected by different types of food. As a result of the study, they stated that I (wheat flour + wheat bran) and II (wheat embryo + yeast + glycerol) nutrients can be used for the mass production of this insect. Türkoğlu and Özpınar (2021) added fish flour and corn flour in different proportions to the nutrient ratio and this provided that the ratio of wheat flour in the standard diet consisting of wheat flour and bran (1:1) of *E. kuehniella* remains the same. Some biological characteristics of *E. kuehniella* such as adult emergence, egg, larva, pupa and adult weights, adult lifespan and number of eggs per female were investigated in these foods. According to the results of the study, it was stated that the different foods showed positive results in the production of *E. kuehniella* more than the standard food.

In this study, the effect of adding ground hazelnut shells at different rates to the host standard diet on the developmental period and emergence rate of *E. kuehniella* was investigated. In this context, the studies aim to create a quality, economical and sustainable production model for the research of alternative nutrient possibilities in mass production of biological control and evaluate the shell fruit wastes.

MATERIALS and METHODS

The Mediterranean flour moth *E. kuehniella* Zeller (Lepidoptera: Pyralidae), which has been cultivated for a long time in the Biological Control Laboratory of Ankara University Faculty of Agriculture, Plant Protection Department, constitutes the main material. The nutrient content of host *E. kuehniella* is as in the Table 1.

The shell of the Giresun hazelnut variety obtained from Giresun province was used to add certain proportions to the standard nutritional formulation.

E. kuehniella was reared in climate rooms (25±1ºC, 60-70% proportional relative humidity, 16 hours light and 8 hours dark photoperiod conditions). Hosts were put in 15 x 20 x 8 cm tubs with ventilated tulle on the cover, decontamination with sodium hypochlorite (1%) in cultivation used. Standard food was prepared during the rearing of the host. The prepared standard food was sterilized by keeping in an oven set at 60°C for 3 days to prevent external contamination. Different food combinations used for the experiments were shown in Table 2.

Each container was transferred from sterile food at the specified rates and 1000 host eggs were laid on it. Experiments were made with 3 replications. Egg to the first adult moth emergence was recorded for the development time. Moths that completed their development and emerged were recorded daily and the emergence rate was calculated as a percentage. Analysis were conducted in SPSS 25.0 package program. The difference between the means was evaluated using one-way ANOVA, by Duncan test within 0.05 error limits ($P<0,05$).

RESULTS and DISCUSSION

The data on the adult emergence rate and development time of *E. kuehniella* growing in different food combinations were given in Table 3. Since no improvement was observed in the E food group, it was not evaluated statistically. In terms of exit emergence rate, data were statistically found significant ($f= 456,129$, $df= 3$, $P= 0,000$).

The development time and adult emergence rate parameters of *E. kuehniella* were investigated in the study on ground hazelnut

Table 1. Standard nutritional ratio and contents of *Ephestia kuehniella.*

Standard food formulation	40% wheat flour (Yelmenler/Tip 5)
	20% corn flour (Şakiroğlu)
	20% barley flour (İpek Değirmen)
	10% bran (Mis un)
	10% glycerine (Birpa)

Table 2. Content of different combinations of foods.

Food Group	Food Contents
A	200 g standard food (control)
B	150 g standard food + 50 g ground hazel nutshell
C	100 g standard food + 100 g ground hazelnut shell
D	50 g standard food + 150 g hazelnut shell
E	200 g of ground hazelnut shell

Table 3. Adult emergence rate and development time of *Ephestia kuehniella* in different food combinations.

Food Combinations	Adult emergence rate (%)	Development time (days)
	Mean values±SE	Mean values±SE
A [200 g standard food (control)]	91,86±1,865[a]	41,00±0,00[a]
B (150 g standard food + 50 g ground hazelnut shell)	18,16±26,18[c]	48,33±2,08[a]
C (100 g standard food + 100 g ground hazelnut shell)	82,00±1,044[b]	41,33±0,57[a]
D (50 g standard food + 150 g hazelnut shell)	95,63±0,348[a]	41,00±0,00[b]
f	456,129	33,595
P	0,000	0,000

shells added at different rates to the standard host food. No moth emergence was observed in the E food group, which consists of entirely hazelnut shell. While the development time is 41 days in the control, it is 48.3 days in B, 41.3 days in C, and 41 days in D. It was observed that the development time increased in group C and D. As a matter of fact, the development time was 46.2 days for whole wheat flour (Siddiqui and Barlow,1973); 50.82 days for artificial feed consisting of white corn flour and yellow corn (commercial hybrid AG-106), 51.05 days for brewer's yeast (3%) for yellow and white corn (Magrini *et al*., 1993); 52.2 days for maize flour + whole wheat flour + yeast (48.5% + 48.5% + 3%) (Lima-Filho *et al*., 2001), 43 days for whole wheat flour (Locatelli and Limonta, 1998) and 44.4 and 55 days for corn flour and wheat flour, respectively (Ayvaz *et al*.,2008); they reported that it was in wheat flour with 50.98 days. The total development time of *E. kuehniella* in pre-adult stages varied between 46.2-55 days on different foods.

The adult emergence rate was found 91.86 % in A, 18.16 % in B, 82.00 % in C and 95.63 % in D. The highest emergence rate was obtained in group D. The adult emergence rates we obtained are higher than in other studies. The addition of 5 % yeast to corn flour increased the adult emergence rate from 40 % to 65 %. In the wheat flour diet, the addition of bran, yeast, and glycerin caused a 43% increase in adult emergence (Kurtuluş *et al*., 2020).

In the study, different amounts of hazelnut shells were added to the standard food ration of the host *E. kuehniella*. It was observed that the developmental period was prolonged, and the adult emergence rate decreased as the amount of host standard food was decreased, however, the amount of ground hazelnut shell increased.

CONCLUSION

When the biological parameters such as development time and emergence rate of *E. kuehniella* were examined depending on the nutrient combinations, it was observed that there were significant differences. As a result of the study, it is understood that hazelnut wastes can be used in the mass production of *E. kuehniella* as well as standard food. However, more detailed studies are needed to determine the long-term effects of these wastes being used as food on *E. kuehniella*.

In this study, in which the effect of hazelnut shells on the recycling of the waste in mass production in Türkiye was investigated, it was concluded that a more economical mass production food could be developed for *E. kuehniella* by adding hazelnut shell wastes to the standard food in certain proportions. However, to clarify the effect of hazelnut shells added to the standard food mixture, the adaptation process of *E. kuehniella* for the food should also be taken into account. To determine the adaptation of *E. kuehniella* to the new food, more detailed studies should be done in which *E. kuehniella* was grown on the same food for several generations.

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