



The effects of population densities and diet on *Tribolium castaneum* (Herbst) life parameters



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ABSTRACT

The effects of population densities (10, 25, 50 and 100 adults/50 g) and three diet types (protein-rich, carbohydrates-rich and compound feed) on life parameters (first emergence, development rate, number of progeny and body weight) of *T. castaneum* progeny were assessed. For each diet type and population density unsexed adults were allowed to feed and oviposit for 7 days before removal.

No progeny developed on protein-rich diets (sunflower meal, soybean concentrate, and corn gluten). In carbohydrates-rich diets (corn feed flour, wheat bran, coarse wheat) and compound feed for pigs and laying hens, first adults required the least time to emerge in wheat bran and control diet (wheat flour + 5% yeast) (15.2–16.5 days), and the longest in corn feed flour (23.1–24.5 days). In wheat bran and control diets, the adult emergence period was the shortest (15.7 and 15.2 days) at the initial population densities of 100 and 50 adults/50 g, and significantly longest (16.5 and 16 days) at the lowest density. Conversely, adults fed on feed for hens diet emerged the latest, after 22.5 days, at the population density of 100 adults/50 g, and the earliest, after 18.6 days, at 25 adults/50 g. The shortest period of adult emergence at all population densities was found in the control (15.9–20.2 days) and wheat bran (18–29.7 days), and the longest in feed for hens (56.2 days) and pigs (59.5 days) at the highest population density. Considering all densities, number of progeny were the highest in control diet (498–1226 adults) and wheat bran (354–1344 adults), and lowest in coarse wheat (220–300 adults). With increasing population density, progeny body weight decreased, and the highest weight was found in control diet and wheat bran (1.7 and 1.6 mg) at the lowest population density, and the lowest weight (1.0 mg) in hen and pig feeds at the highest density.

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1. Introduction

Global feed production for domestic animals has approached an annual volume of one billion tons, according to reports by the International Feed Industry Federation – IFIF (www.ifif.org) and the current increase in global demand requires steps to be taken towards reducing losses and improving the quality and safety of these products. The quality and safety of plant feeds are considerably threatened by stored-product insect pests, which annually damage 10–20% of the stored products worldwide (Gorham, 1991; Mason and McDonough, 2012).

The red flour beetle, *Tribolium castaneum* Herbst, is an important pest of stored plant products, especially processed commodities, which makes it one of the most important pests in facilities for manufacturing and storage of plant feeds (Rees, 2004; Mahroof and Hagstrum, 2012). The type of stored plant products and their nutritive value can significantly affect the speed of development and abundance of *T. castaneum* progeny. Higher insect numbers increase the damage that this and other stored-product insects cause (Sokoloff et al., 1966a, 1966b; Baker, 1988; Jagadeesan et al., 2013). The most widely used feeds are plant products rich in carbohydrates (corn and wheat meals) and proteins (soybean, sunflower and a variety of soybean and sunflower products), and compound feeds (ready-to-use meals) have high contents of vitamins, amino acids, micro- and macro-nutrients (Lević and Sredanović, 2011; Lević et al., 2012; Corrent, 2013, 2015; Laune,

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2015; Cerrate, 2015; Liu and Selle, 2015).

Tribolium castaneum has been observed to have a shorter life cycle and produce a greater number of progeny on whole grain flour, while its cycle is considerably longer and number of progeny considerably lower on brown and rice flour diet (Wistrand, 1974). Conversely, cotton seed (Ahmad et al., 2012) and some starch (Wong and Lee, 2011) diets are poor nutritive sources for *T. castaneum* progeny. Additives, such as brewer's and baker's yeast, added to different diets have stimulating effects, i.e. cause shorter development cycle and higher number of *T. castaneum* progeny (Sokoloff et al., 1966a; Lale et al., 2000). The types of diet or their combination may also significantly affect the body weight of progeny of various stored-product insects (LeCato, 1976) or pheromones secreted by males of species such as *T. castaneum* (Ming and Lewis, 2010). Apart from the type of diet, initial population density may also have a direct or indirect impact on the reproduction, development rate, number of progeny and body weight of stored-product insects (Taylor, 1974; Longstaff, 1995; Assie et al., 2008). Depending on the quality of diet, high initial population densities of *T. castaneum* may cause significantly longer life cycles and lower number of progeny (Longstaff, 1995).

Previous research mainly focused on the occurrence, development and harmfulness of *T. castaneum* in stored products intended for human diet, while information about its harmfulness and development in primary and processed plant products is scarce, despite the high scope of losses caused in feed industry each year. The present study therefore examined the effect of different initial population densities (10, 25, 50 and 100 adults) and substrates as feed diets, namely: a) carbohydrate-rich diets: corn feed flour, wheat bran (wheat feed flour) and coarse wheat meal b) protein-rich diets: corn gluten meal, soybean concentrate and sunflower meal, and c) feed products, i.e. compound feed for fattening pigs and compound feed for laying hens, on several life parameters (first emergence, development rate, number of progeny and body mass of adults) of *T. castaneum* progeny.

2. Material and methods

2.1. Test insects

A laboratory population of *T. castaneum*, reared in an insectary, was used in tests that followed the procedures described by Harein and Soderstrom (1966), and Bry and Davis (1985). The population was reared in 2.5 L glass jars containing white wheat flour with 5% active dry yeast. Air temperature in the insectary was 25 ± 1 °C, and relative humidity $60 \pm 5\%$.

2.2. Feed substrates as diets

Differentiation between protein-rich and carbohydrates-rich types of animal feed is based on their predominant nutritive components, i.e. those containing mostly proteins belong to the protein-rich type, while others mostly containing carbohydrates belong to the carbohydrates-rich type (Colović et al., 2015).

The substrates showed in Table 1 were used as feed diets: 1) carbohydrate-rich plant feed diets: coarse wheat meal produced by milling whole wheat grain of cv. NS 40S (Institute for Field and Vegetable Crops, Novi Sad); wheat feed flour – wheat bran (Letina d.o.o, Novi Bečej); corn feed flour (Mirotin Tisa d.o.o, Savino Selo); 2) protein-rich plant feed diets: corn gluten (Jabuka A.D. Starch Industry, Pančevo), soybean concentrate (Soja Protein, Bečej), sunflower meal (Letina d.o.o, Novi Bečej), and 3) feed products, i.e. a compound feed for fattening pigs (Letina d.o.o, Novi Bečej), and a compound feed for laying hens (Letina d.o.o, Novi Bečej). The control diet was a soft wheat flour type 500 containing

supplementary brewer's yeast (5%).

All diets used in this study were exposed to 60 °C for 10 h to eliminate potential insect infestation (Tuncbilek and Kansu, 1996). After heat treatment, all substrates were kept at 25 ± 1 °C temperature for 12 h before using them in the experiments.

2.3. Bioassay

The experiment was carried out in the laboratory following the modified methods described by Longstaff (1995). Each type of diet (50 g) was placed into 200 mL plastic containers, separately for each of four population densities (10, 25, 50 and 100 adults) of *T. castaneum*. Unsexed adults aged two to four weeks were then added to each diet/population density combination in four replicates. The containers were covered with cotton cloth, fixed with rubber bands and put in an incubator (Sutjeska, Serbia) set to 30 ± 1 °C temperature and $50 \pm 5\%$ r.h. The entire procedure was repeated twice. The beetles were allowed to feed and oviposit for 7 days after which period they were gently removed by sieving with minimal disturbance of the developing progeny, and the containers were again put in the incubator. Adult mortality was $\leq 1\%$ in all trial combinations and all adults discarded.

Detailed checks of all containers began 10 days later in order to determine the moment of first emergence of F_1 adults and that moment was marked as day 1 for each diet/population density combination. Once the first adult developed, each diet was examined daily, and any new adults were counted and removed. Adult emergence was recorded in each container until the last adult developed. During the count checks, new adults were randomly selected and placed in 200 mL plastic containers with soft wheat flour and left in a room at 25 ± 1 °C temperature and $50 \pm 5\%$ r.h. Ten days later, total body mass of 10 adults was measured on an analytical scale (Denver instrument, USA) and average body weight of F_1 adults calculated. The entire procedure was repeated ten times in the course of the experiment, always with new adults, except for the adults developing in the feed for laying hens at the population density of 100 adults, where the entire procedure was repeated eight times.

The data were processed to obtain information about the first adult emergence, adult development rates, average total number of progeny and their body weight. In the protein-rich diets, i.e. corn gluten meal, soybean concentrate and sunflower meal, low numbers of larvae were detected in daily checks and no individuals reached the pupal stage. These diets were excluded from further data processing.

2.4. Data analysis

Number of progeny were analyzed by repeated ANOVA processing. The repeated factor was the days of development rate (examined daily), while the number of progeny was the response variable, and the main effects were diet and population density. Before analyses, progeny number in the F_1 generation were transformed using $\log(x+1)$. However, the tables show untransformed means and standard errors. A one-way ANOVA was used for comparing: the first emergence of adults, adult development rates, average total number of progeny and their body mass, and the means were separated by Fisher's LSD test at $P < 0.05$ (Sokal and Rohlf, 1995). The data were run on StatSoft, 2005 version 7.1 (StatSoft Inc., Tulsa, Oklahoma).

3. Results

3.1. First emergence and development rates of adults

The average number of days between parent removal and the

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