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Population Growth of *Tribolium confusum* (Coleoptera: Tenebrionidae) on Various Commercial and Non-commercial Flour

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Abstract. *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae) is a major stored product pest that can damage flour in storage. The infestation of *T. confusum* causes contamination of stored grain, such as flour. Research about the population growth of *T. confusum* in various commercial and non-commercial flours is still limited. This study aims to determine the population growth of *T. confusum* in various commercial and non-commercial flours. The study was conducted using the no-choice test method (NCTM). This study used a treatment jar containing 30 g of diet and infested 15 pairs of *T. confusum* adults for 7 days. Data obtained from this research were analyzed using analysis of variance (ANOVA) and further analyzed using the Duncan Multiple Range Test (DMRT) at a 5% significance level. The results showed that the number of larvae, pupae, and F1 progeny of *T. confusum* was higher in non-commercial red rice flour (80, 50 individuals; 59, 50 individuals; 57, 50 individuals) compared to other types of flour. The chemical characteristics of diets that can affect the population growth of T. confusum include fat, ash, carbohydrate, and phenol content. In conclusion, understanding the chemical characteristics of flour is crucial for developing a strategy to control *T. confusum*.

Keywords: commercial flours; confused flour beetle; F1 progeny; non-commercial flours

INTRODUCTION

Flour is a storage material that is widely used in Indonesia as a raw material for making food (Hendrival et al., 2022; Nasution et al., 2017). One of the flours used in Indonesia is wheat flour, which is made from wheat. In addition, flour can also be made from various commodities, including milled rice (Afgani et al., 2023), black rice, red rice (Arifin et al., 2023), white glutinous rice (Martiyanti et al., 2022), soybeans, and mung beans (Ekafitri & Isworo, 2014; Nasution et al., 2017). Based on data from the Ministry of Agriculture (2023), flour production in Indonesia decreased by 6.40% from 2022 (15.874.000 tons) to 2023 (14.857.000 tons). Several factors influence the reduction in flour production. One of them is improper storage conditions, which is caused by the attack of stored product pests. The attack of stored product pests can cause a decrease in the quality and quantity of flour in storage. One of the stored product pests that can infest flour in storage is *T. confusum*.

T. confusum can attack various stored commodities (polyphagous), including rice, corn, barley, wheat, soybeans, lentils, cocoa, rice flour (Hagstrum & Subramanyam, 2009), millet, cowpeas, and various spices (Pai, 2010). The presence of *T. confusum* in stored commodities can cause contamination (dead insect parts, exuvia, and feces) (Mahroof & Hagstrum, 2012) and unpleasant odors due to benzoquinone secretion produced by a pair of glands in the abdomen of *T. confusum* (Mahroof & Hagstrum, 2012; Rees, 2004). The benzoquinone secretion produced by *T. confusum* can change the color and smell of stored products (Mahroof & Hagstrum, 2012). In addition, *T. confusum* infestation also causes a decrease in the nutritional content of the stored products, and mold growth (Nowaczyk et al., 2009), and consumer rejection (Jung et al., 2020).

The level of damage to stored products caused by T. confusum infestation can be influenced by the physical and chemical characteristics of the diets (Kogan, 1989).

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Physical characteristics include shape, hardness of diets, surface or texture (Parra et al., 2012), and particle size of diets (Locatelli et al., 2008). Chemical characteristics include the nutritional content (Farrar et al., 1989; Kogan, 1989) (i.e. carbohydrate, protein, fat, vitamin, and mineral) and volatile compounds (Astuti, Lestari, et al., 2020). The suitable physical and chemical factors of diets can affect the population growth of *T. confusum*. Fardisi et al. (2013) and Fardisi et al. (2019) reported that the development of *T. castaneum* larvae was faster in flour with a small particle size (<0.7 mm). Furthermore, population growth and development of *T. castaneum* is more suitable in wheat with protein content between 6 and 16% (Ajayi et al., 2019; Astuti, Rizali, et al., 2020; Đukić et al., 2022; Shaurub et al., 2022).

Previous research has studied the development of *T. confusum* in soybean flour and pigeon pea flour (Ajayi et al., 2019) and the development of *T. castaneum* in various commercial and non-commercial flours (Astuti, Rizali, et al., 2020). Commercial flour is produced on a large scale by factories and can be found in supermarkets, whereas non-commercial flour is typically used for small-scale or personal needs and is produced manually by grinding the basic flour ingredients using a flour grinding machine. Non-commercial flour has healthier nutritional content compared to commercial flour, including low fat content, high protein (Aliyah & Setiawati, 2018), and no additional additives or preservatives during processing (Astuti, Rizali, et al., 2020). However, research on population growth and the biology of T. confusum in various commercial and non-commercial flours has not been conducted; therefore, this study is necessary. However, research on the population growth of *T. confusum* in various commercial and non-commercial flours has not yet been conducted, so this research needs to be undertaken. This research aims to determine the population growth of *T. confusum* in various commercial and non-commercial flours, including milled rice flour, red rice flour, black rice flour, white glutinous rice flour, mung bean flour, and soybean flour. This research is expected to provide information for those who need, such as flour producers, regarding the population growth of *T. confusum* in various commercial and non-commercial flours, and can be a basis for controlling *T. confusum* in storage.

METHODS

This research was conducted at the Plant Pest Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya, from November 2024 until April 2025. This research was conducted in laboratory conditions at 26.8 ± 0.71°C and RH 44.1 ± 3.76%. This research utilized six types of flour, including commercial and non-commercial varieties: milled rice flour, red rice flour, black rice flour, white glutinous rice flour, mung bean flour, and soybean flour.

Diets Preparation and Insect Culture

The non-commercial flour used in this research was obtained by grinding the diets using a grinder, while the commercial flour was obtained from a supermarket. Non-commercial flour consisted of six types of flour and the basic ingredients are obtained from agricultural institutions or farmer groups so that the variety of basic flour ingredients is more certain, including milled rice (Shinta Nur variety) was obtained from Kusuma farmer group, Purworejo Regency; red rice (Aek Sibundong variety) and black rice (Hare Kwa variety) were obtained from Sumber Makmur II farmer group, Lawang District, Malang; white glutinous rice was obtained from the Avia Supermarket, Klojen District, Malang; and mung beans (Vima-4 variety) and soybeans (Dena-1 variety) were obtained from Plant Assembly and Testing Center (PATC) for Various Nuts, Pakisaji District, Malang Regency. Then, the basic flour ingredients were grinded using a flour grinding machine. Then, the flour was sieved using a nylon sieve (20 mesh) to obtain the same particle size of flour. Commercial flour consisted of six types of flour products that

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can be easily found in Supermarkets, including milled rice flour (Bola Deli®), white glutinous rice flour (Bola Deli®), red rice flour (Sun®), and soybean flour (Mahkota™) were obtained from Avia Supermarket; mung bean flour (6 Enam™) was obtained from Lai Lai Supermarket, Klojen District, Malang; and black rice flour (N790™) was obtained from N790 Market, Kepanjen District, Malang Regency.

The six types of commercial and non-commercial flour were used in the study because these flours are derivatives of the *T. confusum* host range, widely used by Indonesians and have not been extensively researched. Furthermore, the classification of commercial and non-commercial flours was based on dietary sources. Commercial flour is produced on a large scale by factories and obtained from Supermarkets, while non-commercial flour is obtained by grinding the basic flour ingredients in-house.

The diets used in the study were sterilized using the cold sterilization method by Heinrichs et al. (1985). The diet was placed in a plastic ziplock (p=30cm; l=20 cm) and placed in a freezer (-15°C) for 7 days. Then, the diet was transferred to a refrigerator (5°C) for 7 days. Afterward, the diet was placed at room temperature (27±2°C) for at least 2 weeks. Insect culture was conducted at the Plant Pest Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya. *T. confusum* culture was done by modifying the method of Shah et al. (2021). *T. confusum* culture was carried out using wheat flour and oat flour (2:1). Then, 150 *T. confusum* adults, without distinguishing between males and females, were infested into a culture jar (d = 9 cm; h = 15 cm) that had been filled with diets for 7 days (Gerken & Campbell, 2020). After 7 days, the adults were removed from the culture jar, and the diets were infested with eggs, and the pupae emerged. Male and female pupae are distinguished based on the presence of a pair of appendages at the posterior ventral. Then, the pupae were waited until F1 progeny emerged (Kavallieratos et al., 2020; Namin et al., 2018). The F1 progeny of *T. confusum* used in this research were 7–14 days old (Romadoni & Hendrival, 2018).

Analysis of Chemical Characteristics of Diets

A proximate analysis was conducted at the Plant Assembly and Testing Center (PATC) for various nuts in Malang Regency. Proximate analysis was conducted to determine the nutritional content, including carbohydrates, fat, protein, ash, and water content in commercial and non-commercial flours, including milled rice flour, red rice flour, black rice flour, white glutinous rice flour, mung bean flour, and soybean flour.

In addition, phenol analysis was conducted at the Plant Pests and Diseases Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya. Phenol analysis was conducted to determine the content of phenol compounds in commercial and non-commercial flour, including milled rice flour, red rice flour, black rice flour, white glutinous rice flour, mung bean flour, and soybean flour, as one of the volatile compounds that can attract insects in host selection.

Population Growth Experiment

The population growth experiment used the no-choice test method (NCTM). This experiment consisted of six types of flour, including commercial and non-commercial varieties, such as milled rice flour, red rice flour, black rice flour, white glutinous rice flour, mung bean flour, and soybean flour, as the treatment diet. Each treatment was repeated four times and arranged in a Completely Randomized Design (CRD).

A total of 30 g of diet was put into a treatment jar (d = 6 cm; h = 9 cm). Then, 15 pairs of *T. confusum* adults were infested in each treatment diet for 7 days. The observed variables included the number of eggs, larvae, pupae, and F1 progeny.

Observed Variables

The observed variables in this study include the number of eggs, larvae, pupae,

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and F1 progeny of *T. confusum*. The number of *T. confusum* eggs was observed 7 days after infestation (DAI). The flour was sieved using a nylon sieve (50 mesh) into a Petri dish (d = 9 cm; h = 1,5 cm). Flour that did not pass through the sieve was placed in another Petri dish, and the number of eggs was counted using a stereomicroscope, a hand counter, and a brush (00). After the observation, the flour was returned to the treatment jar.

The number of *T. confusum* larvae was observed at 14 DAI. The number of larvae observations was carried out at 14 HSI because the larvae had reached the 3rd instar and had emerged more than 50% (Kayode et al., 2014). The flour was sieved using a nylon sieve into a Petri dish. Flour that did not pass the sieve was placed in another Petri dish, and the number of larvae was counted using a stereomicroscope, a hand counter, and a brush (00). After the observation, the flour was returned to the treatment jar. The number of *T. confusum* pupae was observed at 42 DAI because the first pupae were found to emerge on 42 DAI. The number of *T. confusum* pupae was observed at 42 DAI. The observation was conducted the same way as the number of larvae observation.

The number of F1 progeny was observed every day from the first F1 progeny that emerged until no more F1 progeny emerged. The observation was carried out by sifting the flour using a nylon sieve. The number of F1 progeny was observed using a hand counter and brush (00). After the observation, the F1 progeny was separated from the flour, and the flour was put back into the treatment jar.

Data Analysis

The data were analyzed using the Shapiro-Wilk test to assess normality. Data that were not normally distributed were transformed using a logarithmic transformation. Data on the number of eggs, larvae, pupae, and F1 progeny were analyzed using analysis of variance (ANOVA) at an error level of 5%. For significant differences between treatments, the data analysis continued using Duncan's Multiple Range Test (DMRT) at a 5% error level. In addition, a correlation analysis was carried out to determine the relationship between nutrient content and phenol compounds of flour with the number of eggs, larvae, pupae, and F1 progeny of *T. confusum*. The data analysis was done using R statistics software version 4.2.0 (R Core Team, 2023) with the agricolae package (de Mendiburu, 2021).

RESULT AND DISCUSSION

Number of Eggs, Larvae, Pupae, and F1 Progeny of *Tribolium confusum*

The analysis of variance showed that various types of flour significantly affected the number of eggs ($F = 5.86$; $P < 0.05$), larvae ($F = 6.87$; $P < 0.05$), pupae ($F = 18.57$; $P < 0.05$), and F1 progeny of *T. confusum* ($F = 18.00$; $P < 0.05$). The number of eggs in non-commercial red rice flour (86.25 eggs) was higher and significantly different compared to non-commercial soybean flour (10.00 eggs) and commercial soybean flour (1.50 eggs), but not significantly different compared to other types of flour. Furthermore, the number of larvae in non-commercial red rice flour (80.50 individuals) was higher and significantly different compared to non-commercial mung bean flour (15.50 individuals), commercial red rice flour (8.25 individuals), non-commercial soybean flour (6.00 individuals), commercial mung bean flour (5.25 individuals), and commercial soybean flour (1.25 individuals), but not significantly different compared to other types of flour. In addition, the number of pupae in non-commercial red rice flour (59.50 individuals) was higher and significantly different compared to other types of flour, but not significantly different compared to commercial black rice flour (44.25 individuals) and non-commercial black rice flour (38.75 individuals). The number of F1 progeny in non-commercial red rice flour (57.50 individuals) was higher and significantly different compared to other types of flour, but not significantly different compared to commercial black rice flour (44.25 individuals) and non-commercial

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black rice flour (38.75 individuals) (Table 1). Overall, the number of eggs, larvae, pupae, and F_1 progeny was higher in non-commercial flour compared to commercial flour. This is thought to be due to differences in processing between industrial flour and flour for non-commercial purposes. For example, the presence of additives or additional materials in commercial flour during processing. One additive commonly used in stored grains is propionic acid. Propionic acid acts as a mold inhibitor, repellent, and fumigant against stored product pests, so the population of *T. confusum* in commercial flour is generally lower than in non-commercial flour (Astuti, Rizali, et al., 2020).

The population growth of *T. confusum* is thought to be influenced by chemical factors in the diet, including nutrient content and volatile compounds. Correlation analysis reveals that only the number of eggs exhibits a correlation with chemical factors in the diet, while the numbers of larvae, pupae, and F1 progeny show no correlation with chemical factors in the diet. The correlation analysis indicates a negative correlation between the number of eggs with the ash ($r = -0.62$; $P = 0.02$), fat ($r = -0.67$; $P = 0.01$), and phenol content ($r = -0.63$; $P = 0.02$). It means that the higher the ash, fat, and phenol content in the flour, the fewer eggs are laid by female adults of *T. confusum*. Commercial soybean flour has a higher ash content (5.79%), fat (20.92%), and phenol (6.44 ppm) compared to other types of flour (Table 2). The results also showed that the number of *T. confusum* eggs in commercial soybean flour (1.50 eggs) was lower compared to other types of flour (Table 1). Astuti et al. (2013) reported that the phenol content in rice is negatively correlated with the number of eggs laid by the female adults of *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae). Kikuta (2020) also reported that soybeans contain phenol, which acts as a repellent, feeding deterrent, inhibits growth, and poisons for stored product pests. Furthermore, Ghada et al. (2025) stated that the phenol content in *Moringa oleifera* leaf extract can be toxic to the immature and adults of *T. castaneum* and inhibits *T. castaneum* egg laying (oviposition).

The present study showed a negative correlation between ash and fat content in flour with the number of eggs. This result was contradictory to several previous studies. Pasha & Abd-Eltawab (2022) reported that the number of *T. confusum* F1 progeny has a positive correlation with the ash and fat content in diets. The contradictory study is thought to be due to differences in the diet used in the previous study (wheat, maize, barley, oat, and sorghum) with the present study, so that the chemical factors (nutrients) contained in the diet will also be different. The ash (0.78–2.37%) and fat content (1.29–2.76%) in the previous study (Pasha & Abd-Eltawab, 2022) were lower compared to the ash (0.13–6.01%) and fat content (0.12–20.92%) in the present study (Table 2). The presence of high ash and fat content in the diet is thought to inhibit the growth of *T. confusum*. According to Chirigos et al. (1960)Excessively high or low mineral content in the diet and an imbalance in nutritional content can inhibit the population growth of *T. confusum*. Furthermore, Mickel & Standish (1946) reported that soybean flour with a fine texture and low-fat content is more attractive to insects for egg laying.

Fat content in diets is a source of energy reserves for insects (Lazzari & Lazzari, 2012), a component of cell membranes, hormones, and nutrient transporters, as a structural material to build other molecules (Cohen, 2015). Based on Wong & Lee (2011), the fat content of 2.65% in flour can support the population growth and development of *T. confusum*. In addition, the ash content in the diet, which consists of minerals (Cholilie & Zuari, 2021; Parra, 2012), plays a role in biological processes, including enzymatic reactions, ecdysis hormone production, and metabolic processes in insects (Parra, 2012).

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Table 1. Mean Number of *T. confusum* Eggs, Larvae, Pupae, and F1 Progeny on Various Commercial and Non-commercial Flour

Flour Types	Number of eggs ($\bar{x}$ ± SD)[1]	Number of larvae ($\bar{x}$ ± SD)[1]	Number of pupae ($\bar{x}$ ± SD)[1]	Number of F1 progeny ($\bar{x}$ ± SD)[1]
Commercial milled rice flour	77.75 ± 34.49 a	42.25 ± 23.58 bcd	0.50 ± 1.00 d	0.50 ± 1.00 c
Commercial red rice flour	35.00 ± 30.03 abc	8.25 ± 1.50 cde	8.25 ± 1.50 c	6.75 ± 1.70 c
Commercial black rice flour	61.25 ± 53.43 ab	45.00 ± 40.06 abc	44.25 ± 38.82 ab	44.25 ± 38.82 a
Commercial white glutinous rice flour	59.75 ± 26.60 ab	36.25 ± 22.09 bcde	0.50 ± 1.00 d	0.50 ± 1.00 c
Commercial mung bean flour	18.75 ± 5.90 bc	5.25 ± 1.89 de	0.00 ± 0.00 d	N/A
Commercial soybean flour	1.50 ± 2.38 c	1.25 ± 1.89 e	0.00 ± 0.00 d	N/A
Non-commercial milled rice flour	55.50 ± 41.10 ab	30.25 ± 19.41 bcde	15.00 ± 9.12 bc	13.75 ± 9.74 bc
Non-commercial red rice flour	86.25 ± 45.11 a	80.50 ± 42.69 a	59.50 ± 28.26 a	57.50 ± 32.52 a
Non-commercial black rice flour	75.00 ± 30.24 a	52.50 ± 24.47 ab	38.75 ± 16.39 ab	38.75 ± 16.39 ab
Non-commercial white glutinous rice flour	77.00 ± 37.87 a	47.50 ± 25.37 ab	8.50 ± 4.35 c	6.75 ± 3.59 c
Non-commercial mung bean flour	37.25 ± 33.33 abc	15.50 ± 24.09 bcde	10.50 ± 14.38 c	9.00 ± 12.51 c
Non-commercial soybean flour	10.00 ± 10.61 bc	6.00 ± 7.34 de	1.25 ± 1.50 c	1.25 ± 1.50 c

Note: The number in the same column followed by the same letters are not significantly different ($P < 0.05$). SD is the standard deviation.
[1]Data were transformed into log(x+1) for analysis purposes. N/A is a developmental phase that does not emerge.

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This study showed that *T. confusum* requires different nutrient content than *T. castaneum*, even though both pests are in the same genus. This is supported by Wong & Lee (2011) that the F1 progeny population of *T. castaneum* was higher in a diet with low carbohydrate content compared to the diet with high carbohydrate content. The carbohydrate requirement of *T. castaneum* is in contrast to *T. confusum*, which can grow on a diet with high carbohydrate content (Ajayi et al., 2019).

Table 2. Chemical Characteristics of Various Commercial and Non-commercial Flours

Flour types	Water (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Phenol (ppm)
Commercial milled rice flour	9.98	0.81	0.58	7.66	90.95	0.51
Commercial red rice flour	1.59	2.75	2.09	8.12	84.54	0.57
Commercial black rice flour	5.10	1.78	2.43	7.37	83.80	0.61
Commercial white glutinous rice flour	10.14	0.64	0.12	7.31	85.24	0.88
Commercial mung bean flour	11.46	0.13	0.21	0.76	87.44	3.39
Commercial soybean flour	4.65	5.79	20.92	30.23	6.44	6.44
Non-commercial milled rice flour	11.62	0.48	0.68	10.22	90.95	0.56
Non-commercial red rice flour	11.76	2.28	2.09	11.47	86.20	0.61
Non-commercial black rice flour	11.48	2.06	3.74	10.45	85.88	0.62
Non-commercial white glutinous rice flour	10.85	0.48	0.78	9.53	89.22	0.82
Non-commercial mung bean flour	8.51	4.88	1.12	19.69	74.32	0.72
Non-commercial soybean flour	6.92	6.01	22.01	28.33	43.65	0.55

In addition, there is a positive correlation between the number of eggs with carbohydrate content ($r = 0.73$; $P = 0.00$). It means that the higher the carbohydrate content in flour, the higher the number of eggs laid by female adults of *T. confusum*. Based on Ajayi et al. (2019), the development of *T. confusum* is influenced by the availability of carbohydrate and water in the flour. Flour with high carbohydrate and water content can increase the eggs laid by *T. confusum*. Based on Lazzari & Lazzari (2012), the carbohydrate content in the diet acts as an energy source and for amino acid production. Furthermore, *Tenebrio* spp. (Coleoptera: Tenebrionidae) can grow optimally on a diet with high carbohydrate content (70%), while they are inhibited on a diet with low carbohydrate content (<40%). In addition, Đukić et al. (2022) reported that *T. castaneum* can grow optimally on a carbohydrate content of 53%. However, the development of *T. castaneum* can be inhibited on a diet with a very high carbohydrate content (>98%).

The number of F1 progeny of *T. confusum* in non-commercial red rice flour and non-commercial black rice flour was higher compared to other types of flour. The high number of F1 progeny in non-commercial red rice flour and non-commercial black rice flour is thought to be due to the high number of eggs laid by female adults. Based on Wong & Lee (2011), a

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suitable diet for *T. castaneum* can increase the number of F1 progeny. The high number of F1 progeny of *T. castaneum* is also thought to be influenced by the short development time. Furthermore, Ajayi et al. (2019) stated that the F1 progeny population of *T. confusum* was higher in fresh soybean flour, roasted soybean flour, roasted pigeon pea flour, and wheat flour compared to fresh pigeon pea flour. According to Kavallieratos et al. (2020), *T. confusum* was unable to complete development in the two white rice strains. This is thought to be due to the loss of nutrients such as protein, fat, vitamins, and minerals during the milling process. The development of *T. confusum* was optimized by adding thiamine, riboflavin, and niacin to the diet. Furthermore, (Pasha & Abd-Eltawab, 2022) reported that the F1 progeny population of *T. confusum* was higher in cracked barley with high carbohydrate and protein content. In addition, the population growth of the *T. castaneum* was higher in Pioneer 21 corn flour compared to other corn flour varieties (Astuti, Lestari, et al., 2020). Furthermore, Astuti, Rizali, et al. (2020) stated that the development of *T. castaneum* is more suitable in corn, wheat, rice, and soybean flour. According to Arthur & Campbell (2008), in storage, *T. confusum* can be controlled using insecticides. Insecticide control in storage is often less effective, possibly due to the abundance of diet in the storage. Proper sanitation in storage can reduce pest populations and increase the effectiveness and penetration of insecticides. Furthermore, controlling *T. confusum* using pyrethrin aerosols has shown recovery of *T. confusum* after being knocked down.

This study is interesting because the results of *T. confusum* population growth was higher in non-commercial flour than in commercial flour. Based on Astuti, Rizali, et al. (2020) the development of *T. castaneum* is more suitable in non-commercial flour compared to commercial flour. This is thought to be due to the differences in treatment between commercial and non-commercial flour. Commercial flour can contain additive materials (preservatives) during the processing, so that it can inhibit the development of *T. castaneum*. In addition, further study is needed regarding the population growth of *T. confusum* in other host ranges besides flour, due to the wide host range of *T. confusum*, including various nut, spices, and corn. This study was limited to the population growth of *T. confusum* in various commercial and non-commercial flours; therefore, further research on the preferences and development of T. confusum in different flours is also necessary.

CONCLUSION

The population growth of *T. confusum* was higher in non-commercial red rice flour. In this study, chemical characteristics of diets including ash, fat, carbohydrate, and phenol content only affected the number of eggs. High ash, fat, and phenol content in the diet will reduce the number of eggs laid by female adults of *T. confusum*, while high carbohydrate content in the diet can increase the number of eggs.

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