

The influence of a DDGS diet on the development and oviposition rate of *Tribolium castaneum* (Herbst)

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Abstract

Dried Distillers Grains with Solubles (DDGS) is used in livestock feeds and finishing diets to replace maize or other grains. As more of this product is available to the feed industry, the effect it might have on the vulnerability of animal feed to insect infestation is unknown. This research focused on the influence of old generation DDGS as food and oviposition resource of red flour beetle *Tribolium castaneum* in contrast with a traditional a flour (90%)/yeast (10%) diet. Larval development was significantly faster ($P<0.05$) on a flour/yeast diet (19.15 ± 0.16 d) compared to the DDGS (45.44 ± 0.72 d). Both DDGS and the flour/yeast diet had no significant influence on egg hatch or pupation time. These results indicate that this type of DDGS is not as suitable a developmental diet compared to the standard laboratory diet and that the addition of DDGS to animal feeds should not increase feed vulnerability to flour beetle infestation. Additionally, in a no-choice situation, oviposition rate was significantly lower ($P<0.05$) on DDGS compared to the flour/yeast diet. In conclusion, old generation DDGS is not a good substrate for red flour beetle and thus vulnerability of products to red flour beetle development is not increased with DDGS as an ingredient.

Keywords: DDGS, Red flour beetle, *Tribolium castaneum*, Oviposition, Development

1. Introduction

Dried Distillers Grains with Solubles (DDGS) is a byproduct when maize or other distiller grains are dry milled. The fractionized starch portion is fermented and then alcohol is removed by distillation for the production of ethanol as fuel and alcohol for beverage (Cromwell et al., 1993; Ileleji et al., 2007). The remaining solid (DDGS) contains protein, fiber, starch, oil and ash with approximately 2-3 times higher concentration of nutritional components than the raw grain (corn) which DDGS is originally derived from except starch, which is lower in DDGS (Shurson et al., 2003). Studies show that different types of DDGS vary in color, odor, concentration of nutritional elements and digestibility. DDGS have been used in livestock feeds, especially pigs and cattle, or finishing diets in all of types of feed production to replace maize or other grains (Shurson et al., 2003; Stein et al., 2009). As more of this product is available to the feed industry, understanding the effect it might have on the vulnerability of animal feed to insect infestation is important. The objective of this study was to determine the vulnerability of old generation DDGS to infestation by red flour beetle by examining the development and oviposition rate of the red flour beetle, *Tribolium castaneum* (Herbst), on DDGS in contrast with a standard laboratory diet.

2. Materials and methods

2.1. Insects and diets

Red flour beetle colonies were maintained in environmental chambers at $27\pm 1^\circ\text{C}$ in the Department of Entomology at Purdue University. A diet of wheat flour (90%) and brewer's yeast (10%) was used for the colony maintenance and this diet was used as the control for comparison to a diet of DDGS. The DDGS diet used in this experiment was obtained from an "old" generation dry-grind fuel ethanol process plant. The approximate percentage of components (w/w% dry basis) in the bulk composite was crude protein (26.55); crude fat (10.56); crude fiber (6.1), and ash (4.19) (Ileleji et al., 2007).

2.2. Developmental rate

Eggs were obtained by placing about 100 adult red flour beetles on a thin layer of wheat flour (90%) and brewers' yeast (10%) in a jar (400 mL) for 24 h at 32.5°C in the environmental chamber. One day old eggs were sifted from the laboratory diet using a No. 80 sieve (Seedbuero Equipment Company (Des Plaines, IL, USA)/180µm hole size). Eggs were then placed singly in the wells of a 16-well plate half filled (2 mL) with one of the test diets to determine the developmental period. Wells were checked twice a day until larval emergence. Once larvae emerged, and for the duration of larval and pupal stage, well plates were checked on a daily basis until adult emergence. Sixty-four wells were used for each test diet.

2.3. Oviposition rate

Pupae were sexed and kept in separate containers until adult emergence. One pair of 3-5 d-old adults was placed in a Petri dish half-filled (20 mL) with either test diet and held at 32.5°C in the environmental chamber. Preliminary experiments indicated the unsuitability of DDGS, thus more DDGS plates were prepared (thirty two dishes of flour/yeast diet and seventy dishes of DDGS). After a 3 wk oviposition period, both adults were removed from the Petri dish. Since it was difficult to separate eggs from the DDGS diet, the numbers of larvae alive after two additional weeks were counted. Thus oviposition numbers recorded reflect the number of eggs laid, less those eggs that did not hatch and those that did not survive the first two weeks of life.

3. Results and discussion

3.1. Developmental rate

The larval stage, in contrast with other stages of development, was significantly elongated when fed a diet of DDGS ($P < 0.05$). Development on flour/yeast diet averaged 19.15 ± 0.16 d compared to 45.44 ± 0.72 d when larvae fed a diet of DDGS (Table 1). Developmental times for the flour and yeast diet were comparable to other published rates for this insect on similar diets (Good, 1936; Howe, 1956). As expected there was no effect of diet on the length of the egg or pupal stage since these are non-feeding life stages (Table 1). Egg hatch on both diets demonstrated higher rates than Howe's results, but mortality rates were similar to published rates (Howe, 1956). This elongated development period for larvae on DDGS is good news for grain handlers, feed processors and millers who store DDGS, especially during the warmer storage periods. Infestations by storage insects may grow significantly slower, resulting in less damage over the storage period.

Table 1 Influence of diet on average developmental periods and mortality rates with comparable published data.

Diet	Egg		Larva		Pupa	
	X±S.E.(d)	Hatch (%)	X±S.E.(d)	Mortality (%)	X±S.E.(d)	Mortality (%)
Flour and Yeast	3.76± 0.03	96.29	19.15± 0.16	7.69	4.75± 0.07	5.9
DDGS	3.79± 0.02	97.91	45.44± 0.72	11.2	4.81± 0.05	2.9
Wheat feed (Howe, 1956)	2.9	75	14.6	7	4.6	2.5

The difference in development time for red flour beetle on these two diets may be related to nutritional content of the diet. We are still investigation this possibility. A proximate analysis of DDGS particles in old generation DDGS by Illeleji et al. (2007) indicated protein levels in the acceptable range for insect development. Shurson et al. (2003) examined the amino acid composition of old generation DDGS and found they contained (dry matter basis, % of diet) 0.92% arginine, 0.61% histidine, 1.00% isoleucine, and 2.97% leucine. These amounts are within the acceptable minimum requirements of red flour beetle (Taylor and Medici, 1966). They found that red flour beetle require arginine (0.4%), histidine (0.2%), isoleucine (0.3%) and leucine (0.6%) for survival, but that these were just minimal levels. Higher levels found in their confused flour beetle (*Tribolium confusum* Jacquelin du Val) control diet (histidine (0.6%); isoleucine (1.2%); leucine (1.4%); phenylalanine (0.8%); and tryptophan (0.2%)) improved larval growth (measured by insect weight) significantly. They did not measure developmental time. This weight gain difference could also be true for red flour beetle since it is closely related to confused flour beetle. The elongated larval development period on DDGS that we found might be related to the amino acid profile. We are currently examining the amino acid profile of our control diet to determine if the

levels are acceptable, but do not anticipated that it contains below minimum levels of important amino acids.

3.2. Oviposition rate

Twenty-six of the 70 red flour beetle females on the DDGS diet laid no eggs, and in 12 instances one of the pair died with no oviposition occurring compared to the flour/yeast dishes, in which all females laid eggs and none died (Fig. 1). The number of eggs that hatched and survived two weeks was significantly lower ($P < 0.05$) on DDGS (17.37 ± 1.22 eggs per female ($n=32$)) compared to a flour/yeast diet (204.7 ± 10.99 eggs per female ($n=32$)). The DDGS rate decreased to an average of 9.59 ± 1.33 eggs per female ($n=58$) when females that survived but did not lay eggs are included. Thus oviposition rate in the control diet was 12-21 times higher when compared to DDGS as an oviposition substrate.

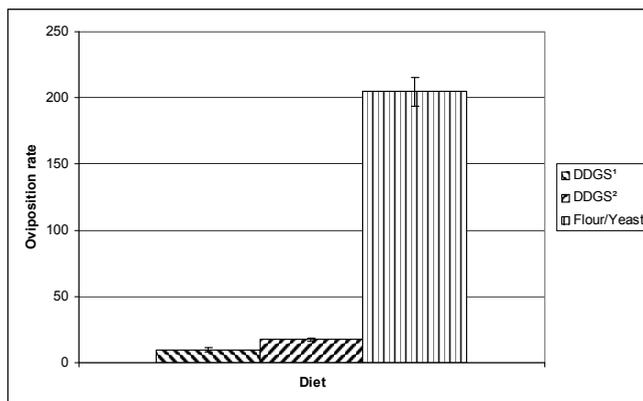


Figure 1 Red flour beetle oviposition rate during a 3-week period on flour/yeast ($n=32$) or DDGS with ($n=58$) or without ($n=32$) females that did not lay eggs.

Howe (1962) found that the mean number of eggs per female laid in 7 wks on finely divided wheat feed at 32.5°C and 70% r.h. was 539.2 eggs. This is equal to 77 eggs per week which is comparable to our average of 68 eggs per week at 32.5°C on the control diet. Although these averages do not take into consideration a cyclic nature of oviposition, the numbers are within a reasonable approximation. Additionally, our numbers could be a slight under estimation of oviposition due to the mortality of larvae in the first few weeks. However, it would be an under estimation for both the control and DDGS diet and thus the relative magnitude of the difference would not change and DDGS would still be considered a relatively unsuitable diet for red flour beetle. Thus in a no-choice situation, red flour beetle females will choose to either not lay eggs or lay very few eggs when presented with a DDGS diet. We are currently investigating this situation. Oviposition data combined with developmental data indicates that even if eggs are laid on DDGS, the development time is greatly increased, resulting in a significantly extended life cycle. Therefore the feed industry is not at greater risk for red flour beetle infestation when using old generation DDGS in feeds.

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