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Moisture content in a wheat germ diet and its effect on the growth of *Plodia interpunctella* (Hübner)☆

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Abstract

The growth rate of *Plodia interpunctella* larvae feeding on wheat germ was highly dependent upon the water content in the diet. The water content in a cereal diet is established by the hygroscopicity of the dietary components and the relative humidity (r.h.) in the equilibrating atmosphere. The larval growth rates on wheat germ increased with corresponding increases in r.h. over the range of 40–85%. Similar changes in r.h. had a measurable, albeit minimal, impact on the time required for embryonic development and egg hatch. The water content of wheat germ was further increased by supplementing the germ with the humectant, glycerol. The larval growth rate increased with each incremental increase in dietary water content irrespective of whether it resulted from increases in r.h. or glycerol. However, glycerol supplementation provided an additional boost to the growth rate that was in addition to and distinct from the dietary water increase.

Keywords: Moisture; Wheat germ; Diet; Growth; *Plodia interpunctella*

1. Introduction

Cereal products are naturally hygroscopic, i.e. they take up or give up moisture to the surrounding atmosphere until an equilibrium is established (Pixton, 1967; Thorpe, 2001). Citing Oxley (1948), Pixton goes on to state "that the relationship between moisture content and r.h. is best represented by a sigmoid curve rising steeply above 80 per cent r.h.". Thus, the moisture content of a cereal-based diet is reliant upon the relative humidity (r.h.) and can be adjusted up or down by corresponding changes in r.h.

The moisture content of cereal grains and their products is an important criterion that has to be considered when such products are placed in storage. A r.h. of 70% or lower is considered safe for storage of cereal products, whereas a r.h. of 75% and above promotes mold development and spoilage (Pixton, 1967). What we do not know is how well the growth and development of the Indian meal moth, *Plodia interpunctella*, fits within this framework of moisture considerations for storage of cereal products.

Silhacek and Murphy (2006) found that wheat germ provided optimum support for the growth and development of *Plodia* larvae when supplemented with 30% glycerol (w/w) at 70% r.h. Glycerol is a humectant and is commonly added to foods and diets to increase their moisture content. The purpose of this study was to determine if the glycerol supplementation of the wheat germ diet for *Plodia* increased the larval growth rate by increasing its water content.

2. Materials and methods

2.1. Test insects

Plodia interpunctella was reared at 30 °C, 70% r.h. in clear polystyrene boxes (14 cm × 19 cm × 9 cm deep) on the standardized *Plodia* diet described by Silhacek and Miller (1972). This diet consisted of ground dog food, rolled oats,

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cornmeal, whole wheat flour, wheat germ, brewer's yeast, glycerol and honey. A 16L:8D photoperiod was maintained with the scotophase routinely initiated at 12:00 PM. Twenty-one days after culture set up, moths were collected for oviposition. For culture setups, eggs were collected each day over a 1 h period during the last 4 h of the photophase. Experimental eggs were obtained by taking a 5 min "cut" during the middle of this oviposition period.

2.2. Dietary moisture

Wheat germ diets (Silhacek and Murphy, 2006) were prepared with 0%, 10%, 20%, 30% and 40% glycerol (w/w). The diets were mixed, covered with foil and left overnight at ca. 22 °C and 60% r.h. to minimize stickiness before adding the eggs. Test diets were incubated for 13 d in each of four incubators maintained at 30 °C and having r.h. of 40%, 55%, 70% and 85%. Any change in moisture contents of the test diets during the l3 d incubations were determined in samples taken after 3, 7, 10 and 13 d equilibration by using a Digital Moisture Balance (Model AD-4714, A & D Co. Ltd., International Division, Tokyo, Japan). These analyses were repeated three times using fresh preparations of diet, and average moisture contents ± SD were calculated for each determination point. The equilibrium moisture contents at the four test humidities were calculated from the means of the 10 and 13 d determinations. Three replicate means were averaged for each r.h. to obtain an average moisture content ± SEM. The means were compared using a *t*-test to determine any significant differences ($P < 0.05$).

2.3. Larval growth

Larval growth rates on wheat germ incubated at 40%, 55%, 70% and 85% r.h. were determined in an experiment where 25 freshly laid eggs (0–5 min old) were placed on each of three replicate test diets. Each diet was placed in a 30 dram polystyrene vial with a screw cap bottom and a screened (0.150 mm aperture, 2.5 cm diameter) top, and incubated at 30 °C under a 16L:8D photoperiod at one of the four test humidities. The growth of larvae at the different humidities was monitored visually until individual larval weights were ca. 1–2 mg. Then, each day a group of five larvae was selected randomly from each test container, weighed and returned to the diet. Daily weighing was continued until pupation or until 14 d after setup. When larval weighing was continued after day 14, it was less frequent as indicated on the graphs.

2.4. Embryonic development

Twenty-five freshly laid eggs (0–5 min old) were placed in a 17 mm × 5 mm deep vial cap, which was then positioned in the center of a 4 × 4 cm weighing boat and surrounded with a small amount of *Plodia* diet to trap larvae as they hatched. The loaded weighing boats were then placed in desiccators containing saturated salt solutions that provided a range of r.h. that ranged from 7% to 75%. All manipulations and incubations were conducted at 30 °C. After the onset of egg hatch, the time and number of eggs hatched were recorded every 30 min until hatching was complete. Each determination was repeated three times and analyzed to provide an average time of hatch ± SD. R.h. was monitored using HOBO data loggers (Onset Computer Corporation, Bourne, Maine).

3. Results and discussion

3.1. Adjusting water content in wheat germ diets by incubating at different r.h.

Kretschmer wheat germ, taken from a newly opened, vacuum-packed jar had a water content of ca. 4.0% (Fig. 1). The fresh germ took up water very rapidly during the first day of incubation at higher r.h. Incubations at 70% r.h. or less usually achieved an equilibrium within 3 d. However, equilibration could take as long as 7 d when the magnitude of moisture uptake was greater. The equilibrium moisture contents of wheat germ samples after incubation at each of the four humidities ranged from 6% at 40% r.h. up to a high of 17.5% at 85% r.h.

The growth rates of Indian meal moth larvae on wheat germ equilibrated at the four test humidities shown in Fig. 2 increased with increases in r.h., i.e. with increases in the water content of the wheat germ. These observations indicated that the water content in the wheat germ had a marked stimulatory effect on larval growth. The maximum larval growth rate observed on wheat germ having 17.5% moisture was still considerably less than that on *Plodia*

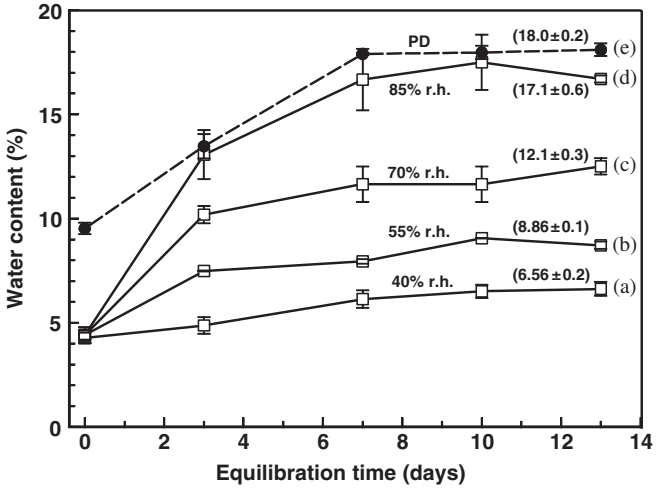

Fig. 1. Water content in wheat germ diets at various times during equilibration at 30 °C and the four test humidities. *Plodia* diet equilibrated at 70% r.h. is included for reference. Each point is the mean of three determinations ± the SEM. The mean water content ± SEM of each equilibrated diet is indicated in parenthesis; water contents with the same lower case letters were not significantly different at $P < 0.05$ (two-tailed *t*-test).