Starches and Insect Control

Starches affect red flour beetle development and reproduction.

Natural starch is an abundant nutrient carbohydrate $(C_6H_{10}O_5)_n$, found mainly in the seeds, fruits, tubers, roots, and stem pith of plants, notably in corn, potatoes, wheat, and rice, and varying widely in appearance according to source but commonly prepared as a white, amorphous, tasteless powder. Natural starch usually consists of 25% amylose (linear starch polymers) and 75% amylopectin (branched starch polymers).

Resistant starches (RS) include starches that are resistant to enzymatic hydrolysis in the small intestines of humans. RS are classified as RS1, RS2, RS3, and RS4.

- RS1 refers to resistant starch that is encased physically by whole grains.
- RS2 is a granular resistant starch.
- RS3 refers to non-granular, retrograded, or crystalline resistant starch.
- RS4 is a manufactured resistant starch.

Whole grains can deliver RS1, green bananas deliver RS2, and RS3 is found in ready-to-eat breakfast cereals, bread crusts, coocked and cooled potatoes, and cooked and cooled pasta. RS4 is manufactured from various sources, including wheat, potato, and tapioca, and is available from a variety of ingredient suppliers.

Red Flour Beetles

The literature has very little information on the effects of various starches on red flour beetle development and reproduction. One study published in 1966 showed 100% mortality of larvae of the red flour beetle, a major pest of flour mills, when they were fed potato starch.

In the laboratory, my graduate student, Xue Meng, conducted a series of experiments to see:

1. How well larvae develop on six different starches with various amylose contents.

2. Whether or not adult flour beetles are attracted to starches.

3. If flour beetles lay eggs on starches.

Development Studies

The six types of starches used included waxy corn starch (2% amylose), corn starch (25% amylose), wheat starch (25% amylose), cross-linked wheat starch (70% total dietary fiber), high-amylose starch (70% amylose), and potato starch (12-20% amylose).

The development on starches was compared with development on flour alone and flour plus 5% by weight of brewer's yeast diet. The latter diet is used in the laboratory for mass-rearing this species.

Pest Management

Dr. Bhadriraju Subramanyam

About 90% of the starch particle sizes were below 15 to 68 microns, whereas 80% of the flour particle sizes were below 132 microns. Therefore, starch particle sizes were smaller than that of the flour particles, and it is possible for larvae or adults of red flour beetle to consume them.

> On starches, development of larvae was adversely affected, and larvae failed to develop beyond second instars. Additionally, survival on flour and flour plus yeast was far superior to survival on starches.

About 5g each of starch, flour, and flour plus yeast (5% by weight) were transferred individually into 30-ml plastic condiment cups. Fifty red flour beetle eggs were added into each cup. Three cups were sampled every three days. Larvae from cups were recovered.

Measurements were made on the following aspects: length of the larvae, width of the head capsule (to indicate stage of larval development – instars), weight of larvae, and proportion of the total larvae that were alive at the observed time periods.

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The worst larval survival was on potato starch, followed by wheat starch and corn starch. Potato starch, which belongs to the RS2 type, is resistant to enzyme digestion due to low surface-to-volume ratio of the granules and cross-linking between molecules provided by enriched phosphorus content in these compact granules.

The cross-linked wheat starch and 70% amylose corn starch are resistant to enzyme degradation, becaue their tightly packed structure reduces enzyme access to the starch chains. The development results are consistent with this finding.

The adverse effects of starches on growth of larvae compared to flour or flour plus yeast suggest that the starches lack certain essential nutrients for normal development. What these constituents are at this point is unclear, but we speculate that it could be protein components that these starches lack.

Adult Preference Tests

In 30cm-diameter and 8cm-high arenas, 2.5g of a starch and 2.5g of flour were placed at the north and south ends. Fifty unsexed adults of the red flour beetle were released at the center of the arena. All arenas were checked at 36, 48, 60, and 72 hours after adult introduction to determine the number of adults retained in starch and flour.

These studies showed that 48-80% of

the released adults were retained in starch and flour in each arena.

The results also showed that the number of adults retained in starches did not vary significantly from those in flour, suggesting that starches were as attractive as flour to the adults.

Egg-Laying Tests

A pair of newly-emerged adults of flour beetles were placed on 2.5g each of the six starches, flour, and flour plus yeast diet in 30-ml plastic condiment cups. Every three days, the adults were sifted form the starch or flour and moved to fresh starch or flour diets. There were four such transfers. The number of eggs laid was counted every three days ending on day 15.

These results showed that on average, red flour beetle laid 97 and 109 eggs per female on flour and flour plus yeast, respectively, whereas on starches, the average number of eggs laid ranged from 0.1 to three eggs per female. The low number of eggs laid on starches suggests that triggers for egg laying are absent in starches.

Currently, tests are underway with different percentages of protein admixed with wheat starch to determine whether protein plays an important role in development, survival, and oviposition of the red flour beetle.

A simple test in the laboratory showed that adults placed on a sieve above flour do not lay eggs and need to be in the flour to lay eggs. This suggested that feeding may stimulate egg laying.

In additional tests, we observed that red flour beetles placed on flour and then transferred to starches laid eggs. Similarly, beetles that failed to lay eggs on starches when placed on flour laid eggs during the next three days, reinforcing that feeding on suitable substrates (flour) is necessary for egg laying.

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Effect of Starch vs. Flour on Larval Development

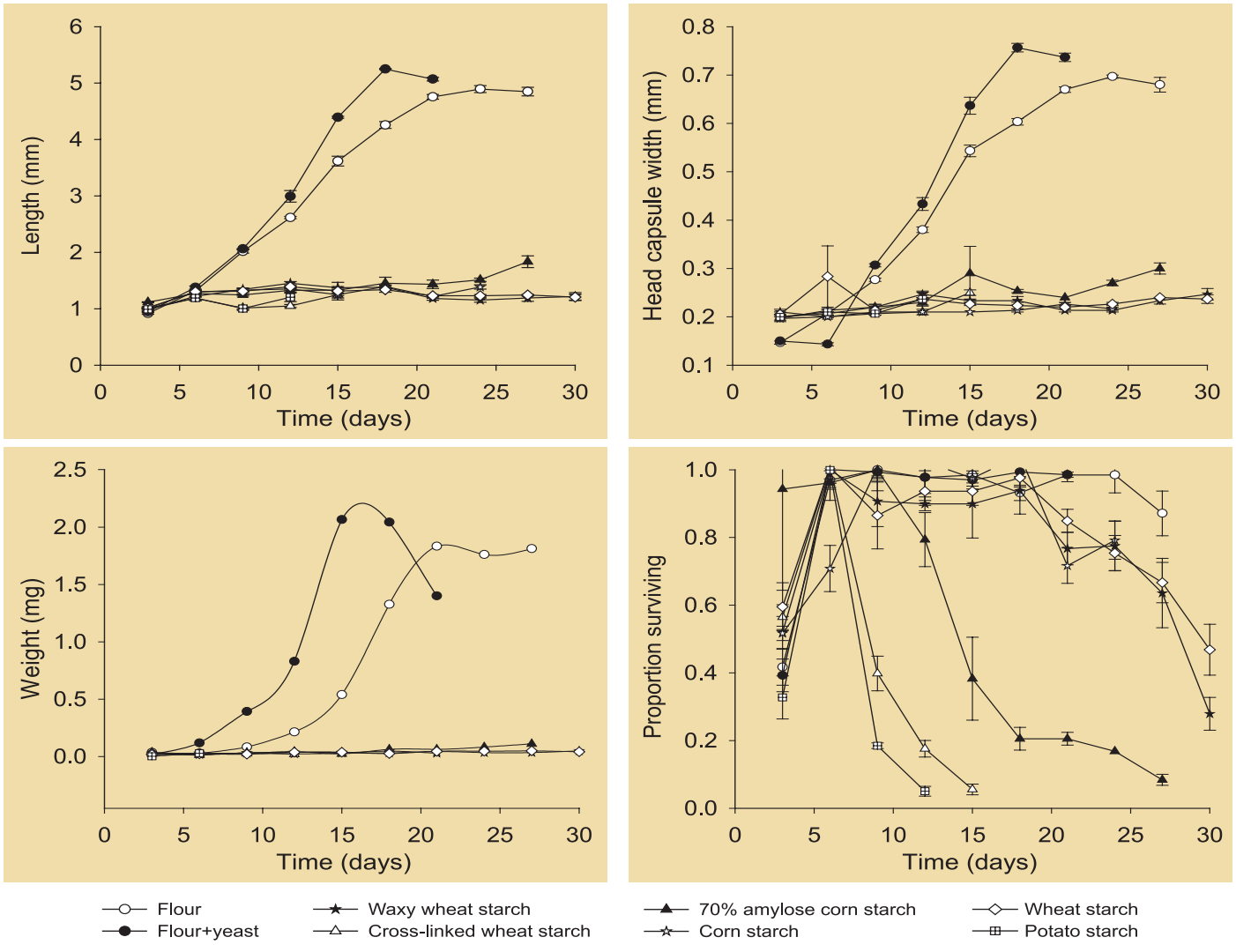

Illustration courtesy of the Kansas State University Department of Grain Science and Industry.