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Form-Fill-Seal Machine for Mass Rearing Noctuid Insects

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Abstract

The egg-implanting operation for noctuid moths is performed with an in-line form-fill-seal machine, which consists of a heating unit, tray-forming press, diet-dispensing head with a diet-dispensing pump, cooling tunnel, egg and corncob grits dispenser, tray-sealing press, and a guillotine. The process includes forming the rearing trays, filling the trays with diet, cooling the diet, dispensing eggs mixed in sterile corncob grits on top of the diet, sealing the trays, then cutting the trays for storage and shipping. Each of these processes is discussed in detail separately.

Introduction

For many years, farmers have relied mainly on insecticides for the control of noctuid pests such as the tobacco budworm, *Heliothis virescens* F.; the corn earworm, *Helicoverpa zea* Boddie; and the beet armyworm, *Spodoptera exigua* (Hübner). Problems such as insecticide resistance and environmental contamination may occur with the singular use of insecticides for control of pest insects. Since natural enemies can help regulate pest populations, incorporating biological control as a component of an integrated pest management program can reduce insecticide usage. Production of natural enemies for field-release requires that the technology for mass rearing the hosts for the natural enemies be established. With these goals in mind, an in-line form-fill-seal machine was modified to mechanize production of the

tobacco budworm, the corn earworm, and the beet armyworm.

In 1971, an Anderson Formseal machine Model 655-BBS-9 was purchased from Anderson Brothers Manufacturing Company in Rockford, Illinois, by the Southern Grains Insects Research Laboratory, USDA, ARS in Tifton, Georgia. This machine had a heating unit, forming press, sealing press, and trimming press. A guillotine was substituted for the trimming press. Diet-filling and egg-infesting stations were designed, built, and synchronized to make a continuous automated process (Sparks and Harrell, 1976). The diet-filling machine poured diet into each of the 32 cells of a rearing tray via tubes (a single tube poured diet into a single cell). An egg-filler then dropped eggs into egg channels, which connected to the diet cells. When the eggs hatched, the larvae would crawl via the egg channels into the diet cells to feed. Eggs were not placed directly onto the diet because hot diet caused egg mortality. This form-fill-seal machine with the diet-filling machine and egg-filler was used to rear more than 6 million corn earworm pupae from March 1972 to February 1974.

In 1985, this machine was donated to the GAST Rearing Facility, USDA, ARS, at Mississippi State, Mississippi, by the Tifton laboratory. Modifications were made to increase the efficiency of the production process. A cooling tunnel was added to cool the diet to make it possible to place eggs directly onto the diet. New molds were made for the tray-forming press and tray-sealing press. The new molds eliminated the egg channels, which were no longer necessary. A diet-dispensing head with a pump and an egg and corncob grits dispenser were designed to replace the less efficient diet-filling machine and egg-filler previously used. A modified Mylar lidding (Davis et al., 1990; Davis, 1996) was substituted for Tyvek as lidding because the new Mylar is more permeable to air. Also, a flash sterilizer was added to the system to sterilize the diet.

The total operation for rearing noctuids in multicellular trays is performed with the in-line form-fill-seal machine (FFSM), which is powered electrically and pneumatically. From front to rear, the parts of the FFSM consist of a heating unit, tray-forming press, diet-dispensing head with a diet-dispensing pump, cooling tunnel, egg and corncob grits dispenser, tray-sealing press, and a guillotine (Figure 1). The process includes forming the rearing trays, filling the trays with diet, cooling the diet, dispensing eggs on top of the diet, sealing the trays, and then trimming the trays for storage and shipping.

Egg Implanting Operation

Tray-forming Process

The rearing trays are made from roll stock, polyvinyl chloride plastic 15 cm wide with 15.0-mil gauge (American Mirrex Corp., Newcastle, Delaware), which is held on a rod at the front of the FFSM (Figure 1). The plastic is preheated (to about 150° C) as it passes through the heating unit. Then the plastic moves over the tray-forming press where air pressure (100 ± 10 psi) forces the material into a 32-celled mold (Figure 2) forming the tray, which immediately cools.

The resulting 32-celled tray is 14.6 cm wide by 55.1 cm long by 1.8 cm deep; each cell is 3 cm in diameter and 1.8 cm deep with a rounded bottom 1.5 cm in radius. Trays are formed sequentially in a continuous ribbon and moved intermittently along the processing line by the FFSM.

Diet-filling Process

The agar soybean flour-wheat germ diet (King and Hartley, 1985) is mixed and then sterilized in a flash sterilizer (Cherry-Burrell Corp., Louisville, Kentucky). The diet (41-43°C) is pumped continuously from the flash sterilizer to a semiliquid diet tube (Eckford Dairy Supply, Starkville, Mississippi), which is 5.1 cm in diameter and 76.2 cm in length (Figure 3). The diet is then pumped by the diet-dispensing pump (Filling Unit 2971-1, FSV-260-1; National Instrument Co., Baltimore, Maryland) (Figure 3) into the diet-dispensing head (Figure 2).

Diet is forced through a hole in the diet-dispensing head to fill a single cell of the rearing tray with about 7 ml of diet. Since the diet head has 32 holes, a 32-celled tray can be filled at one time. A hole in the diet head is 2 mm in diameter,

large enough to allow diet to pass through, but small enough to keep diet from dripping from the head once the cells are filled with diet.

Diet-cooling Process

After the tray is filled with diet, it passes through a cooling tunnel (Griffin 1979a) which is about 1.3 m long (Figure 4). A single unit air conditioner releases cold (0-2°C) air into the tunnel. This cold air cools and solidifies the diet.

Egg-dispensing Process

The procedures used for adult handling, egg production, and egg collection for noctuid moths have been described in detail by Jenkins et al. (1995). Once fresh eggs are obtained, 20 ml of eggs are mixed with 1,020 g of corncob grits (Anderson Cob Grit Company, Maumee, Ohio). The corncob grits is a 1:1 mixture of 20/40 mesh:40/60 mesh. Eggs with corn cob grits are poured into the egg and corncob grits dispenser (Figure 4), which meters and dispenses ~ 0.65 g of egg and corncob grits mixture onto the diet.

The egg and corncob grits dispenser is an automated version of the hand inoculator for dispensing lepidopterous larvae developed by Davis and Oswalt (1979). The egg and corncob grits dispenser has 32 holes (1.4 cm in diameter), one hole per tray cell, and releases 2-6 eggs per cell. To reduce static electricity, tensile is placed underneath the rearing trays when the eggs are being dropped onto the diet. A positive air flow from the HEPA filter system (Micro Air Media Air Cleaners, Jackson, Mississippi) moves clean air across the trays after eggs are dispensed onto the diet to reduce contamination of the diet in open trays.

Tray-sealing Process

The rearing trays are covered and sealed with Mylar (Oliver Products, Grand Rapids, Michigan; 200-gauge lidding cut 15 cm wide; contains 1.6-2.4 kg heat seal glue per 100 m^2 in dot patterns; processed with 50 perforations per 6.45 cm^2). A sponge, wetted with 0.004% Coverage Plus disinfectant (Calgan Vestal Laboratories, Inc., St. Louis, Missouri), wipes the Mylar before covering the tray to reduce static electricity. The tray-sealing press consists of a heating unit on top and a 32-celled mold to hold the rearing tray. The heating unit seals (130° C) the Mylar lid onto the tray when pressed down on the mold.

Tray-trimming process

A guillotine cuts the trays into sections of two trays each. Each section of trays is shaken by hand to spread the egg and corncob grits mixture evenly over the diet. The sections are then stacked in sanitized rackveyors (Griffin, 1979b).

Production Efficiency

The described process produces 13 trays/min resulting in around 800 larvae/minute or 49,000 larvae/hour. Material cost, excluding colony maintenance costs and labor costs, is $2.25 to $2.40 per tray. More detailed information concerning the various operations of this machine can be obtained by request.

Machine vs Hand Methods for pupal production

To determine the efficiency of the form-fill-seal machine in producing pupae, a comparison was made between this machine and a hand-planting method of implanting eggs onto the diet. For the hand-planting method, eggs were

transferred individually and gently onto the diet in a tray. Data on implanting times, number of eggs per cell, percentage of cells with eggs and first instars, percentage egg hatch, percentage of cells with pupae, and pupal weights were collected for 8 trays (32 cells per tray; 256 cells total) of diet for each method. Even though mean pupal weights were higher when eggs were hand planted onto diet versus implanted by the egg/corn cob grits dispenser on the FFSM, production of pupae on a tray was much lower for the hand method in comparison to the machine method for implanting eggs (Table 1). Thus, in terms of pupal production, the FFSM method for implanting eggs was much more efficient than the hand method.

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Table 1. Comparison of pupal production of *Heliothis virescens* between the form-fill-seal machine and the hand method of implanting eggs.

	Form-fill-seal machine	Hand
Mean egg implanting time (min)	0.08 a	5.25 b
Mean number of eggs per cell	5.08 a	1.00 b
Mean percentage of cells with eggs	100.00 a	100.00 a
Mean percentage egg hatch	73.90 b	26.20 b
Mean percentage of cells with first instars	97.40 a	26.20 b
Mean percentage of cells with pupae	81.30 a	25.10 b
Mean pupal weight (mg)	243.50 a	322.90 b

Means followed by the same letter in a row are not significantly different (P > 0.05; t-test)