FACTORS AFFECTING OVIPOSITION AND DEVELOPMENT OF THE FACE FLY, *MUSCA AUTUMNALIS* DEGEER (DIPTERA: MUSCIDAE)

by

DARRELL EDWARD BAY

B. S., Kansas State University, 1964

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

Approved by:

C. W. Pitts
Major Professor

TABLE OF CONTENTS

INTRODUCTION AND LITERATURE REVIEW

The face fly, *Musca autumnalis* DeGeer (Diptera: Muscidae), was first reported in North America in 1952 at Middletown, Novia Scotia (Vockeroth, 1953). Prior to that time, it was confined to Asia, Europe, and northern Africa (Patton, 1933). Since its introduction into North America, the face fly has steadily extended its range over the northern half of the United States.

The life history and habits of the face fly were extensively studied by Hammer (1942) and recently reviewed by Tesky (1960). The female face fly feeds most frequently on mucous secretions from the eyes, nose, and mouth of cattle. Male face flies are seldom found on cattle. Face flies are considered by Hammer (1942) to be facultative bloodsuckers feeding on the blood exuding from wounds made by obligatory blood sucking flies or other injuries. Hammer (1942) and Derbeneva-Ukhova (1942) reported adult flies to frequently feed on fluids on the surface of cattle manure. Hammer (1942) also reported adult face flies feeding on the nectar of a wide variety of flowers and believed that this nectar was the principal diet of the flies before the cattle were pastured in the spring.

Gravid females characteristically oviposit their eggs singly in fresh cattle manure with the mast extending upward (Patton, 1933b; Hammer, 1940; Tesky, 1960). Upon hatching, the coprophagous larvae require three to four days to develop through three instars. The mature larvae then crawl to a drier habitat, generally the edge of the manure dropping or the surrounding soil, and pupate. Duration of the pupal period is about ten days. Thus development from the egg to adult requires approximately two weeks, although this period is somewhat variable due to climatic conditions.

The exact determination of economic losses attributable to the infestation of cattle with face flies is extremely difficult to evaluate. As a result of their feeding habits, face flies are a considerable annoyance to cattle. Consequently, infested cattle spend a great deal of time and energy ineffectually warding off these flies with resulting lowered gains in beef cattle and decreased milk production among dairy animals.

Various methods of control have been attempted, none of which have proved adequate. The spreading of manure so that it will dry out and no longer present a suitable larval habitat is effective but somewhat impractical for pasturing cattle. The use of conventional insecticides may or may not be effective depending upon the method of application. Spraying or dipping generally produces the best results. Systemic insecticides, used as feed additives, also offer a measurable degree of control against larval development. However, the current use of insecticides presents problems by virtue of their cost, potential or actual residues in milk and meat, and hazards to man and animals. Thus the ideal method of control theoretically lies in rendering the manure unsuitable for adult oviposition and/or larval development through the manipulation or alteration of the cattle's diet. Unfortunately, little is known concerning the stimuli inducing oviposition or of the factors relative to survival and development of the larvae although the chemical composition and physical consistency of the manure are presumed to be two of the principal elements involved.

The objective of the present study was to investigate the factors in manure influencing larval development and adult oviposition in an attempt to make cattle manure unsuitable for face fly propagation by altering or manipulating the animal's diet. Additional experiments employing manures of different species of animals were conducted to determine if face fly oviposition and larval development were restricted to bovine manure.

METHODS AND MATERIALS

Maintenance of Face Fly Colony

The Kansas State University laboratory colony of face flies originated in the spring of 1963 with a shipment of pupae from C. M. Jones, United States Department of Agriculture, Lincoln, Nebraska. Adult flies were maintained in cages 12 inches long, 8 inches wide, and 10 inches high. The bottom and back of these cages consisted of one-inch thick boards which corresponded to the above specified dimensions. A piece of 20 mesh wire screen, stapled to the bottom and back, provided the sides and top. A nylon sleeve was stapled onto the screen and bottom of the cage to provide ready access to the interior. This sleeve was closed with a rubber band when the cage was being used.

Adult face flies were fed a dry diet developed at Kansas State University consisting of one part dried bovine blood (Nutritional Biochemical Corporation), one part non-fat dry milk, and four parts sucrose. Water was supplied separately in a two-ounce soufflė cup provided with a styrofoam float to minimize drowning.

Mature, eight to ten-day old, flies were "egged" to maintain the colony by placing an 8 x 8 x 2 inch aluminum pan filled with fresh bovine manure in the cage. Bovine manure was collected from bulls at the Kansas Artificial Breeding Service Unit (KABSU). After 24 hours these pans were removed and placed in larger vinyl pans partially filled with fine sand to serve as a pupation site. The manure was held in a screen cabinet to prevent contamination by other flies. When the pupae had sufficiently hardened, they were sifted from the sand with a one-pint paper ice cream carton modified by replacing its bottom with a 20 mesh wire screen. The pupae were then placed in a seven-ounce Dixie cup and introduced into a cage where they emerged.

The laboratory colony was maintained at constant conditions of 27° C and 70 percent relative humidity by automatically controlled temperature and humidity units in a specially equipped rearing room. Light was furnished by eight 43 inch General Electric fluorescent light bulbs and programed to maintain a 16 hour photoperiod.

Collection of Manure Samples

The bovine manure used for egging the laboratory colony of face flies was collected from bulls (*Bos taurus*) at the Kansas Artificial Breeding Service Unit (KABSU). This manure was also used as the control when other animal manures or experimental bovine manures were tested. The different manures tested in this study were as follows: bison (*Bison bison*) and deer (*Odocoileus virginianus*) feces from Sunset Park Zoo, Manhattan, Kansas; sheep (*Ovis aries*) and pig (*Sus scrofa domesticus*) manure from the Gooch Research Farm, Manhattan, Kansas; and horse (*Equs caballus*) manure from the Kansas State University Horse Barns, Manhattan, Kansas. The diets on which these animals were maintained are given in the appendix. All manure samples were collected in labeled one-pint paper ice cream cartons for conveyance to the laboratory. Care was exercised in the collection of all manures to assure that they were fresh and free from contamination by field flies.

In the experiments where the relationship of cattle diet to face fly production was being studied, the animals employed were placed on a test diet and maintained at the Kansas State University Dairy Barns. Manure samples were collected manually from the rectum of the animals once a day and placed in labeled one-pint paper ice cream cartons for delivery to our laboratory.

Bioassays

Face fly larvae required for bioassays were obtained by "egging" the adult fly colony with manure placed in 100 x 15 mm petri dish bottoms. This concentrated the larvae and facilitated their detection in the manure.

A 100-gram aliquot of the test manure was placed in a labeled, one-pint, wide-mouthed, Mason jar with a one-inch layer of sand to serve as a site for pupation. A portion of the "egged" manure was then placed in a second petri dish, and the larvae washed out with distilled water. Twenty-five first instar larvae were transferred to the test sample with a medicine dropper. To avoid adding additional moisture to reconstituted freeze-dried manure (see Lyophilization Procedure), the larvae were transferred with a small camel hair brush.

A 20 mesh wire screen lid was placed on the jar and the sample placed in a screen cabinet to prevent contamination. After seven days, the pupae were sifted from the sand and placed in a one-half ounce soufflé cup. Pupae were weighed on a Type B5 Mettler analytical balance and replaced in the jar until the adult flies emerged. The number of adults were multiplied by a factor of four to determine the percent emergence.

Moisture Determinations

Ten-gram aliquots of fresh manure samples were weighed to the nearest one-tenth of a gram into 60 x 15 mm petri dishes and dried in an oven at 100° C for 24 hours. After sufficient cooling, the samples were reweighed and the loss converted to percent moisture of the manure sample.

Lyophilization Procedure

Distilled water was added to the manure and mixed in a Waring blender until a thick puree resulted. The manure puree was evenly coated to the interior of a standard 24/40 taper 1000 ml round bottom flask. A standard 24/40 adaptor, coated with Dow Corning High Vacuum Grease, was fitted to the flask and the sample quick-frozen in dry ice and ethyl alcohol.

The quick-frozen sample was then attached to the vacuum drum of the Aminco Universal Model Freeze-Dry Apparatus. This apparatus was operated on the mechanical refreigeration system aided by an auxilary condenser containing dry ice and ethyl alcohol. A period of 12 to 15 hours was required to completely remove the water content of the manure. The dry samples were removed from the flasks and placed in one-quart, wide-mouthed, Mason jars, coated with nitrogen to prevent oxidation, and stored in a freezer at -20^{o} C. An appropriate amount of distilled water was added to reconstitute the freeze-dried manure. Bioassays were then performed as on fresh manure samples.

Oviposition Tests

To investigate the suitability of a single manure as an oviposition site, the aliquot to be tested was placed in a 100 x 15 mm petri dish and introduced into a cage containing approximately 300 six-day old adult face flies of both sexes for two hours. The sample was removed and the eggs deposited were counted under a broadfield microscope. This procedure was repeated every other day for six days. The numbers of eggs and age of the flies were recorded for each replicate.

To test the preference of one manure over another as an oviposition site, the petri dish was divided into equal sections corresponding to the number of manures to be evaluated. A 100 x 15 mm petri dish was used for testing a maximum of three manures. More than three manures were placed in a 150 x 20 mm petri dish. The manures were introduced into a cage containing approximately 500 six-day old adult flies of both sexes. All manures were at the same level in the petri dish. The numbers of eggs and age of the flies were recorded for three replicates.

RESULTS AND DISCUSSION

Quantitative Manure Requirement for Larval Development

Since the results of many experiments were to be evaluated in terms of the weight of the developing face fly pupae and/or the percent of adult flies emerging, an essential preliminary was the determination of the quantity of manure required per larva to give maximal growth and development. This was established through bioassays of a variable and constant manure weight method.

In the first experiment 25 first instar larvae were placed in quantities of manure ranging from 5 to 100 grams (Table 1). In two cases the range was extended to 625 and 1250 grams to determine if an increased quantity of manure per larva affected development. The results of this experiment indicated that pupal weight progressively increased up to 27.7 mg at 1.8 grams of manure per larva and then averaged 27.8 mg throughout the remainder of the range (Plate I). Adult emergence remained relatively constant, averaging 77.5 percent, throughout the entire range (Plate II).

In the second experiment, varying numbers of first instar larvae were placed in constant 50-gram samples of manure (Table 2). The results of this experiment closely correlated those of the previous one. Pupal weight progressively increased up to 26.0 mg at 2.0 grams of manure per larva and then averaged 26.7 mg throughout the remainder of the range (Plate I).

A greater effect on emergence was apparent in this experiment than in the previous one. Emergence progressively increased up to 80.8 percent with 1.25 grams of manure per larva and then remained relatively constant, averaging 85.3 percent, throughout the remainder of the range (Plate II).

These experiments indicated that a minimal amount of 2.0 grams of manure per larva was necessary to obtain both maximal pupal weight and percent adult emergence. The suboptimal results may have been due to intraspecific competition among the larvae or to a subliminal nutrient supply. Both experiments showed that extending the range to 25 and 50 grams of manure per larva had no effect on either pupal weight or percent emergence (Tables 1 and 2).

On the basis of this data, it was decided to perform subsequent bioassays with 25 larvae and 100-gram aliquots of manure samples giving 4 grams of manure per larva.

Table 1. Pupal weight and percent adult emergence of 25 larvae placed in increasing quantities of bovine manure.

Total Grams Manure	Grams Manure Per Larva	Rep. No.	$\bar{X}_s$ Pupal Wt. (mg)	Percent Emergence
5	.2	1	8.2	68
		2	7.4	68
		3	9.0	68
			8.2*	68.0*
10	.4	1	14.7	68
		2	12.7	84
		3	15.6	72
			14.3*	74.7*
15	.6	1	18.6	72
		2	17.1	64
		3	17.8	72
			17.8*	69.3*
20	.8	1	18.9	76
		2	20.0	72
		3	22.5	72
			20.5*	73.3*
25	1.0	1	18.9	84
		2	21.0	76
		3	20.7	88
			20.2*	82.7*
30	1.2	1	25.4	68
		2	23.6	72
		3	24.8	68
			24.6*	69.3*
35	1.4	1	24.6	88
		2	22.2	88
		3	24.5	68
			23.8*	81.3*
40	1.6	1	23.0	84
		2	24.9	84
		3	24.9	68
			24.3*	78.7*

Table 1 (Cont.)

Total Grams Manure	Grams Manure Per Larva	Rep. No.	$\bar{x}_s$ Pupal Wt. (mg)	Percent Emergence
45	1.8	1	28.6	68
		2	28.0	64
		3	26.6	80
			27.7*	70.7*
50	2.0	1	26.3	68
		2	27.0	72
		3	28.1	76
			27.1*	72.0*
55	2.2	1	26.6	80
		2	27.3	76
		3	26.9	88
			26.9*	81.3*
60	2.4	1	27.5	84
		2	28.3	80
		3	26.1	100
			27.3*	88.0*
65	2.6	1	27.0	72
		2	27.3	72
		3	26.2	72
			26.8*	72.0*
70	2.8	1	27.9	92
		2	27.2	76
		3	28.1	76
			27.7*	81.3*
75	3.0	1	30.4	80
		2	29.9	88
		3	29.6	72
			30.0*	80.0*
80	3.2	1	27.3	76
		2	30.7	84
		3	29.9	96
			29.3*	85.3*

Table 1 (Cont.)

Total Grams Manure	Grams Manure Per Larva	Rep. No.	$\bar{x}_s$ Pupal Wt. (mg)	Percent Emergence
85	3.4	1	27.9	76
		2	29.3	96
		3	27.3	84
			28.2*	85.3*
90	3.6	1	27.1	72
		2	28.8	88
		3	28.2	76
			28.0*	78.7*
95	3.8	1	27.9	68
		2	27.7	84
		3	28.1	80
			27.9*	77.3*
100	4.0	1	28.6	80
		2	28.1	76
		3	28.9	84
			28.5*	80.0*
625	25.0	1	28.2	72
		2	29.5	84
		3	28.3	84
			28.7*	80.0*
1250	50.0	1	28.1	88
		2	29.1	72
		3	27.9	76
			28.4*	78.7*

* = $\bar{x}$

Table 2. Pupal weight and percent adult emergence of varying numbers of larvae placed in 50-gram samples of bovine manure.

Total No. Larvae	Grams Manure Per Larva	Rep. No.	$\overline{X}_s$ Pupal Wt. (mg)	Percent Emergence
200	.25	1	7.5	12.0
		2	8.4	15.5
		3	6.9	14.0
			7.6*	13.8*
100	.50	1	13.0	51.0
		2	13.5	46.0
		3	13.0	59.0
			13.2*	52.0*
67	.75	1	15.2	55.0
		2	14.5	60.0
		3	15.1	58.5
			14.9*	57.8*
50	1.00	1	18.0	70.0
		2	18.9	72.0
		3	19.5	68.0
			18.8*	70.0*
40	1.25	1	22.0	82.5
		2	20.3	80.0
		3	21.7	80.0
			21.3*	80.8*
33	1.52	1	24.0	84.0
		2	22.9	84.0
		3	22.5	81.0
			23.1*	83.0*
29	1.72	1	23.1	79.3
		2	22.5	89.7
		3	23.3	79.3
			23.0*	82.8*
25	2.00	1	24.9	80.0
		2	26.5	88.0
		3	26.6	84.0
			26.0*	84.0*

Table 2 (Cont.)

Total No. Larvae	Grams Manure Per Larva	Rep. No.	$\bar{X}_s$ Pupal Wt. (mg)	Percent Emergence
22	2.27	1	27.0	77.3
		2	26.7	86.4
		3	26.9	72.7
			26.9*	78.8*
20	2.50	1	26.2	80.0
		2	26.1	80.0
		3	26.6	85.0
			26.3*	81.7*
18	2.78	1	28.2	88.9
		2	29.3	100.0
		3	27.2	94.9
			28.2*	94.6*
17	2.94	1	27.5	82.3
		2	25.8	94.1
		3	26.4	82.3
			26.6*	86.2*
12	4.17	1	26.3	91.7
		2	26.3	91.7
		3	25.5	91.7
			26.0*	91.7*
2	25.00	1	26.8	100.0
		2	27.8	50.0
		3	27.5	100.0
			27.4*	83.3*
1	50.00	1	29.9	100.0
		2	27.2	100.0
		3	25.8	100.0
			27.6*	100.0*

* = $\bar{X}$

EXPLANATION OF PLATE I

The relationship of grams of bovine manure per larva to pupal weight as determined by a constant and variable manure weight method.

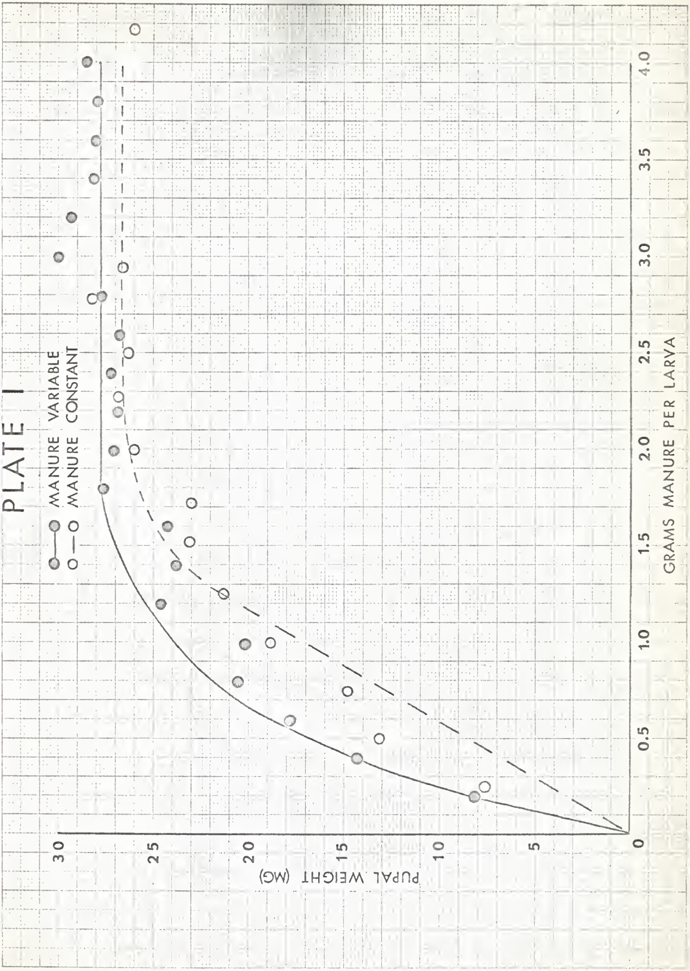


PLATE I
MANURE VARIABLE
MANURE CONSTANT
PUPAL WEIGHT (MG)
0
5
10
15
20
25
30
GRAMS MANURE PER LARVA
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

EXPLANATION OF PLATE II

The relationship of grams of bovine manure per larva to percent adult emergence as determined by a constant and variable manure weight method.

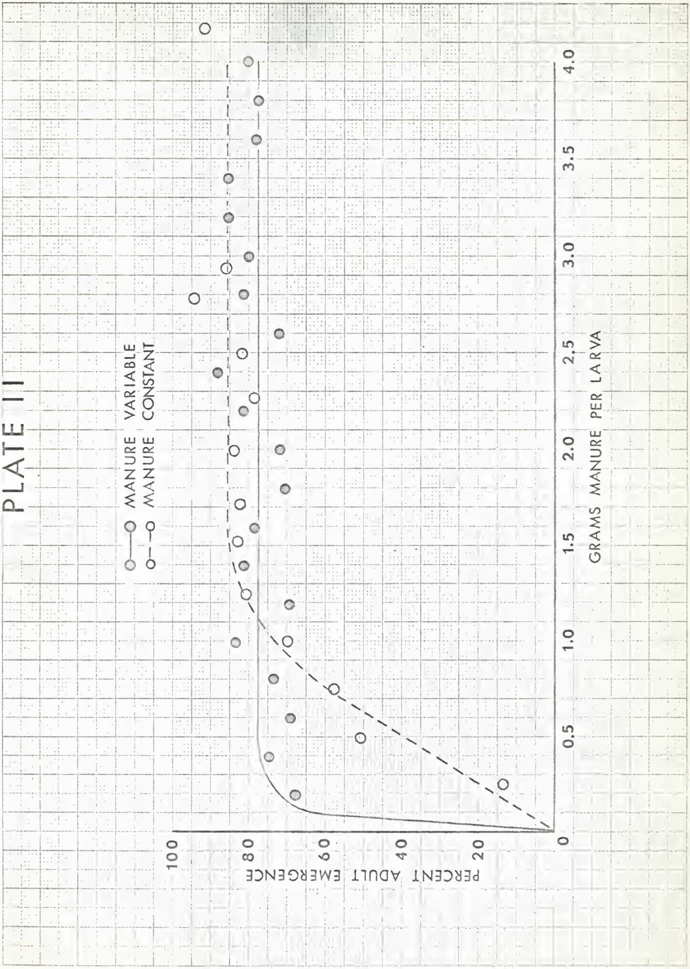


PLATE III
MANURE VARIABLE
MANURE CONSTANT
100
80
60
40
20
0
PERCENT ADULT EMERGENCE
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
GRAMS MANURE PER LARVA

Emergence From Cow and Bull Manure

To determine if physiological differences between cows and bulls may be expressed in their manure thus affecting larval development, an experiment employing three cows and three bulls was conducted. All animals were fed on the KABSU diet. Manure samples were collected and face fly bioassays performed every other day over a one-month interval.

The results, presented in Table 3, show that the average emergence of face flies from bull manure was 80.8 percent compared to 79.7 percent from cow manure. Pupal weights were not recorded, but no difference was visibly evident. It was concluded, therefore, that any differences in bovine manure attributable to bovine sex had no effect on larval development.

Influence of Moisture

In a preliminary report, Treece (1966) found the moisture range of bovine feces to be very narrow, and no correlation of moisture with diet could be demonstrated. Morgan and Graham (1966) reported that the feces from animals fed prairie hay and freshly cut green oats were considerably drier than those from animals fed alfalfa and sorghum hay diets. The average pupal weight and number of adult horn flies emerging decreased in the drier feces.

Bioassays. Experiments conducted in our laboratory showed the moisture content of fresh bovine manure from six animals fed on the KABSU diet was subject to some daily variation over a one-month period. Moisture ranged from 79.0 to 85.0 percent with a mode of 83.5 percent (Table 4). These percentages are comparable with those determined by Treece (1966) and Morgan and Graham (1966). Plate III shows that the average percent emergence of face flies was lower from the drier manure samples, even over this relatively narrow range.

Table 3. Percent adult emergence from cow and bull manure.

Day	Cow Manure	Percent Emergence(a)	Bull Manure	Percent Emergence(a)
1	1	80	1	84
	2	68	2	76
	3	84	3	80
		77.3*		80.0*
3	1	76	1	80
	2	92	2	84
	3	76	3	72
		81.3*		78.7*
5	1	84	1	76
	2	80	2	80
	3	80	3	76
		81.3*		77.3*
7	1	72	1	84
	2	84	2	88
	3	80	3	76
		78.7*		82.7*
9	1	76	1	76
	2	76	2	84
	3	84	3	76
		78.7*		78.7*
11	1	80	1	76
	2	84	2	88
	3	76	3	92
		80.0*		85.3*
13	1	84	1	72
	2	84	2	100
	3	84	3	72
		84.0*		81.3*
15	1	80	1	84
	2	80	2	80
	3	80	3	80
		80.0*		81.3*

Table 3 (Cont.)

Day	Cow Manure	Percent Emergence[a]	Bull Manure	Percent Emergence[a]
17	1	92	1	84
	2	72	2	72
	3	72	3	84
		78.7*		80.0*
19	1	76	1	72
	2	76	2	88
	3	80	3	72
		77.3*		77.3*
21	1	88	1	84
	2	68	2	88
	3	88	3	80
		81.3*		84.0*
23	1	80	1	84
	2	80	2	76
	3	84	3	76
		81.3*		78.7*
25	1	80	1	80
	2	76	2	88
	3	76	3	80
		77.3*		82.7*
27	1	72	1	80
	2	100	2	76
	3	76	3	84
		82.7*		80.0*
29	1	72	1	92
	2	80	2	72
	3	76	3	88
		76.0*		84.0*
Average, all days		79.7		80.8

[a] Based upon 25 larvae per sample.

* = $\bar{x}$

Table 4. Moisture range and percent adult emergence from fresh bovine manure.

Percent Moisture	No. Samples[a]	Av. No. Flies[b]	Av. Percent Emergence
79.0	2	16	64
79.5	1	18	72
80.0	3	17	68
80.5	4	18	72
81.0	9	17	68
81.5	5	19	76
82.0	18	18	72
82.5	27	20	80
83.0	20	21	84
83.5	38	20	80
84.0	24	19	76
84.5	13	21	84
85.0	16	19	76

[a] Samples taken from six cows, maintained on the KABSU diet, over a one-month period.

[b] Figures represent averages to the nearest whole fly of the number of flies emerged from 25 larvae per sample.

Morgan and Graham (1966) minimized the effect of moisture on horn fly larval development by the use of a liquid manure extract soaked on a cotton pad. In this manner, they could effectively study different manure substrates at a constant moisture content. There are no reports in the literature of attempts to control the moisture content of manure at various levels and thus study the effect on larval development. This was done in our laboratory by the freeze-dry process as previously discussed.

Preliminary bioassays were conducted to determine if this technique had any adverse effect on larval development or adult emergence. Freeze-dried samples of KABSU manure were reconstituted with the condensate resulting from the lyophilization process and with distilled water to a moisture content of 83.5 percent. The reconstituted samples were tested against fresh KABSU manure as a control. The results of three replicates, presented in Table 5, show that the average pupal weight was 28.1 mg from fresh manure, 27.3 mg from the manure reconstituted with the condensate, and 27.5 mg from the manure reconstituted with distilled water. The average percent emergence was 85.3 percent from fresh manure, 81.3 percent from manure reconstituted with the condensate, and 84.0 percent from the manure reconstituted with distilled water. Since no distinct difference in average pupal weight or percent emergence existed between fresh and reconstituted manures, this technique was concluded to be of practical value in extending the moisture range of bovine manure.

The lowest moisture content to which freeze-dried samples could be homogenously reconstituted was 65 percent, thus it was decided to use a moisture range at five percent intervals from 65 to 95 percent. The results of three replicates at each interval indicated that maximal pupal weight and percent emergence occurred at 85 percent moisture (Table 6). This is meaningful in that maximum productivity occurred very near the 83.5 percent average moisture content of fresh bovine manure. Larvae were unable to survive in manure at the upper and lower limits of the range. Plates III and IV show the tendency for the percent adult emergence and pupal weight respectively to increase with an increasing moisture content of the manure.

Table 5. Pupal weight and percent adult emergence from fresh and reconstituted bovine manures.

Manure Substrate	Rep. No.	$\bar{x}_s$ Pupal Wt. (mg)	Percent Emergence[a]
Fresh Manure	1	28.7	88
	2	27.6	84
	3	28.6	84
		28.1*	85.3*
Reconstituted With Condensate[b]	1	27.5	80
	2	27.6	84
	3	26.8	80
		27.3*	81.3*
Reconstituted With Distilled Water[b]	1	27.0	80
	2	28.2	92
	3	27.4	80
		27.5*	84.0*

[a] Based upon 25 larvae per sample.

[b] Samples reconstituted to 83.5 percent moisture.

$* = \bar{x}$

Table 6. Pupal weight and percent adult emergence from freeze-dried bovine manure reconstituted at various moisture levels.

Percent Moisture[a]	Rep. No.	$\bar{x}_s$ Pupal Wt. (mg)	Percent Emergence[b]
65	1	0.0	0
	2	0.0	0
	3	0.0	0
		0.0*	0.0*
70	1	9.1	8
	2	8.9	16
	3	8.8	12
		8.9*	12.0*
75	1	18.4	44
	2	18.2	36
	3	17.9	36
		18.2*	38.7*
80	1	24.9	64
	2	24.9	68
	3	25.2	72
		25.0*	68.0*
85	1	28.1	80
	2	27.8	76
	3	27.4	84
		27.8*	80.0*
90	1	22,9	4
	2	23.7	8
	3	23.0	8
		23.2*	6.7*
95	1	0.0	0
	2	0.0	0
	3	0.0	0
		0.0*	0.0*

[a] Samples reconstituted with distilled water.

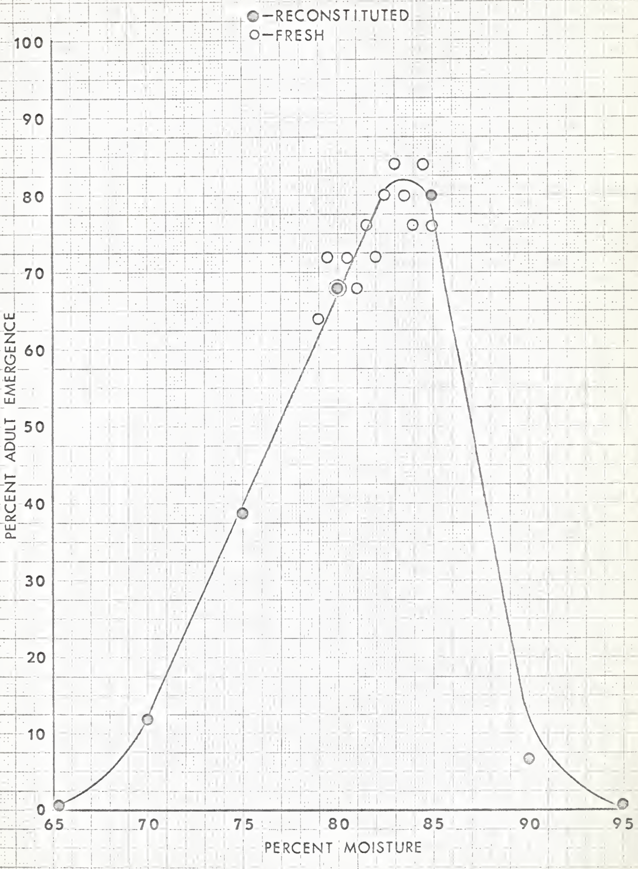
[b] Based upon 25 larvae per sample.

* = $\bar{x}$

EXPLANATION OF PLATE III

The relationship of moisture content of fresh and reconstituted bovine manure to percent adult emergence.

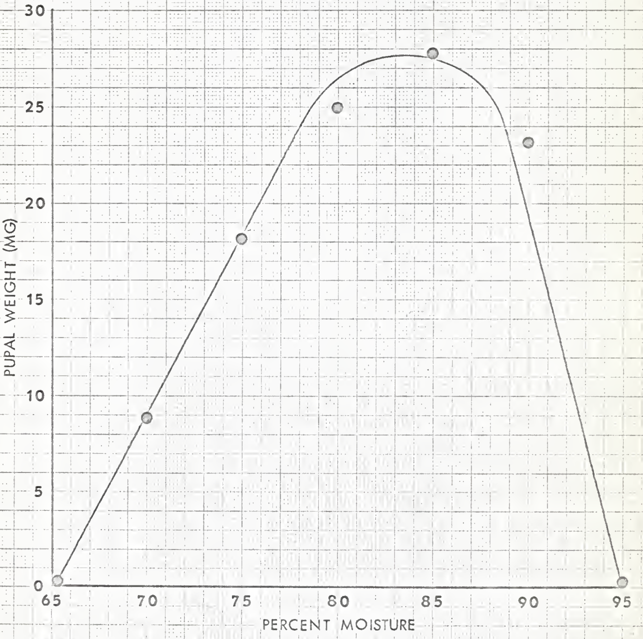
PLATE III


●—RECONSTITUTED
○—FRESH
PERCENT ADULT EMERGENCE
100
90
80
70
60
50
40
30
20
10
0
65
70
75
80
85
90
95
PERCENT MOISTURE

EXPLANATION OF PLATE IV

The relationship of moisture content of reconstituted bovine manure to pupal weight.

PLATE IV


30
25
20
15
10
5
0
PUPAL WEIGHT (MG)
65
70
75
80
85
90
95
PERCENT MOISTURE

Oviposition Preference Tests. A preliminary experiment was conducted to determine if freeze-drying and subsequent reconstituting of manure samples adversely affected the oviposition behavior of adult face flies. Freeze-dried samples of KABSU manure were reconstituted to 83.5 percent moisture with the condensate and distilled water, and tested against fresh KABSU manure by introducing them into a cage of 500 six-day old flies. The numbers of eggs oviposited in each manure are tabulated in Table 7. Of the total 1705 eggs laid, 96.54 percent were deposited in the fresh manure. Freeze-dried manures reconstituted with the condensate and distilled water were equally unfavorable as oviposition sites. This would indicate that some volatile factor(s) influencing oviposition behavior had been lost during the freeze-dry process since the volatile chemicals should have been removed during lyophilization. The preference for fresh bovine manure over reconstituted manure as an oviposition site by adult face flies is illustrated in Figure 1. Nothing is known concerning the chemistry of the oviposition factor(s).

Table 7. Oviposition preference in fresh and reconstituted bovine manures.

Manure Substrate	No. Eggs Per Day Age of Flies in Days 6	8	10	Total Eggs Per Manure	Percent Eggs Per Manure
Fresh Manure	663	486	497	1646	96.54
Reconstituted With Condensate[a]	10	17	19	46	2.70
Reconstituted With Distilled Water[a]	3	6	4	13	.76
Total	676	509	520	1705	

[a] Samples reconstituted to 83.5 percent moisture.

When flies were not given a choice between fresh and reconstituted manures, no difference in oviposition was apparent. This was determined by introducing each of the test manures into three separate cages of 300 six-day old flies. The average number of eggs laid in three replicates was 588 in fresh manure, 423 in manure reconstituted with the condensate, and 482 in manure reconstituted with distilled water. These results would indicate that when odor was not a factor, oviposition was mediated by contact chemoreception. According to Dethier (1961), the choice of an oviposition site by the black blow fly (Phormia regina) was mediated by contact and odor was not a factor. Larsen et al. (1966) have shown that

Figure 1: The preference for fresh bovine manure (top) over reconstituted bovine manure (bottom) as an oviposition site by face flies.

while odor was important in attracting gravid female house flies (*Musca domestica*) to feces, contact stimuli were dominant in the selection of an oviposition site. Since flies oviposited equally well in reconstituted manures when fresh manure was not available to them, this technique was concluded to be satisfactory to test the effect of the moisture content of manure on oviposition.

Freeze-dried bovine manure was reconstituted with distilled water at five percent intervals over a 65 to 90 percent moisture range and presented to a cage of 500 six-day old face flies to test for oviposition preference. The total numbers of eggs oviposited in each manure are given in Table 8. Of the total 1833 eggs laid, 750 or 40.91 percent were deposited in manure reconstituted to 80 percent moisture. This was closely followed by 602 eggs, or 32.04 percent, laid in manure reconstituted to 85 percent moisture. Plate V shows an increased preference for reconstituted manure as an oviposition site as the moisture content increases. These results may correlate with those of Barton-Brown (1962) which showed that contact with water increased the oviposition rate of the blow fly *Lucilia cuprinia*.

As in the bioassay studies where a correlation between face fly productivity and the moisture content of reconstituted manure existed, maximal oviposition in reconstituted manure occurred in the relatively narrow range of fresh bovine feces. This may be of decided practical value in nature since the drier manures should present unfavorable development and oviposition sites. Attempts to correlate the moisture content of bovine manure with cattle diets, and the effect on oviposition will be subsequently discussed.

Table 8. Oviposition preference in freeze-dried bovine manure reconstituted at various moisture levels.

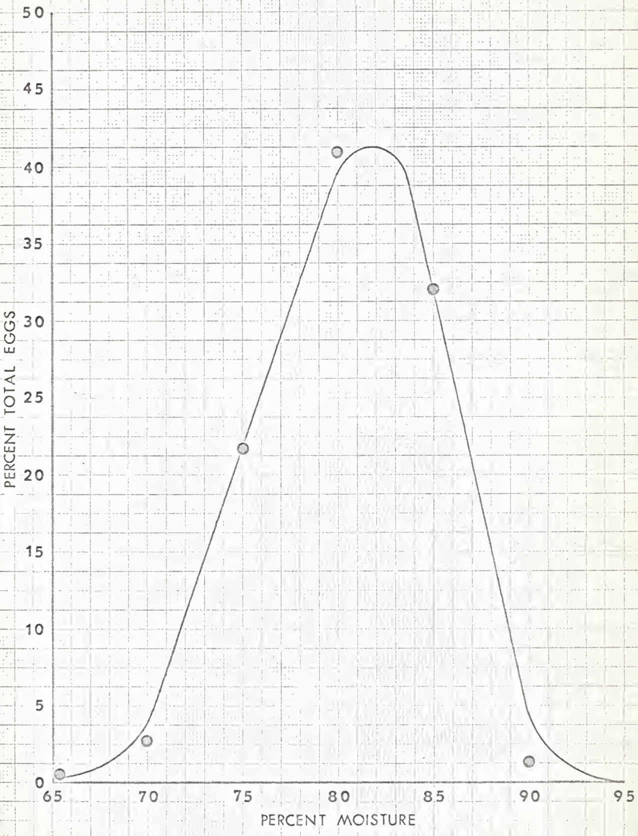
Percent Moisture[a]	No. Eggs Per Day Age of Flies in Days 6	8	10	Total Eggs Per Moisture	Percent Eggs Per Moisture
65	0	7	1	8	0.44
70	18	11	20	49	2.67
75	134	103	162	399	21.78
80	241	221	288	750	40.91
85	180	165	257	602	32.04
90	9	1	15	25	1.36
Total	582	508	743	1833	

[a]Samples reconstituted with distilled water.

EXPLANATION OF PLATE V

The relationship of moisture content of reconstituted bovine manure to percent total eggs laid.

PLATE V


PERCENT TOTAL EGGS
0
5
10
15
20
25
30
35
40
45
50
65
70
75
80
85
90
95
PERCENT MOISTURE

Influence of Bovine Diets

Bioassays. To study the influence of different bovine diets on face fly productivity, preliminary experiments were conducted by feeding 12 test animals on high roughage and high grain diets. The test diets employed and the amounts consumed daily were as follows: alfalfa hay (12 pounds), cracked corn (10 pounds) plus alfalfa hay (2 pounds), milo (10 pounds) plus alfalfa hay (2 pounds), prairie hay (12 pounds), cracked corn (10 pounds) plus prairie hay (2 pounds), and milo (10 pounds) plus prairie hay (2 pounds). The physical consistency of the feces passed varied with the diets of the test animals. Soft, moist feces resulted from cattle fed high grain, low roughage diets; while small, hard pellets were passed by those animals fed only prairie hay. The feces produced from animals fed only alfalfa hay were somewhat intermediary being moist but firm.

Samples were collected and bioassays conducted every other day for 30 days. The average percent of adult flies emerging from the feces passed by animals on the different diets is presented in Table 9. Emergence was correspondingly high from all manures except those animals fed prairie hay.

Since there appeared to be a correlation between bovine diet, physical consistency, and percent emergence, a second test was conducted similar to the previous one to collect additional data on moisture content and pupal weights. Alfalfa and prairie hay diets were fed as before, but corn and milo were mixed together to supply high grain diets with minimal roughage. Samples were collected every other day, and bioassays conducted over a one month period.

The experimental results in Table 10, show that the maximal average pupal weight and percent emergence were attained in manures of the highest

Table 9. Percent adult emergence from fresh manures of cattle fed six different diets.

Diet	Animal No.	Percent Emergence[a]
Alfalfa Hay	1	73.1
	2	79.7
Alfalfa Hay Plus Corn	3	81.6
	4	78.5
Alfalfa Hay Plus Milo	5	73.7
	6	77.6
Prairie Hay	7	60.1
	8	57.3
Prairie Hay Plus Corn	9	77.5
	10	81.4
Prairie Hay Plus Milo	11	79.2
	12	77.9

[a] Average of 15 bioassays; 25 larvae per bioassay.

moisture content. Minimal average pupal weight and percent emergence were in manures of the lowest moisture content.

Since the average pupal weights and percent emergence at different moisture levels of the test manures closely paralleled those from reconstituted freeze-dried KABSU bovine feces (Plates III and IV), the test manures were lyophilized and reconstituted to 83.5 percent moisture with distilled water. The results in Table 11, show that maximal average pupal weight and percent emergence occurred from the high grain manures while the lowest pupal weight and percent emergence occurred from prairie hay feces.

Table 10. Pupal weight and percent adult emergence from fresh manures of cattle fed four different diets.

Diet	Animal No.	Av. Percent Moisture[a]	Av. Pupal Wt.[a] (mg)	Av. Percent Emergence[a]
Alfalfa Hay	1	75.1	19.7	75.5
	2	76.5	19.3	72.1
Alfalfa Hay Plus Grain	3	82.7	28.9	79.4
	4	82.2	29.3	83.8
Prairie Hay	5	74.3	14.1	45.4
	6	73.6	13.4	51.7
Prairie Hay Plus Grain	7	83.9	29.5	81.3
	8	82.6	30.0	81.5

[a]Average of 15 bioassays; 25 larvae per bioassay.

These experiments indicate that maximal face fly development occurred in manures passed from animals on high grain diets, irregardless whether the roughage was alfalfa or prairie hay. Prairie hay diets were the most unsatisfactory for face fly development while alfalfa hay diets were slightly better. Although the manures produced by cattle fed high roughage diets were drier than those produced by animals fed high grain diets, the decreased development in the former cannot be entirely attributed to their moisture contents since reconstitution of freeze-dried samples to a higher moisture content did not increase pupal weight or the percent of adult flies emerging. This differential development indicates the importance of the chemical composition of manure in influencing face fly development.

Table 11. Pupal weight and percent adult emergence from reconstituted manures of cattle fed four different diets.

Diet[a]	Rep. No.	$\bar{x}_s$ Pupal Weight (mg)	Percent Emergence[b]
Alfalfa Hay	1	16.7	72
	2	15.9	84
	3	16.1	76
		16.2*	77.3*
Alfalfa Hay Plus Grain	1	29.4	64
	2	28.7	72
	3	28.3	68
		28.5*	68.0*
Prairie Hay	1	11.1	48
	2	13.4	52
	3	12.6	40
		12.7*	46.7*
Prairie Hay Plus Grain	1	28.4	76
	2	28.9	76
	3	27.1	72
		28.1*	74.7*

[a] Samples reconstituted to 83.5 percent moisture with distilled water.

[b] Based on 25 larvae per sample.

* = $\bar{x}$

Oviposition Preference Tests. Fresh aliquots of the test manures were introduced into a cage of 500 six-day old flies on three different days. The numbers of eggs laid on each manure are tabulated in Table 12. The preferred oviposition sites in all cases were the manures passed by cattle on high grain diets. Prairie hay manure was the most unfavorable oviposition site.

Table 12. Oviposition preference in fresh bovine manure of cattle fed four different diets.

Diet	No. Eggs Per Day Age of Flies in Days 6	8	10	Total Eggs Per Manure	Percent Eggs Per Manure
Alfalfa Hay	72	94	107	273	17.88
Alfalfa Hay Plus Grain	159	176	243	578	37.85
Prairie Hay	11	31	15	57	3.73
Prairie Hay Plus Grain	185	153	281	619	40.54
Total	427	754	646	1527	

In an attempt to correlate oviposition preference on fresh test manures with their moisture contents, freeze-dried samples were reconstituted with distilled water to 83.5 percent and tested as before. The resulte, in Table 13, show that 92.77 percent of the total eggs laid were deposited in manure passed by animals fed a high grain, low alfalfa hay diet. All other manures were unfavorable oviposition sites.

The moisture contents and physical consistencies of the reconstituted manures were sufficiently similar to suggest the presence of a nonvolatile chemical factor(s) since the volatile compounds should have been drawn off in the lyophilization process. The various contact chemoreceptors of the face fly would be able to detect such a difference and enable it to make dicriminatory choices in oviposition sites. The nature of the nonvolatile factor(s) remains obscure. If oviposition preference was mediated by some chemical factor(s) in the manure as a result of the high grain diet, the

Table 13. Oviposition preference in reconstituted bovine manures of cattle fed four different diets.

Diet[(a)]	No. Eggs Per Day Age of Flies in Days 6	8	10	Total Eggs Per Manure	Percent Eggs Per Manure
Alfalfa Hay	9	7	11	27	1.59
Alfalfa Hay Plus Grain	539	414	625	1578	92.77
Prairie Hay	16	2	23	41	2.41
Prairie Hay Plus Grain	29	9	17	55	3.22
Total	593	432	676	1701	

[(a)]Samples reconstituted to 83.5 percent with distilled water.

reconstituted manure from those animals fed high grain, low prairie hay diets should also have been a favorable oviposition site. Likewise, if the response was due to some factor in the manure as a result of the alfalfa hay, the reconstituted manure from those animals fed alfalfa roughage should have offered a favorable oviposition site.

Productivity from Other Manures

The utilization of bovine feces for face fly larval development is well known. Except for the reported finding of larvae in pig dung (Vainshtein and Rodova, 1940), development is considered to be restricted to bovine manure. However, there is no published experimental evidence ruling out other feces as sources of propagation.

Bioassays. Experiments were conducted in our laboratory to determine if face fly larvae could successfully undergo development in other types of manures. The feces tested were horse, sheep, pig, deer, and bison. Bovine manure was used as a control. The diets of all animals contained a source of roughage and grain. The results, presented in Table 14, indicate that all manures tested supported larval development although some were more satisfactory than others. The average percent of adult flies emerging from horse, pig, bison, and deer feces was comparable to that from bovine manure; the average emergence from sheep feces was restricted to 5.3 percent. Average pupal weight was unaffected by development in pig and bison manure but was reduced in horse, sheep, and deer feces as compared to bovine manure.

The average moisture content of sheep feces, which yielded the lowest average pupal weight and percent emergence, was low at 64.3 percent (Table 14). Reconstituted bovine manure gave no development at 65 percent moisture (Table 6). The average moisture content of horse and deer feces was also low at 74.5 and 70.3 percent respectively. Average pupal weights from these feces paralleled those from freeze-dried bovine manure reconstituted to similar moisture contents (Plate III). No such correlation existed with percent emergence (Plate IV).

When the effect of the moisture content of different feces was neutralized by freeze-drying and reconstituting the samples with distilled water to 83.5 percent, there was no distinct difference in pupal weight or percent adult emergence (Table 15). These results substantiate those obtained by reconstituting freeze-dried bovine manure over a wide range to show the importance of moisture on larval development.

Oviposition Preference Tests. Fresh aliquots of each sample were introduced into a cage of 500 six-day old flies. The pelleted sheep and

Table 14. Pupal weight and percent adult emergence from fresh manures of six species of animals.

Manure Substrate	Rep. No.	Percent Moisture	$\bar{x}_s$ Pupal Weight (mg)	Percent Emergence[a]
Bovine	1	83.5	28.7	84
	2	82.5	27.6	84
	3	82.0	28.7	76
		82.7*	28.3*	81.3*
Horse	1	74.0	20.0	84
	2	75.0	19.5	72
	3	74.5	18.9	68
		74.5*	19.5*	74.7*
Sheep	1	63.5	17.7	4
	2	65.5	18.9	4
	3	64.0	18.3	8
		64.3*	18.3*	5.3*
Pig	1	79.5	27.7	64
	2	79.0	27.4	64
	3	80.5	27.5	72
		79.7*	27.5*	66.7*
Bison	1	82.0	28.9	76
	2	80.5	28.5	84
	3	83.0	29.3	80
		81.8*	28.9*	80.0*
Deer	1	71.0	18.9	80
	2	69.5	18.1	72
	3	70.5	19.4	80
		70.3*	18.8*	77.3*

[a] Based upon 25 larvae per sample.

* = $\bar{x}$

Table 15. Pupal weight and percent adult emergence from reconstituted manures of six species of animals.

Manure Substrate[(a)]	Rep. No.	$\bar{x}_s$ Pupal Weight (mg)	Av. Percent Emergence[(b)]
Bovine	1	28.4	76
	2	27.5	88
	3	28.3	76
		28.1*	80.0*
Horse	1	27.4	56
	2	28.2	80
	3	28.6	60
		28.1*	65.3*
Sheep	1	27.9	72
	2	27.9	88
	3	27.5	72
		27.8*	77.3*
Pig	1	27.9	80
	2	26.8	80
	3	28.1	64
		27.6*	74.7*
Bison	1	28.5	84
	2	28.1	80
	3	27.1	76
		27.9*	80.0*
Deer	1	28.8	88
	2	27.5	68
	3	28.0	72
		28.1*	76.0*

[(a)] Samples reconstituted to 83.5 percent moisture with distilled water.

[(b)] Based upon 25 larvae per sample.

$* = \bar{x}$

deer feces were broken up to more nearly resemble the physical consistencies of the other test manures. The numbers of eggs laid in each manure are tabulated in Table 16. Eggs were found in all six manures, but the few present in the drier horse, sheep, and deer manure were merely laid on the surface rather than being characteristically deposited with the mast extending upward. Preference for the other manures as oviposition sites were as follows: bison (63.95 percent), bovine (26.78 percent), and pig (8.80 percent).

Table 16. Oviposition preference in fresh manures of six species of animals.

Manure Substrate	No. Eggs Per Day Age of Flies in Days			Total Eggs Per Manure	Percent Eggs Per Manure
	6	8	10		
Bovine	97	215	142	454	26.78
Horse	1	2	0	3	0.18
Sheep[a]	0	0	1	1	0.06
Pig	36	89	24	149	8.80
Bison	417	398	269	1084	63.95
Deer[a]	3	0	1	4	0.23
Total	554	704	437	1695	

[a]Pelleted feces broken up to more nearly resemble the physical consistencies of the other test manures.

When each of the six manures was individually introduced into cages of 300 six-day old flies, oviposition was again largely restricted to bovine, pig, and bison manure (Table 17). The eggs found on the horse, sheep, and deer feces were again not deposited in the face fly's characteristic manner.

Table 17. Oviposition in fresh and reconstituted manures when no choice was offered.

Manure Substrate	Age of Flies in Days	Number of Eggs[(a)] Fresh	Reconstituted
Bovine	6	101	203
	8	132	296
	10	196	216
		143.0*	238.3*
Horse	6	7	3
	8	6	8
	10	9	2
		7.3*	4.3*
Sheep[(b)]	6	2	291
	8	0	317
	10	7	236
		3.0*	281.3*
Pig	6	63	184
	8	148	235
	10	98	173
		103.0*	197.3*
Bison	6	187	269
	8	163	328
	10	231	279
		193.7*	292.0*
Deer[(b)]	6	25	235
	8	41	275
	10	44	219
		36.7*	243.0*

[(a)] Samples reconstituted to 83.5 percent with distilled water.

[(b)] Fresh pelleted feces broken up to more nearly resemble the physical consistencies of the other test manures.

* = $\bar{x}$

In an attempt to correlate oviposition in these different manures with their moisture contents, freeze-dried samples were reconstituted to 83.5 percent moisture and tested as before. When flies were not given a choice between the reconstituted manures by presenting them to separate cages, the only distinct difference in oviposition occurred in the horse feces (Table 17). Oviposition occurred equally well in reconstituted bovine, pig, sheep, bison, and deer manure. The preferred oviposition site, when all six reconstituted manures were made available to a single cage of flies, was again bison manure (Table 18). Preferences for the other manures as oviposition sites (in descending sequence) were as follows: sheep, pig, bovine, deer, and horse.

Table 18. Oviposition preference in reconstituted manures from six species of animals.

Manure Substrate[a]	No. Eggs Per Day Age of Flies in Days 6	8	10	Total Eggs Per Manure	Percent Eggs Per Manure
Bovine	133	73	39	245	8.51
Horse	10	3	11	24	0.83
Sheep	397	186	238	821	28.51
Pig	325	181	147	653	22.67
Bison	478	321	194	993	34.48
Deer	39	78	27	144	5.00
Total	1382	842	656	2880	

(a)Samples reconstituted with distilled water to 83.5 percent moisture.

There was a marked preference for bison over bovine manure in all cases even though the moisture content and physical consistency of the two manures were similar. This would substantiate the existence of a chemical factor(s). The chemical factor(s) may be a nonvolatile acting as contact stimulus since the volatile compounds should have been drawn off during the lyophilization process. Furthermore, this chemical property must be inherent in sheep feces since reconstituted samples were preferred over reconstituted bovine manure. This preference, manifested only in reconstituted samples, substantiates the importance of moisture and physical consistency in the selection of oviposition sites.

The results of the oviposition tests with the different types of manures, when coupled with those from the bioassay experiments, indicate that the face fly may successfully oviposit and develop in nature in bison, pig, and bovine manures. The failure to develop in fresh sheep and deer feces appear to be attributable to their low moisture contents since larvae successfully developed and adults oviposited in these reconstituted manures. Although larvae were able to complete development in both fresh and reconstituted horse manure, neither of these proved to be adequate oviposition sites when tested separately from the other manures. The unsuitable nature of horse manure as an oviposition site may be due to its coarse physical texture which existed even in reconstituted samples.

SUMMARY AND CONCLUSIONS

Experiments were conducted to determine the factors relating to face fly productivity in manure. A preliminary test was the determination of the quantity of manure per larva required for maximal development. Results showed a minimum of 2.0 grams of manure per larva was necessary to give both maximal pupal weight and percent adult emergence. Any difference in manure attributable to bovine sex had no effect on larval development. The average emergence of face flies from cow manure was 79.7 percent compared to 80.8 percent from bull manure.

A correlation between the moisture content of bovine manure and face fly productivity was demonstrated by lyophilization and reconstitution of the freeze-dried feces over a wider moisture range than existed in fresh samples. Lyophilized manure reconstituted to 85 percent moisture produced maximal pupal weight and percent adult emergence. The average moisture content of fresh bovine manure was 83.5 percent; decreased development was noted in drier samples. Adult flies favored freeze-dried manure reconstituted to 80 and 85 percent moisture as oviposition sites. There was a marked preference for fresh over reconstituted bovine feces indicating the presence of a volatile oviposition factor(s) drawn off during the lyophilization process.

The effect of different cattle diets on the physical consistency and chemical composition of the resulting manures also influenced face fly production. Animals fed prairie hay passed hard, pelleted feces while those fed high grain, low roughage diets produced soft, moist manures. Maximal development occurred in the manures passed from animals maintained on high grain diets. The decreased development occurring from prairie hay manure could not be entirely attributed to its lower moisture content since development was also hindered in the reconstituted samples. The decreased development noted in reconstituted samples indicates the importance of the chemical composition of the manure as a result of the animal's diet. Adult flies also favored the feces from high grain diets as oviposition sites.

Since this preference was also apparent in reconstituted samples having similar moisture contents and physical consistencies, a nonvolatile factor(s) influencing oviposition was suggested.

A study of the feces of six species of animals revealed that the face fly may successfully propagate in nature in other than bovine manure. Larval development was unaffected in fresh horse, bison, and pig dung; but was decreased in the drier sheep and deer feces. This decreased development may be attributable to their lower moisture contents since reconstituted samples gave results comparable with the other manures studied. Adult flies favored fresh bison, bovine, and pig manure as oviposition sites. A marked preference for bison over bovine manure existed in both fresh and reconstituted samples substantiating the existence of a nonvolatile chemical factor(s) affecting oviposition. The unfavorability of fresh sheep and deer feces may be attributable to their low moisture contents since oviposition occurred more readily in reconstituted samples. Horse manure was a highly unfavorable oviposition site, even when reconstituted, probably due to its coarse physical consistency.

It appears that the best possibility for making bovine manure unsuitable for face fly propagation by manipulation of the animal's diet lies in controlling those factors influencing adult oviposition. Larval development was affected by the moisture content of the manure, but the moisture range of fresh bovine manure was too narrow to expect any measurable decrease in production. The chemical composition of the manure also influenced larval development, but production remained relatively constant as long as a source of roughage and grain was included in the diet. Adult oviposition, on the other hand, appeared to depend on four separate factors. The moisture content of the manure influenced oviposition, but again the moisture range of fresh bovine manure is too low to expect much of an effect in nature. The physical consistency of the manure also appeared to affect oviposition as evidenced by the highly unfavorable nature of the coarse horse manure as an oviposition site. A volatile chemical factor(s) drawn off during lyophilization was important in at least the initial attraction of the flies to the manure. A nonvolatile factor(s), probably mediated by contact chemoreception, appeared to allow flies to make discriminatory choices in the selection of an oviposition site. Further studies are necessary to determine the nature of these chemical factors and the degree to which they may be employed in controlling the face fly.

ACKNOWLEDGMENTS

I wish to gratefully acknowledge my major professor, C. W. Pitts, for his invaluable advise, assistance, and encouragement during the course of this research problem and the preparation of the manuscript.

Special thanks are extended to Larry David and Roger Diekman for their efforts in the maintenance of the laboratory colony and the collection of samples.

I would also like to thank George M. Ward, Associate Professor of Dairy Science, and his staff for their care of animals and collection of samples used in diet tests.

Appreciation is also expressed to Sue Valder for her aid in the preparation of various experiments.

Sincere thanks go to my wife, Ann, for her necessary patience and understanding during the completion of this study.

Partial financial support was furnished by United States Department of Agriculture research grant number 427-15-11; and National Institutes of Health Graduate Training Grant Number 1-T01-AI-00328-01 AID.

REFERENCES CITED

Barton-Browne, L. 1962. The relationship between oviposition in the blow fly Lucilia cuprinia and the presence of water. J. Insect Physiol. 8:383-91.

Derbeneva-Ukhova, B. B. 1942. On the development of ovaries and on the imaginal nutrition in dung flies (in Russian). Med. Parasitol. 11:35-97. Abstract in Rev. Appl. Entomol. (B). 32:118. 1944.

Dethier, V. G. 1961. Behavior aspects of protein ingestion by the blow fly Phormia reginia Meigen. Biol. Bull. 121:456-470.

Hammer, O. 1942. Biological and ecological investigations on flies associated with pasturing cattle and their excrement. Vidensk. Medd. Dansk. Naturh. Foren., Kbh. Bind 105:141-393.

Larsen, J. R., Pfadt, R. E., and L. G. Peterson. 1966. Olfactory and oviposition responses of the house fly to domestic manures, with notes on an autogenous strain. J. Econ. Ent. 59:835-837.

Morgan, N. O., and O. H. Graham. 1966. Influence of cattle diet on survival of horn fly larvae. J. Econ. Ent. 59:835-837.

Patton, W. S. 1933. Studies on the higher Diptera of medical and veterinary importance. A revision of the genera of the Muscini, Subfamily Muscinae, based on a comparative study of the male terminalia. I. The genus Musca Linnaeus. Ann. Trop. Med. Parasit. 27:135-156.

Patton, W. S. 1933b. Studies on the higher Diptera of medical and veterinary importance. A revision of the species of the genus Musca, based on a comparative study of the male terminalia. II. A practical guide to the Palaeartic species. Ann. Trop. Med. Parasit. 27:327-345, 397-430.

Tesky, H. J. 1960. A review of the life-history and habits of Musca autumnalis DeGeer (Diptera: Muscidae). Canad. Ent. 92:360-367.

Treece, R. E. 1966. Effect of bovine diet on face fly development - A preliminary report. J. Econ. Ent. 59:153-156.

Vainshtein, B. A., and R. A. Rodova. 1940. Les lieux de developement des mouches de fumier dans les conditions du Tadjikistan montagneux (in Russian). Med. Parasit. 9:364-368.
Abstract in Rev. Appl. Entomol. (B). 31:126. 1943.

Vockeroth, J. R. 1953. Musca autumnalis Deg. in North America (Diptera: Muscidae). Canad. Ent. 85:422-423.

APPENDIX

Animal Diets

KABSU Diet:

- KABSU Feed Formula
  - Corn (934 lbs.)
  - Oats (400)
  - Bran (400)
  - Linseed Oil (200)
  - Soy Meal (100)
  - Salt (40)
  - Di-Calcium Phosphate (2Q)
  - Vitamin A (1)
  - Molasses (85)
- Alfalfa Hay
- Prairie Hay

Bison Diet:

- Range Cubes
- Alfalfa Hay
- Prairie Hay

Deer Diet:

- Milo
- Corn
- Wheat
- Alfalfa Hay
- Prairie Hay

Sheep Diet:

- Range Cubes
- Alfalfa Hay

Pig Diet:

- Corn
- Alfalfa Hay

Horse Diet:

- Cracked Corn
- Bran
- Wheat
- Alfalfa Hay
- Prairie Hay

FACTORS AFFECTING OVIPOSITION AND DEVELOPMENT OF THE FACE FLY, *MUSCA AUTUMNALIS* DEGEER (DIPTERA: MUSCIDAE)

by

DARRELL EDWARD BAY

B. S., Kansas State University, 1964

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

Bioassay and oviposition experiments were conducted to determine factors in manure affecting production of the face fly, Musca autumnalis DeGeer (Diptera: Muscidae). A preliminary test determined the quantity of manure per larva required for optimal development. By varying either the number of larvae or the amount of manure, a minimum of 2.0 grams of manure per larva was found to be necessary to give both maximal pupal weight and adult emergence.

Any difference in manure attributable to bovine sex had no effect on larval development. The average emergence of face flies from cow manure was 79.7 percent compared to 80.8 percent from bull manure.

A correlation between the moisture content of bovine manure and face fly productivity was determined by lyophilization and reconstitution of the freeze-dried samples over a wider moisture range than existed in nature. Lyophilized manure reconstituted to 85 percent moisture produced maximal pupal weight and percent adult emergence. The average moisture content of fresh bovine manure was 83.5 percent; decreased development occurred in drier samples. Adult flies favored freeze-dried manure reconstituted to 80 and 85 percent moisture as oviposition sites. There was a marked preference for fresh over reconstituted bovine manure indicating the presence of a volatile oviposition factor(s) drawn off during lyophilization.

Cattle diet also influenced face fly larval development and adult oviposition. Maximal development resulted from the soft, moist manure passed by animals fed high grain, low roughage diets while development in the hard, pelleted manure passed by animals fed prairie hay roughage decreased pupal weight and percent emergence; however, the decreased development in the latter could not be entirely attributed to its lower moisture content since development was also hindered in reconstituted samples. Adult flies favored the manure passed by animals on high grain diets as oviposition sites. Since this preference was also manifested in reconstituted manures, a nonvolatile factor(s) influencing oviposition is indicated.

A study of the manures of six species of animals showed that the face fly may successfully propagate in other than bovine manure. Larval development was unaffected in horse, bison, and pig manure. Pupal weight and percent emergence were decreased by development in the drier sheep and deer manures. This decreased development may be attributable to the lower moisture contents of the latter since reconstituted samples gave results comparable with the other manures studied. Adult flies favored fresh bison, bovine, and pig manure as oviposition sites. The unfavorability of fresh sheep and deer manure may be attributable to their lower moisture contents since oviposition occurred more readily in reconstituted samples. A marked preference for bison over bovine manure existed in both fresh and reconstituted samples substantiating the existence of a nonvolatile chemical factor(s) influencing adult oviposition. Horse manure was a highly unfavorable oviposition site, even when reconstituted, probably due to its coarse physical consistency.