Evaluation of the Dosage of Various Ingredients and the Possible Substitutes for Carrot in the Carrot-Yeast Medium in the Larval Culture of the Oriental Fruit Fly, *Dacus dorsalis* HENDEL

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INTRODUCTION

The oriental fruit fly, *Dacus dorsalis* HENDEL, is a devastating pest of banana, mango, citrus and many other fruits, which is prevalent in many of the tropical and sub-tropical countries. Its distribution in Japan is so far limited to the Amami Islands which is detached from the mainland in the southernmost territories.

Since the initiation of Japanese Plant Protection Service, a strict measures has been taken to prevent the introduction of this menacing insect by the enforcement of the overall embargoes on the host plants produced in, and shipped from, the habitat areas. In view of the possible removal of the embargo which is keenly desired in foreign and domestic trading circles, but which would only be feasible by the discovery of a safe and perfect disinfection measures applicable to the plant protection service, comprehensive studies must be made on the possibility of its establishment in Japan, the nutritional requirements as well as the control of this pest. For all these studies, however, it is vitally important to obtain from among the materials available in this country a suitable food for the mass production of test flies. The author, in his approach to this problem, attempted a series of experiments on the nutritional evaluation of the composition of the Finney's fortified carrot medium in relation to the larval developments and the search for the possible substitutes for some of the ingredients of the medium.

MATERIALS AND METHODS

The experiment was carried out in Phytotrone with the room temperature regulated at 25°C and the relative humidity at 80 to 90 %, respectivery.

The parent stock of the test flies had been imported from Amami Island in the pupal stage under the special permit in conformity with the Plant Quarantine Law.

Mass breeding of the stock was carried out in boxes covered with silken net. Adult flies were fed on the artificial diet consisting of a protein hydrolysate of yeast and soy bean, and sucrose that were given separately in different petri dishes. Water was supplied by keeping a cotton-ball constantly soaked with water. Pre-oviposition periods of the adults fed on this diet were about two weeks.

The abult flies were induced to oviposit through pinholes into a hollow plastic lemon which contained a cotton ball soaked with orange juice.

For larval culture, 50 g of the diet was placed in a Petri dish of 9 cm diameter. Each dish was inoculated with 100 eggs which had been raid for less than 4 hours. The egg period of about two days was usually needed before hatching. All the test were replicated three times. The composition of the basal diet is as follows;

Fresh carrot	100 g
Water	50 m*l*
Dried Brewer's yeast	4 g
Hydrogen chloride (Conc.)	0.4 m*l*
Buthyl *p*-hydroxybenzoate	0.14 g

Among the ingredients used, fresh carrot was employed as the carbohydrorate and minerals sources, while yeast as the protein and B vitamins sources. Hydrogen chloride and Buthyl *p*-hydroxybenzoate were added either as pH regulator or the inhibitor of undesirable

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Table 1. Experimental design.

Item	Dosage/Amount of fresh carrot
Kinds of yeast (Dried Brewer's yeast)	0, 0.5, 1.0, 1.5, 2.0~5.0 g/100 g
(Dried Baking yeast)	1, 2, 3, 4, 5 g/100 g
Quantity of Conc-H cl	0, 0.25, 0.50, 0.75~1.50 ml/200 g
Amount of Buthyl *p*-hydroxybenzoate	0, 0.1, 0.2, 0.3 g/100 g
Water content in the medium	30, 40, 50, 60, 70, 80 ml/100 g
Population in the larval culture	1, 5, 10, 20, 30, 50, 100, 150~300 eggs/50 g*

* Amount of the medium.

molds which are likely to occur before and after being fed.

All the ingredients except carrot were mixed in a beaker and boiled for a few minutes. The fresh carrot was finery sliced and added to the mixture, and these, in turn, were reduced to a gravy-like paste in a high speed mixer.

In each test, only one factor was varied in concentration from that indicated in the formulation of the basal diet (Table 1).

The development of the larvae in culture was observed daily. When grown mature, they were taken out of the dish, and the number of survived larvae was counted. Average body weight was measured by weighting 30 larvae or all the larvae when the survival was less than 30 larvae. Mature larvae were then transferred into Petri dishes containing sand of 10% moisture content, and the emergence and sex ratio of adult flies were observed.

RESULTS

Nutritional evaluaton of the ingradients of the carrot-yeast medium.

(a) Kinds of yeast and their quantity.

Two kinds of yeast, Brewer's type and Baking type, were used in the test. Since the water content of the Brewer's yeast was determined to be 3.15%, while the Baking yeast contained 6.88%, 1 g in gross weight of the former was equivalent to 0.962 g of the latter.

The data shown in Table 2 and 3 indicates that, in both yeasts, the average body weight of mature larvae showed an increase, attaining the maximum at the dosage of 4 g, and the increasing rate was greater in the Brewer's yeast than in the Baking yeast, while the

Table 2. Effect of the dosage of Brewer's yeast on the larval development.

Dosage of yeast per 100 g of carrot		Number of eggs hatched	Larval period in days	Number of mature larvae	Average weight of mature Larva in mg*	Number of emergence
A	0	249	6—12	197	11.6±1.7	177
B	0.5	264	6—11	247	12.9±1.0	240
C	1.0	271	6— 7	230	15.2±1.2	219
D	1.5	271	6— 7	254	17.9±0.7	247
E	2.0	257	5— 6	252	18.9±0.9	247
F	2.5	283	5— 6	268	19.1±0.8	260
G	3.0	288	5— 6	266	20.5±0.8	260
H	3.5	270	5— 6	248	20.7±0.7	246
I	4.0	266	5— 6	243	21.6±0.8	236
J	4.5	261	5— 6	250	21.0±0.8	243
K	5.0	254	5— 6	242	21.0±1.0	237

* Difference significant at 5% level is indicated as follows;
$A \neq B = C < D = E = F$, $E = F = G$, $D < G = H$, $G = H = I$, $F < I = J = K$.

Table 3. Relation between the dosage of Baking yeast and the larval development.

Dosage of yeast per 100 g of carrot		Number of eggs hatched	Larval period in days	Number of mature larvae	Average weight of mature larva in mg*	Number of emergence
A	0.5	257	9—13	253	17.6±0.8	245
B	1.0	273	9—12	243	17.6±0.8	235
C	2.0	254	8— 9	215	18.9±0.9	206
D	3.0	277	7— 8	258	18.9±1.0	254
E	4.0	277	5— 6	263	20.6±0.8	260
F	5.0	286	5— 6	254	20.8±0.9	242

* Difference significant between B and E (or F) at 5% level.

larval period was shorter in the former than in the latter. No further increase in the average body weight was observed by the dosage of more than 4 g. The larval period in case of the dosage of 4 g was 5 to 6 days and the average body weight at the maximum was about 21 mg.

The larval recovery at any dosage levels was 84.9 to 98.1% in the Brewer's yeast and 84.6 to 94.9% in the Baking yeast, whereas the pupal period and the rate of emergence were 11 to 12 days and 95.3 to 99.2%, respectivery. Apparrently, these developmental factors are least affected by the different dosage of both yeasts.

Fairly good larval recovery of 79.1% and also good emergence of 89.8% were obtained even when the yeast were entirely omitted from the diet. However, the larval period became much prolonged and the individual larva grew smaller.

In order to determine the possible influence of the dosage of yeast on the survival of the larvae of both sexes, the sex ratio of the emerging adults was surveyed. The male in the Brewer's yeast and the female in the Baking yeast was always greater in number than the opposite sex. No correlation, however, was found between the sex ratio and the dosage of yeast.

(b) Effect of pH

In this test, the amount of yeast was reduced to 1.5g. pH test paper was used to measure the hydrogen ion concentration of the media just after preparation. The results are shown in Table 4. Good growth of the larvae was always obtained on the acid side and the optimum pH range was found to be 4.2 to 5.0 approximately. As the pH moved from this optimum range to either side, the larval period became longer and the average body weight lighter. The larval recovery in this test was 91.1 to 98.3%. The pupal periods were nearly 11 days and 92.3 to 98.6% of the pupae emerged. Within the pH range tested, it has been shown that the pH of the media does not substantially affect any of the larval recovery, the pupal periods or the number of emergence. It was also noted that the larvae, when reared in the media of unsuitable pH, could modify it toward the favorable side, and the pH in the last stage of the larval development always fell within or nearly within the optimum range mentioned above. That the larvae of oriental fruit fly can tolerate a wide range of acidity and alkalinity is clearly demonstrated by the results of this test and those reported by Maeda et al (1952).

(c) Relation of the dosage of Buthyl *p*-hydroxybenzoate and days in storage of the medium to the larval development.

In stead of Sodium benzoate, a mold inhibitor of general use, Buthyl *p*-hydroxybenzoate (BPHB) was used in this test. The 50 eggs were inoculated into the media which had been stored at 10°C for 3, 5, 7 and 10 days, respectively. The results given in Table 5 and 6 shown that the storage period has no great influence upon the larval recovery and the body weight of mature larvae. To a certain extent, however, the dosage of BPHB can be related to the larval recovery. Best larval recovery was obtained in the medium with 0.1 g of BPHB per 100 g of carrot, whereas the yield was generally lower and not constant in the media with 0.3 g.

Undesirable molds occurred abundantly on the non-BPHB medium, and after a few days in storage, it was

Table 4. Effect of hydrogen-ion concentration of medium on the larval development.

Quantity of Conc-Hcl per 200 g of carrot	pH	Number of eggs hatched	Larval pariod in days	Number of mature larvae	Average weight of mature larva in mg**	Number of emergence
0	5.8	281	7	273	17.0±1.2	264
0.25	5.4	286	7	281	17.6±2.4	277
0.50	5.0	254	7	242	18.6±0.8	222
0.75	4.6	259	7	254	19.0±1.4	241
1.00	4.2	282	7	270	19.8±1.2	263
1.25	3.8	258	9—10	243	18.1±0.9	234
1.50	3.4	257	13—14	234	17.3±0.9	216
0.50*	7.2	279	9—11	267	17.3±0.8	259

* 35 % NaOH solution.

** No difference at 5 % level among the average body weight in each media except 0.25 m*l* dosed medium.

Table 5. Relation of the dosage of Buthyl *p*-hydroxybenzoate and the days in storage of the medium to the larval development.

Dosage of Butyl *p*-hydroxybenzoate per 100 g of carrot (g)	Days in storage at 10°C	Number of eggs hatched	Larval period in days	Number of mature larvae	Average weight of mature larva in mg*	Number of emergence
0	0	136	5—7	117	20.0±0.8	79
	3	127	5—7	113	20.1±1.8	99
0.1	0	135	5—6	129	21.9±0.8	78
	3	132	5—6	129	21.9±0.8	116
	5	128	5—6	119	21.7±0.7	101
	7	137	5—6	131	20.9±0.8	80
	10	140	5—6	133	21.6±0.8	131
0.2	0	147	5—6	138	19.7±0.8	123
	3	141	5—6	123	19.5±0.8	113
	5	136	5—6	128	20.0±0.8	120
	7	132	5—6	126	19.0±1.1	119
	10	140	5—6	123	19.5±0.9	101
0.3	0	139	5—7	128	18.7±1.5	122
	3	136	5—7	105	16.7±4.1	93
	5	143	5—7	136	18.8±1.0	130
	7	96	5—7	89	18.0±1.6	84
	10	127	6—8	96	16.3±0.8	95

* Difference significant at 5 % level between 0.1 g (or 0.2 g) dosed group and other groups, but no difference between the former two groups.

no longer usable. The media with more than 0.1 g of BPHB could be stored entirely mold-free for 3 days, and even after 7 days, the mold growth was slight and quite negligible.

Within the range tested, no positive relation between the dosage and the effect of mold control was recognized. However, when reared the non-BPHB and 0.3 g BPHB media, the larval periods were less longer than those in the 0.1 and 0.2 g BPHB media.

(d) Water content of the medium.

50 g of the medium was sampled and weighed for the water content after being dried up at 110°C for 48

Table 6. The occurence of certain microorganisms in the diet containing different dosage of Buthyl *p*-hydroxybenzoate and days in storage.

Buthyl *p*-hydroxy-benzoate (g)	Storage (days)	1			2			3		
		Egg stage	Larval stage		Egg stage	Larval stage		Egg stage	Larval stage	
			1st instar	3rd instar		1st instar	3rd instar		1st instar	3rd instar
0*	0	−	++	+++	−	++	+++	−	+	+++
	3	−	++	+++	−	+++	+++	−	+++	+++
	5	+	+++	+++	+	+++	+++	+	+++	+++
0.1	0	−	−	−	−	−	−	−	−	−
	3	−	+	−	−	−	−	−	−	−
	5	−	+	−	−	−	−	−	−	−
	7	+	+	−	−	−	−	−	−	−
	10	+	+	−	−	−	−	−	−	−
0.2	0	−	−	−	−	−	−	−	−	−
	3	−	−	−	−	−	−	−	−	−
	5	−	−	−	−	−	−	−	+	−
	7	−	+	−	−	−	−	−	−	−
	10	+	+	−	−	−	−	+	+	−
0.3	0	−	−	−	−	−	−	−	−	−
	3	−	−	−	−	−	−	−	−	−
	5	−	−	−	−	+	−	−	−	−
	7	−	−	−	+	+	−	−	+	−
	10	+	+	−	+	+	−	−	−	−

− no occurence, + slight, ++ moderate, +++ heavy.

* The diet with no BPHB and stored in 7 days or longer were not used in the test because of the occurence of unsuitable molds.

hours. The dosage of each ingredient was adjusted to make it equivalent to that of the basal diet. The pupal periods and the number of emergence were not observed in this test.

The data shown in Table 7 indicates that the optimal range of the water content was 88 to 90 %. The content below or above the optimal range was found to be either insufficient or excessive, and incurred some inconvenience in preparation and handling. Since the carrot used in each trial differed in its water content, it was hard to determine the exact quantity of water to be supplied to the basal diet. Approximately, however, 50 to 70 m*l* of water per 100 g of fresh carrot seemed to give the ideal water content to the medium.

(e) Population density.

From 1 to 300 eggs were inoculated into 50 g of the basal medium and the subsequent larval growth was observed.

As is shown in Figure 1, the more the inoculated eggs, the less the body weight of survived mature larvae. Any of the larval recovery, the larval periods, the pupal periods or the ratio of emergence was not or slightly, if any, affected by the population density. Although, in view of standard deviation of the larval body weight, the optimal density appears to lie between 50 to 100 eggs per 50 g of the medium, it is also worthy of note that as many as 300 or more eggs can somehow complete thier stage in so small a quantity of 50 g.

Substitute for carrot in the carrot-yeast medium.

For the mass culture of the oriental fruit fly in

Table 7. Effect of water content of the medium on the larval development.

Quantity of water added per 100 g of carrot(m*l*)	Percent of water content	Number of eggs heatched	Larval period in days	Number of mature larvae	Average weight of mature larva in mg*
30	87.15	273	5—6	261	19.8±0.9
40	88.03	271	5—6	248	20.2±0.8
50	88.62	253	5—6	225	20.9±1.2
60	90.32	269	5—6	262	20.8±0.8
70	91.12	275	6—7	263	22.6±0.9
80	91.59	270	6—7	244	19.3±1.5

* Difference significant at 5 % level between 30 and 70 m*l* added medium.

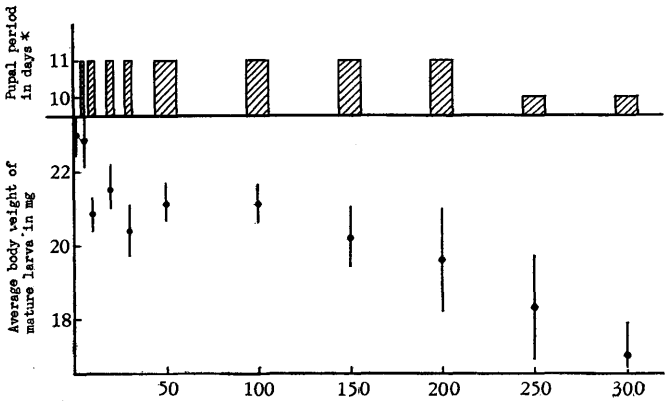

Figure 1. Effect of larval population on their growth.

* Days required for the emergence of more than 90 percent.

Table 8. Comparison of various substitutes for carrot in the carrot-yeast medium.

Fruit or vegetable	Larval period in days	Percent of larval recovery	Average weight of mature larva in mg***	Percent of emergence
Carrot	5— 6	95.8±3.2	21.0±0.8	97.2±1.9
Apple*	9—18	92.1±7.6	16.9±1.4	96.3±3.5
Apple	6— 8	93.3±6.1	19.6±0.8	98.4±1.6
Potato	6— 8	83.9±0.8	17.0±0.9	41.3±7.9
Raddish	10—11	**	19.0	77.8
Sweet potato	6— 8	91.1±0.6	20.1±0.9	94.3±2.3

* Brewer's yeast was added 1.5 g per 100 g of apple.

** Many eggs did not hatch and only 9 larvae survived.

*** Difference significant at 5 % level between apple (*)-yeast (or potato-yeast) medium and others.

Japan, it is a prerequisite to obtain an adequate medium which can be cheaply supplied all the year round. In the search for a possible substitute for carrot in the basal diet, apple, sweet potato, Irish potato and radish were serected for use in this test because of the similarity with carrot in thier texture.

As is shown in Table 8, the apple- and the sweet potato-yeast media gave good larval development almost equal to the carrot-yeast medium. Though the body weight was a little lower, these two media may well substitute the carrot when the latter is not available.

The potato-yeast medium is not promising because of the low rate of emergence.

Larval development in the fruits.

The food value of the carrot-yeast medium and many fresh fruits were compare in this test.

Among the fruits employed, mandarine orange, chinese citron and ponkan were collected in Japan, while the others were foreign products.

The data given in Table 9 indicates that the best growth was obtained in the carrot-yeast medium, as the larval period was shorter, the larval recovery higher and the average body weight greater in this medium than in any other fruits. In most of the fruits tested, the larval development was so erratic that some of them gave fairely good recoveries, whereas in others little or no development was observed. These results may be partly due to undesireble microorganisms which not infrequently invaded the fruits under test. Banana, mandarine orange, grapefruit, chinese citron and lemon were comparatively superior to the others. Though sabogira and grape are, so far as known, not included in the host range of this fly, the larvae were found to attain the development when artificially introduced. Lime and pine apple are not suitable because of the lowest rate of larval recovery.

DISCUSSION

For many years in the past, various kinds of fruits have been used for the mass production of the oriental fruit fly. The use of these fruits, however, is often

Table 9. The comparison of larval development among the carrot-yeast medium and other fruits.

Kinds of diet	Number of experiment	Total number of eggs inoculated	Larval period in days	Percent of larval recovery*	Average weight of mature larva in mg**	Percent of emergence
Carrot-yeast	3	300	5— 6	95.8± 3.2	21.0± 0.8	97.2± 1.9
Banana	3	300	7— 9	92.0± 1.7	19.2± 0.8	94.9± 0.3
Mandarin orange	3	150	7— 8	84.4± 7.9	20.5± 0.9	97.5± 2.4
Grapefruit	3	300	6— 9	85.2± 1.8	20.1± 1.0	96.7± 2.7
Lemon	3	150	8—10	76.7±12.7	18.2± 0.9	91.2± 6.5
Sabogira	3	150	8—11	60.9±19.9	18.9± 0.8	96.4± 4.0
Chinese citron	3	300	12—15	79.1± 2.8	19.6± 0.9	90.3± 3.7
Mango	3	300	6— 8	68.0± 8.2	18.8± 0.9	97.4± 1.9
Grape	3	180	12—16	63.5± 3.0	14.2± 2.5	94.1± 5.3
Ponkan***	3	300	7— 8	60.7± 5.3	19.6± 1.4	98.2± 0.2
Lime	3	150	10—15	41.8± 9.3	14.0± 2.1	60.7±27.1
Navel orange	2	200	6— 9	38.0±24.5	19.6± 0.9	98.5± 1.5
Pine apple	2	240	12—15	1.2	—	—

* F-test on the data obtained by the arc sine $\sqrt{\text{percentage}}$ shown the significant difference at 5% level among the following three groups.
Top group; carrot-yeast and banana.
Second group; mandarine orange, grapefruit, chinese citron and lemon.
Third group; other fruits except lime, navel orange and pine apple.

** Difference significant at 5% level between lemon (or grape, lime) and others except pine apple.

*** *Citrus poonensis* TANAKA.

handicapped by the fact that they are not stable and uniform in their nutritional composition which inevitably leads to more or less erratic larval recovery. The decrease in the larval yields also results from the frequent occurrence of undesirable molds on the inoculated fruits. Besides, it is by far difficult to maintain cheap and constant supply of these fruits all the year round.

Efforts have been made by various workers in order to overcome these disadvantages. Some of the media as are recommended by them are listed in Table 10. Marucci and Clancy (1950) stated that the larval yield of 60 to 70 % and the pupation of 80 to 100 % were obtained in the best test series of their media. Newell, Van den Bosch and Haramoto (1951) reported the use papaya pulp paste with a small dosage of yeast for the rearing of field-collected larvae. Finney (Joint Legisla-

Table 10. The larval media of oriental fruit fly, *Dacus dorsalis* HENDEL.

Author	Composition		Remarks
Taguchi (1963)	fresh carrot (or apple, sweet potato)	100 g	Storable for 10 days at 10°C. About the same larval body weight as that in case of fresh fruits can be attained by the population of 200 eggs per 50 g of this medium.
	water	50—70 m*l*	
	Conc-Hcl	0.4 m*l*	
	Brewer's yeast (or Baking yeast)	4 g	
	Buthyl *p*-hydroxybenzoate	0.1 g	
Finney (1956)	fresh carrot water	800 m*l*	Storable for a few days at 4 to 8°C.
	2N-Hcl	15 m*l*	
	Brewer's yeast	16 g	
	Butoben	1.04 g	
U. S. D. A.*	dehydrated carrot	300 g	Practical medium in Hawaii at present. 1500 eggs can be reared in 2800 m*l* of medium.
	water	2800 m*l*	
	Conc-Hcl (C. P.)	9.1 m*l*	
	Brewer's yeast	84 g	
	Sodium benzoate	2.8 g	
Marucci et al. (1950)	agar	20 g	The optimal population is 2 to 4 larvae per gram of medium.
	banana pulp	220 m*l*	
	water	760 m*l*	
	yeast	30 g	
	sucrose	20 g	
	propionic acid	3 m*l*	
	Moldex	2.4 m*l*	
Maeda et al. (1953)	agar	1.3 g	This synthetic medium adapted for mass production under septic conditions.
	Butoben	0.12 g	
	glucose	4.9 g	
	casein	0.8 g	
	wheat germ oil	0.175 g	
	cholesterol	0.175 g	
	salt mixture (U. S. P. XIII)	0.35 g	
	Brewer's yeast	1.75 g	
	choline chloride	0.07 g	
	water	100 m*l*	

* U. S. D. A. Hawaii Fruit Fly Investigations; Mass production of three species of fruit flies under laboratory room conditions (70~85°F).

itve Committee; Third special report, 1953) found the fortified carrot medium which is of high nutritional and practical value. The fresh carrot in the Finney's medium was later replaced by the dehydrated carrot which is more stable and uniform in its nutritional composition, and more handy in preparation and handling (Christenson, Maeda and Holloway, 1956).

On the other hand, Maeda, Hagen and Finney (1952) studied the nutritional aspect of the larval development in the artificial media (Table 10). Moore (1959) also reported the use of an artificial medium for the olive fly, Dacus oleae Gmel. Few of these investigators, however, has yet fully evaluated the quantitative relation between the ingredients and the larval growth.

According to Maeda et al (1952) and Marucci et al (1950), the yeast is essential to the larval growth in their media, and also in the author's test, the quantity of yeast has been closely related with the body weight of mature larvae and they showed an increase up to the dosage of 4 g per 100 g of the fresh carrot.

As to the pH of the medium, Maeda et al (1952) stated that pH 4.5, 5.5, 7.0 and 8.0 showed no appreciable difference in the larval growth, while the optimal range obtained by the author was pH 4.2 to 5.0. Similar results were obtained in the relationship between the population density and the larval development.

Finney (1956) observed the normal development of larvae in the Butobendosed medium which had been stored for a few days at 4 to 8°C. The author, on the other hand, has found it storable for longer than 10 days at 10°C with no ill effect observed on the larval growth.

When the two protein sources, the Brewer's yeast and the Baking yeast, were compared, the larval periods were shorter and the body weight were greater in the former than in the latter. Sex ratio of the survived larvae, when inferred from that of the emerged flies, also showed a remarkable difference between the two yeasts, namely, the greater number of the male in the former and that of the female in the latter.

The use of the Baking yeast in stead of Brewer's yeast and the apple and sweet potato as substitutes for carrot has not been reported by any previous workers.

From the view-point of nutritional requirements of the oriental fruit fly, it is noted that the effect of the posage of some ingredients is apparently restricted to the larval body weight, whereas the range of influence of some others additionally covers the larval recovery and the rate of emergence. In the author's results, Buthyl *p*-hydroxybenzoate, some fruits and potato as the substitute for carrot fall in the latter group, and this may possibly be due to the lack of some essential nutritional factors or the presence of certain inhibitive substances which needs to be enlightened in the course of future experiments.

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SUMMARY

The nutritional composition of the carrot-yeast medium was evaluated in relation to the larval development of the oriental fruit fly. Some of the possible substitutes for carrot were also descrived. The results obtained are summarized as follows.

(1) The larvae grew normally in either of the Brewer's yeast and Baking yeast medium, and the optimal dosage in either yeast was found to be 4 g per 100 g of fresh carrot.

(2) When inferred from the sex ratio of the emerged adults, the male mature larvae in the Brewer's yeast medium and the female in the Baking yeast medium were always greater in number than the larvae of the opposite sex.

(3) Best larval growth was obtained in the media of pH 4.2~5.0, which contained 0.3 to 0.5 m*l* of hydrogen chloride (Conc.) per 100 g of fresh carrot.

(4) The optimal dosage of Buthyl *p*-hydroxybenzoate was 0.1 g per 100 g of fresh carrot. While the non-mold inhibitor medium allowed an abundant growth of undesirable molds, the mold-inhibitor-dosed medium

could be stored mold-free for more than 10 days at 10 °C. The dosage of 0.3 g, however, was found to be inhibitive to the larval development.

(5) The adequate water content of the medium was determined to be 88 to 90 %, which was prepared by adding 40 to 70 m*l* of water per 100 g of fresh carrot.

(6) The optimum population density was 100 eggs per 50 g of the medium. The higher the population density, the lower the average body weight of mature larvae.

(7) Apple and sweet potato may well be used for the larval culture as the possible substitutes for carrot in the carrot-yeast medium.

(8) Among the twelve kinds of fruits tested, banana, mandarine orange and grape fruit were comparatively superior to the others in view of the periods, the recovery and the average body weight of larvae.

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摘　　要

ミカンコミバエ幼虫飼育のためのニンジン・イースト飼料の組成分量とニンジン代用青果物の検討

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ミカンコミバエ幼虫の飼料として FINNEY (1956) の見出した生ニンジン，酵母，Conc-Hcl，パラヒドロキシ安息香酸ブチル，水の混合磨砕した飼料を用い，個個の構成成分についてその量的変化と幼虫の生育との関係を明らかにした。またニンジン代用青果物について検討し，ニンジン・イースト飼料，各種生果実間の幼虫の生育の比較も行なった。結果は次のとおりである。

(1) 蛋白質およびビタミンB群源である酵母はパン酵母，ビール酵母のいずれを用いても幼虫は良く生育し，酵母の量を漸次増加させるに従って老熟幼虫の体重は増加した。そして両酵母区ともに生ニンジン 100 g に対し 4 g 以上加えた場合に平均体重がほぼ一定となり 21 mg 前後を示した。幼虫生存率や羽化率は酵母の量によってほとんど影響されなかった。

無酵母区においては幼虫期間が長く，幼虫生存率は低下し，しかも老熟幼虫の平均体重は前記のほぼ 1/2 であった。

(2) pH 調整のために加えた Conc-Hcl の量は生ニンジン 200 g に対し 0.25～1.50 m*l* の範囲においては，幼虫生存率，平均体重，羽化率にほとんど影響を与えず，1.25 m*l* 以上加えた区の幼虫期間のみが延長した。しかしミカンコミバエ幼虫が酸性を好むこと，酸性飼料においてはカビの発生が抑制されることを考慮すれば，Conc-Hcl 添加量は 0.5～1.0 m*l* (pH 4.2～5.0) が

適当と考えられる。

（3） 防黴剤，パラヒドロキシ安息香酸ブチルの最適添加量は生ニンジン 100 g に対し 0.1 g で，0.3 g を加えると幼虫の生育が抑制された。また無添加区においてはカビの発生が著しく。そのため幼虫生存率は低下した。また 0.1 g および 0.2 g 添加各区は貯蔵日数（10 ℃）によって幼虫期間，幼虫生存率および平均体重に差異が認められなかった。

（4） 飼料の含水量は調製しやすいことおよび生育がよいことの2点から 88～90 %（生ニンジン 100 g に対し 40～70 m*l*）が適当であった。

（5） 一定量の飼料に対し接種卵数を増すと，老熟幼虫の平均体重は次第に減少し，また一定量の砂に入れる老熟幼虫数を増すと蛹期間はわずかに短縮する傾向を示した。飼料 50 g に対する最適接種卵数は老熟幼虫の体重の変異が小さいことから 100 卵以内が適当であるが，ミカンコミバエ幼虫の最も好む生果実で生育した幼虫の体重とほぼ同程度の体重の個体に飼育するには 200 卵に増加してもよい。

（6） ニンジン代用青果物としては栄養，物理的性状，幼虫の生育に対する影響の各観点からリンゴ，サツマイモ，ジャガイモ，ダイコンのうち前2者を使用できることが判った。

（7） 12 種類の生果実を用いて幼虫の生育を比較した結果，幼虫生存率については高い方から①ニンジン・イースト，バナナ，②ミカン，グレープ・フルーツ，ナツミカン，レモン，③サボジラ，マンゴー，ブドウ，ポンカン，④ライム，ネーブル・オレンジ，パイナップルの4つのグループに別けられ，①②③の各グループ間には有意な差を認めた。老熟幼虫の平均体重はレモン，ブドウおよびライムと他の各生果実区間に有意な差を認めたのみで，大部分の各生果実区においては 18～20 mg を示し区間の相違はなかった。なお寄主として記録されていないサボジラおよびブドウで比較的良好な生育をしたことやパイナップルでは極めて稀にしか生育しえなかった。

以上の結果からミカンコミバエ幼虫の飼料として次の組成が適当であると考えられる。

生ニンジン（またはリンゴかサツマイモ）	100 g
水	40～70 m*l*
Conc-Hcl	0.4 m*l*
ビール酵母（またはパン酵母）	4 g
パラヒドロキシ安息香酸ブチル	0.1 g