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A SIMPLE INSTANT DIET FOR REARING ARCTIIDAE AND OTHER MOTHS

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ABSTRACT. A bean-based semiartificial diet was developed empirically for rearing species of *Rhodogastria* and *Creatonotos* (Arctiidae), foodplants for which were unavailable or unknown. It was also used successfully for Heterocera in 27 genera of five families, and is likely suitable for rearing additional species of moths. Preparation of the diet is simple even in the field, and its components are inexpensive.

There are many practical reasons for attempting to rear insects on artificial diets, in particular to provide food independent of place or season. Numerous diet recipes have been published (Vanderzant 1974, Singh 1977, Singh & Moore 1985), most of which are based on either wheatgerm, wheatgerm + casein or beans. Their diversity arises mainly from their various sources of vitamins, proteins, carbohydrates, fatty acids, and preservatives. Most published diets for Lepidoptera have been tested with only one or a few closely related species, and rearing success can seldom be standardized to permit fully objective comparisons. The suitability of a certain diet for any given but untried species is thus not predictable.

Faced with the need to breed *Rhodogastria* and *Creatonotos* (Arctiidae), we considered artificial diets because the natural foodplants were either unknown or not continuously available. We also wanted a simple medium for use under field conditions in the tropics. To these ends, we modified recipes from the literature in a largely empirical fashion until we ended with an instant diet, which is cheap and easily prepared even during field work in the tropics. This simple diet also

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TABLE 1. Recipe of semiartificial diet. For simple preparation, 6 parts of I, 1 part of agar, and 20 parts of water are combined.

Ingredients	Amount		
	%[1]	g[2]	
Bean flour[3]	15.0	75.0	I
Brewer's yeast	3.5	17.5	I
Ascorbic acid	0.7	3.5	I
Cholesterol	0.1	0.5	I
Sorbic acid	0.1	0.5	I
Methyl-p-hydroxybenzoate	0.1	0.5	I
Streptomycin	0.08	0.4	I
p-formaldehyde	—	0.15	I
Formaldehyde (10%)	0.3		
Germ oil with α-tocopherol[4]	0.7		
Agar agar[5]	3.0	15.0	
Water	76.0	381.0	

[1] Weight/weight, except formaldehyde, which is volume/volume.
[2] To yield ca. 500 g of diet.
[3] Dried white beans ("Weiße Bohnen," *Phaseolus compressus* var. *albus*) obtained from a supermarket and pulverized by coffee grinder.
[4] 10 g α-Tocopherol + 140 ml germ oil ("Mazola® Keimöl," a salad oil produced and distributed by Maizena GmbH, Heilbronn).
[5] High gel-strength powder, research grade (SERVA, Heidelberg, New York).

appeared well suited to rearing other arctiids and a variety of species of other heteroceran families.

MATERIALS AND METHODS

Diets

Diets initially tested were based on wheatgerm, and were similar to those described by Vanderzant (1967) and Bell and Joachim (1976). These we modified by using frozen, tinned, or dried beans (*Vicia faba*, *Soja hispida*), testing mixtures of beans and wheatgerm in different proportions, and adding proteins, salts, and vitamins as well as leaf-powders in varying amounts. Eventually, we omitted several standard ingredients of artificial diets to create a simpler recipe. The diet we found best (Table 1) is prepared by parboiling water, and adding the agar while stirring. Other ingredients are then mixed thoroughly (preferably with an electric hand mixer) with the gelling agar. Flat plastic dishes are filled with this pap to a depth of 4 cm. Cooling and drying is allowed for up to 12 h at room temperature before storage in a refrigerator. With refrigeration, this diet can be stored for at least five weeks; in the field, smaller amounts of diet were prepared to last for three to five days.

After obtaining good rearing results with this diet, we modified it slightly to produce an instant diet which could be prepared more easily, particularly during field work in the tropics. The only departure from the original recipe is that 0.03% p-formaldehyde (solid) was substituted for formaldehyde solution; also, in the field, germ oil and α-tocopherol were omitted. Agar and a mixture of all other solid ingredients were put separately into two plastic containers, which allows for storage and transport (mailing) without refrigeration. When the diet was required, it was prepared by merely mixing agar with boiling water and adding the mixture (and oil) while stirring thoroughly. In practice, we use a 10 ml plastic container to measure 1 part of agar, 6 parts of the mixture, and 20 parts of water (or multiples thereof if more diet is required). However, these proportions work only if the beans are ground finely (as coffee for filtering), and high gel-strength agar (SERVA, Heidelberg, New York) is used; otherwise, different weight-to-volume relationships have to be determined.

Insects

Rhodogastria phaedra (Weymer) from Kenya (East Africa) and *Creatonotos transiens* (Walker) from Sumatra, Indonesia, were extensively investigated. Stocks originated from inseminated females sent to our laboratory. The foodplants of *Rhodogastria phaedra* are unknown, and the few known for other *Rhodogastria* are not available to us. *Creatonotos transiens* is a polyphagous species which we had previously reared successfully on European substitute foodplants such as *Taraxacum officinale* L.

The suitability of the simplest recipe (the instant diet) was tested with several European and tropical Lepidoptera (Table 2) to which we had unexpected access.

In routine cultures, as many as 50 neonate larvae were put into a clear plastic Petri dish (94 mm × 16 mm) containing a piece of diet (about 6 × 6 × 3 mm). Moistened filter paper was sometimes added. Later instars were kept in groups of 10 to 30 in plastic containers (200 × 200 × 95 mm), and given larger (but always 5 mm thick) pieces of diet. Every third day, larvae were transferred to a clean container with fresh diet. For quantitative rearing data, larvae were sometimes kept singly in Petri dishes.

We usually assessed the success of a diet by comparing the visual appearance of adults with field-caught specimens, and by checking the fecundity of females and the fertility of their eggs. In some cultures we also compared diets by weighing pupae, counting eggs, and measuring rates of development. For reasons given below, however, we report only on our final results, and omit the presentation of detailed data.

RESULTS

The diets of Vanderzant (1967) and Bell and Joachim (1976) were only moderately successful with *Rhodogastria* and *Creatonotos*. Better success was achieved by using beans instead of wheatgerm, while substituting casein by albumin and/or eggs as a protein source did not have an obvious effect. Using *Phaseolus* beans as a base, we stepwise left out casein, Wesson's salt (compare Singh 1977) and/or vitamin solutions without reduced rearing success. Later, sucrose, choline chloride, and inositol were found to be unimportant additions. The resulting best recipe from our trials is given in Table 1.

With *Creatonotos* in particular, we noted a dramatic group effect: larvae kept individually resulted in pupae which were up to 30% lighter than those of larvae kept in groups of 15–20. Thus, optimal rearing does not always depend on diet composition alone; indeed, other breeding conditions can be of overriding importance.

Notable general observations were, briefly: 1. White beans (*Phaseolus compressus* var. *albus*) appeared to be a better base for artificial diet than horse-beans (*Vicia faba*); this finding supports the experience of El-Guindy et al. (1979). 2. Soaking beans (previously done by most authors, such as Shorey & Hale 1965) proved unnecessary; pulverizing the seeds greatly simplifies preparation. 3. The use of methyl-p-hydroxybenzoate and sorbic acid enables extended storage of diet without refrigeration, and combats insect pathogens. Their concentration should nevertheless be kept as low as possible, and they can be omitted if the culture is healthy, and the diet is replaced frequently. 4. The quantitative composition of diet ingredients, particularly of water, appears less important than we originally judged from the literature.

Larvae of 38 species of moths, belonging to 27 genera of five families (Table 2) accepted our simple diet and developed with no unexpected mortality to adults that did not differ noticeably in size, color, and other characteristics from field-caught material. Females invariably proved fecund and eggs fertile. Rearing success from newly hatched larvae to adults was 80–100% in all species. Most species were reared for at least four generations (*C. transiens* for 20) without exhibiting apparent changes. However, larvae of sevaral species, including *Euchromia amoena* (Möschler) (Ctenuchiidae), *Antherea pernyi* Buerin-Meneville (Saturniidae), and all Rhopalocera, refused the diet. When checking the suitability of the simple diet with the species listed above, we experienced the following: 1. Preservatives may function as antifeedants; in some species we observed refusal if the concentration of methyl-p-hydroxybenzoate was higher than 0.1%. Hirai (1976) obtained similar results, and also reported noxious effects of sorbic acid. 2. When nonbacterial pathogens affected our cultures, we cured the larvae by adding 0.15% Fumidil B (Abbot Laboratories), a pharmaceutical marketed by CEVA, Paris, to treat honeybees for *Nosema* infection. 3. Using diets can cause a delay of two to three days before

TABLE 2. Species successfully reared on the simple diet.

Species	Origin
Arctiidae	
"Amsacta" emittens Walker	Sri Lanka
Arctia caja L.	Germany
Ammobiota festiva Hufnagel	Turkey**
Callimorpha principalis Coll.	China**
Creatonotos gangis (L.)	Sumatra, India
Creatonotos transiens (Walker)	Sumatra, Java
Cycnia mendica Cl.	Germany**
Diacrisia sannio L.	Germany
Nyctemera sp.	India*
Ocnogyna joiceyi Talbot	Morocco**
Orodemnias cervini Fallou	Germany**
Paralacydes sp.	Kenya
Pericallia ricini Fabr.	India*
Phragmatobia fuliginosa L.	Germany
Rhodogastria bubo (Walker)	Kenya
Rhodogastria carneola Hampson	Kenya
Rhodogastria luteibarba Hampson	Kenya
Rhodogastria phaedra (Weymer)	Kenya
Rhodogastria thermochroa Hampson	Kenya
Rhodogastria vitrea (Plötz)	Kenya
Rhodogastria n. spp. (4)	Kenya
Spilosoma sp.	Borneo
Spilosoma menthastri Esp.	Germany
Teracotona rhodophaea Walker	Kenya
Utetheisa pulchella L.	India*
Ctenuchiidae	
Pseudonacia sp.	Kenya
Sphingidae	
Manduca sexta L.	America
Noctuidae	
Achaea lienardi Boisd.	Kenya
Autographa gamma L.	Germany
Paradiarsia glareosa Esp.	Germany**
Polymixis serpentina Tr.	Yugoslavia**
Staurophora celsia L.	Germany**
Lymantriidae	
Euproctis lunata Hb.	India*
Olene (Dasychira) mendosa Hb.	India*
Pralis securis Hb.	India*

* M. Eckrich, pers. comm.
** K. Heuberger, pers. comm.

newly hatched larvae begin feeding. 4. Diet is best accepted by neonate larvae, and it is often difficult or impossible to switch from foodplant to diet. 5. Addition of leaf powder to the diet (such as *Taraxacum officinale* for *A. gamma*) caused some neonate larvae to start feeding earlier than on diet lacking plant material, but always increased the mortality of the larvae, and greatly prolonged development. 6. Color might be a cue in food detection and acceptance. Larvae of *Autographa* in a choice experiment preferred diet colored green by chromoxide (compare McGinnis & Kasting 1964). However, this did not result in better rearing success.

DISCUSSION

We succeeded in our primary objective of rearing certain tropical moths whose foodplants are unknown or unavailable, and we found a diet suited to a wide spectrum of species. The diet we report not only enabled us to discover the features of previously unknown larvae, so as to facilitate search for their natural foodplants, but also to obtain adults for breeding and experimental studies.

Existing reports of rearing arctiids on artificial diets include those of Göttel and Philogene (1978) for *Pyrrharctia isabella* (J. E. Smith), Vail et al. (1967) for *Estigmene acrea* (Drury), Singh (1977) for *Hyphantria* sp., Conner et al. (1981) for *Utetheisa ornatrix*, Bathon (1977) for *Spilosoma maculata* Stoll., and Moreau (1965) for *Arctia caja* L. Most of these diets are wheat-based. In contrast, our experience with Arctiidae showed that bean-based diets yield superior results. Apparently, beans have higher nutritive value for lepidopterous larvae than wheatgerm. Bean-based diets may also be easier to prepare, and are less expensive. Salts, vitamins, certain proteins, and other ingredients used by other authors can be omitted from bean-based diets, reducing costs significantly (1 kg of our instant diet costs ca. 7 Deutsch-Marks). In broad comparisons among reports, it must nevertheless be understood that significant differences occur in the quantitave and qualitative composition of nutrients between different species/strains of beans (Schlieper 1982).

Our medium turned out to be similar to the one described for noctuids by Shorey and Hale (1965). We have not compared our results with those of others because not only do the recipes differ, but also the species and rearing conditions—variables often as important as diet composition. Furthermore, due to the lack of natural foodplants for most species, we could not compare cultures on plants with those on diets.

We cannot explain why our diet proved successful for the variety of species tested. Though our results are certainly open to further refinement, we here report our findings as they stand now, and briefly discuss our experience because our instant diet is suited to a variety of unrelated species with different foodplant requirements. Also, in contrast to many other diets, it is easy to prepare, and inexpensive, and thus may help other workers, amateur and professional. Even if it should not prove optimal for mass rearing of a given species, our diet may facilitate culturing of species not otherwise culturable, especially in the field.

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