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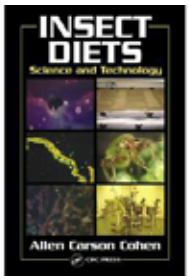

Insect Diets: Science and Technology, Cohen, A.C., 2004, CRC Press, Boca Raton, Florida, USA, 324 p., USD 139.95, ISBN: 0-8493-1577-8.

I suspect that Allen Cohen, author of *Insect Diets: Science and Technology*, never expected that a paleobiologist with an interest in the fossil record and evolutionary biology of plant-insect associations would ever review his book. Yet the title of this 324-page volume piqued an interest, particularly as it is my business to track and understand insect diets in deep time. So, I will provide a review from the point of view of a potential user of the information contained in this volume. My review will stress what will be needed for a second edition, namely, a more eclectic and comprehensive volume of broader interest to evolutionary biologists, paleobiologists, and the diverse strands of the plant-insect associational community. As I see it, a more catholic approach, perhaps combining topics that generated interest in those classics by Balduf (1935, 1939) and Brues (1946), now over 60 years old, would be in order. Perhaps the editors at CRC Press should take heed?

In the preface, Cohen states that *Insect Diets* is a book about artificial insect diets. "The driving force behind this book is the demystification of insect diets as 'black boxes' whose mechanisms and modes of action have been obscured" (p. iii). Cohen ends the preface by "I most hope this book will be a bridge for the caring specialists and their stakeholders to use artificial diets as ever-improving tools to manipulate insects in ways that benefit humanity and our environment" (p. iii). My point here is how do these admirable goals and the data provided therein affect the larger community of entomologists who study insect diets in natural ecosystems, both present and past? How can folks who study natural processes of insect feeding and their patterned effects, particularly on plants, learn from the community of researchers who use artificial insect diets?

Throughout the body of the book, there are gems, interspersed throughout a few chapter sections here and there, and frequently as abbreviated reviews. The most interesting were those chapters that have an application of artificial diets to the natural world. Chapter 1 introduces the broad topics that emerge later in the book. Most of this is reasonably perfunctory, although the distinction between insect dietetics and nutrition was useful in understanding, respectively, the functions of food components versus the practical applications of providing diets. Chapter 2 is more interesting, providing basic definitions, important concepts, and a very brief history of the discipline. Chapter 3 delved into a characterization of insect diets based on how particular ingredients nutritionally serve the insect. These ingredients, namely proteins, lipids, carbohydrates, vitamins, and minerals, play fundamental roles in the efficient functioning of insect metabolism and physiology. This is done through the production of enzymes, cofactors, structural building blocks, neurotransmitters, phagostimulants, and a host of others. The chapter ends with the role that diet additives have in enhancing the palatability and nutritional quality of insect foods. These additives include emulsifiers, stabilizers, antioxidants, antimicrobial agents, flavorings, color additives, and texturizing agents.

Chapter 4 presents a review of research that explains a successful insect diet in terms of feeding stimuli, bioavailability, toxicity, and feeding adaptations, especially mouthpart structure and head-associated sensory structures. In all of this, the connection between insect diets with foods in general (including foods for humans) is constantly made, such as dietary compartmentalization, flavorings, sensory responses, probing by oral and external digestive processes and phagostimulants, the role of solvents in the diet, such visual qualities as color and surface texture, and degradation and shifts to diet inhomogeneity. Case studies involving screwworms, tarnished plant bugs, and others provide examples of these principles. Chapter 5 presents us with the chemistry and physics of insect diets, focusing on the interactions among the major dietary components of food and their role in palatability, including the properties of water, role of pH, the presence of oxygen and its containment by antitoxidants, and diet texture and its role in digestibility and longer-term dietary stability. Chapter 6 involves the manipulation of changes in insect diets and their role in insect colony or individual insect stability. The major point is how to diagnose an insect diet treatment when a colony dies and how to remedy the situation.

By far, the 45 pages of Chapter 7, Insect Feeding Biology and the Logic of Metabolic Systems, was the one I found most interesting. It is a succinct, informative overview on feeding biology, the physiological distinction between liquid versus solid feeding, including various stylet modifications for predation and herbivory, and a general review of mouthpart sensory detection of foods. One criticism that I have is that the author's characterization of mouthpart type (chewing versus sucking) is considerably too coarse and generalized. Subdivisions of each of these—see Labandeira (1997) for the existence of 34 distinct mouthpart types—obscure the roles of food acquisition

within the mandibulate and sucking categories. For example, entomophagous, liquid feeding bugs with styletal apparatuses and nectarivorous butterflies with nonstylate siphons acquire, feed, and process liquid food in very different ways. Additionally, nothing was mentioned of such small-particulate feeders as pollinivores in the terrestrial realm or, more remotely, filterers in the aquatic realm, both of which provide another major way of acquiring food, replete with differing structural modifications and digestive processes from the nominal mandibulate and sucking categories. The chapter ends in a review of the insect digestive system, including digestive structure and function, food degradation and absorption dynamics, and the role of Malpighian glands.

Chapter 8 reviews the environmental factors and biological changes that affect food quality, mostly at microscales and in the lab. Biological changes include fecundity downturns, body weight reduction, and seemingly inevitable population crashes that affect rearing insects on artificial diets. These remedies involve reevaluation of diet components and testing for antinutrients—a concept new to me—that are substances that deter potential consumers. Antinutrients are compartmentalized in plants by temporal or spatial segregation, such as noxious gossypol-laden glands of cotton, a terpenoid that is toxic to a broad spectrum of insect herbivores, and can be targeted or avoided, as appropriate, by insect herbivores. The role of iron in insect diets, evidently of major importance in insect nutrition, closes the chapter. Of increased interest was Chapter 9, which expands on the antinutrient theme to include the importance of such plant secondary compounds as alkaloids, terpenoids, and phenols. Secondary compounds are the most important class of antinutrients for insects, and they either are avoided as toxins or avidly consumed to accumulate in herbivore tissues, where they promote defense, often accompanied by distinctive externally visible warning coloration to signal avoidance by potential predators. The importance of efficiency indices in evaluating the nutritional assimilation of secondary compounds and other substances is discussed at the end.

The remainder of the text, Chapters 10 to 14, provides practical ways for establishing and maintaining artificial diets; how to develop and assemble successful diets; problem solving when diets go wrong; overall quality control; importance of bioassays; the use of appropriate equipment to process diets; and the storing, sterilization, packaging, and compositional control of insect diets. The ways that microbes affect insect diets and their rearing is a useful adjunct to the previous chapters. Gut microbial symbioses, both mutualistic and commensalistic, as well as such distinctive antagonisms as disease and the introduction of deleterious products were presented. The omnipresence of microbial effects in insect diets brought up the issue of worker safety, equipment protection, and the institution of best practices for avoiding biological, mechanical, chemical, and electrical hazards.

I would have expected a more comprehensive, eclectic, and evolutionary approach to Future Prospects for Insect Diets, the title of Chapter 15. This last chapter seems to have extended additional research venues and programs for topics already discussed earlier in the book, rather than to advocate truly new research agendas that would engage a greater portion of the entomological (and paleoentomological) communities. For example, how can insect food science help us understand microevolutionary shifts in host-plant preference or the targeting seen in the modern world? By extension, how can we resolve the analogous macroevolutionary patterns in the fossil record of plant-insect associations? By shifting the focus of future prospects to issues of broader entomological interest, the author could have engaged the interest of researchers outside the immediate field of insect artificial diets. For example, in a recent paper on the origin of pierid butterflies (sulphurs and whites), Wheat and colleagues (2007) suggested an apparent shift of pierid butterflies from legume (Fabales) feeding taxa onto a clade of angiosperm plants, the mustards and relatives (Brassicales), which prominently feature about 16 major lineages with varied types of mustard oils. Evidently this switch was propelled by the origin of a key innovation—the glucosinolate detoxification mechanism—possibly during the Late Cretaceous. But how was this switch nutritionally, digestively, and physiologically mediated? Controlled experiments on artificial diets of appropriate fabalean and brassicalean hosts could offer the solution toward revealing the dynamics of this shift. Gradual or saltatory? If this process occurred by discrete steps, what basal brassicalean clades were likely sequential targets before the derived brassicalean members—Cleomaceae (bee plants and spider flowers), Capparadaceae (capers), and Brassicaceae (true mustards)—were colonized? In the concluding chapter the author cites the major issues advancing artificial insect food nutrition research, namely, refining food technology principles and food matrix analysis, control of microbial contaminants, development of more refined bioassays, assessment of nutrient deficiencies, greater reliance on sophisticated equipment, and advanced nanoanalysis techniques at very small scales. There are other, basic questions that need to be addressed, however, such as the nature of specific, diet-altering mechanisms that cause insects and plants to establish unique patterns of association at geological time scales. Perhaps this is the challenge of the science and technology of insect diets for the 21st century?

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