



THE FOOD INSECTS NEWSLETTER

NOVEMBER 1989

VOLUME II, NO. 3

CHITIN: A Magic Bullet?

Editor's Note: Whole dried insects are about 10 percent chitin, more or less. Although chitin presents problems of digestibility and assimilability in monogastric animals, it and its derivatives, particularly chitosan, possess properties that are of increasing interest in medicine, industry and agriculture. If the time should come when protein concentrates from insects are acceptable and produced on a large scale, the chitin byproduct could be of significant value. At the editor's request Dr. Walter G. Goodman, professor of developmental biology in the Department of Entomology, University of Wisconsin, kindly agreed to prepare a short article for the Newsletter on the characteristics of chitin and some of its potential applications.

What if someone told you that one of the most common biochemicals on this planet was capable of

- significantly reducing serum cholesterol
- acting as a hemostatic agent for tissue repair
- enhancing burn and wound healing
- acting as an anticoagulant
- protecting against certain pathogens in the blood and skin
- serving as a nonallergenic drug carrier
- providing a high tensile strength biodegradable plastic for numerous consumer goods
- enhancing pollutant removal from waste-water effluent
- improving washability and antistatic nature of textiles
- inhibiting growth of pathogenic soil fungi and nematodes
- boosting wheat, barley, oat, and pea yields as much as 20%

Preposterous? Unlikely? Investigators have recently proposed that chitin (see Figure 1a, page 6), a carbohydrate polymer found in invertebrate exoskeletons, protozoa, fungi, and algae is the polymer of the future, with numerous applications to agricultural, biomedical and consumer needs. Its apparent abundance, in combination with its toughness yet biodegradable properties, has made chitin and its derivatives the focus of interest for scientists around the world.

Chitin, an unbranched, poly-B-(14) linked N-acetyl-D-glucosamine, is present in long chains that are often oriented so that adjacent chains are antiparallel. In insects, chitin occurs as a collection of microfibrils approximately 25Å in diameter. These microfibrils form a crystalline array and are ensheathed in a matrix of cross-linking protein. The tissue primarily involved in the synthesis of chitin, the epidermis, is a single layer of cells that secrete the chitin microfibrils so as to form layers

of chitin that are parallel to the upper surface of the cell. As the process continues, the newer layers are secreted in a parallel fashion but the orientation of the fibrils has been slightly rotated. This can be best visualized by placing one hand over the other in a parallel fashion and outstretching the fingers. Keeping the bottom hand in the same plane, rotate it slightly so that looking from the top side the fingers form a grid. As your hands rotate through 180°, note the spatial orientation between the fingers of the upper and lower hands. On a smaller scale, a similar process occurs in the newly secreted layers of fibrils. Thus, micrograph cross-section through the cuticle resembles the end-view of plywood due to the varied orientation of the parallel layers of microfibrils.

Global bioproduction of chitin is enormous and estimated to be greater than 10⁹ tons per year. Such numbers provide the entrepreneurial mind with thoughts of untold quantities of inexpensive, raw product. Yet in a practical sense, the abun-

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dance of exploitable chitin is severely limited. Although insects and fungi have the highest ratio of chitin to body mass, the primary source has been the shellfish industry. Waste products generated from crab and shrimp processors represent a reliable but rather limited source of chitin, thus restricting the use of chitin and its derivatives primarily to high value-in-use utilizations. Moreover, the seasonability of the supply, variability in product quality, and scattered distribution points reduce the attractiveness of chitin as a useful biopolymer. Coupled with these restrictions, chitin is insoluble in both water and most common organic solvents which makes its use in the production of fibers, membranes or agricultural products difficult. Accordingly, considerable emphasis has been placed on the dissolution and restructuring of the matrix and on the formation of soluble chitin derivatives.

One of the most useful derivatives of chitin has been chitosan. This partially deacetylated chitin, discovered in the last century, is produced by boiling chitin in concentrated base. Although chitosan is naturally occurring in certain fungi and green algae, its commercial source remains the shellfish industry. Crab and shrimp exoskeletons are pulverized, then treated with sodium

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A PROGRAM PROFILE:

THE APPLICATION OF INDUSTRIAL TECHNOLOGY FOR PRODUCTION OF INSECTS AS FOOD

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Our objective has been to create industrial technology to mass produce insects, mainly for human food. Although one focus and inspiration has been the need to feed astronauts during extended space voyages, another one is the chronic malnourishment of a large fraction of the earth's human population. A 10% increase in the world supply of animal protein would largely eliminate the malnutrition problem and also decrease the pressure on other protein sources and thereby lower their price and improve their distribution. In

To create the necessary technology we are studying a number of aspects of the problem, e.g.: evaluation of the prices of feedstocks and products and their foreseeable availability and demand; suitability of various converted organisms including their stability and susceptibility to disease as well as opportunities to breed superior races; process flowchart development and process operation schemes; thermodynamic aspects-process heat and mass balances; conversion kinetics and its interaction with reactor design; reactor design itself, process stability and control; unit operations and their performance in the process of various organisms; materials handling; equipment selection and cost; product use and food creation-food science and food engineering; wastes produced and their utilization; overall plant site selection and plant

our investigation we are following a bioengineering approach and we foresee food-grade insect production in industrial plants under closely controlled conditions and on a fairly large scale, e.g., a typical plant would grow 1,000 to 10,000 tonnes/day; a large fraction of the total world demand of 200 million kg/day would be produced in about 100 world-scale plants. We regard conversion from feed into animal tissue as essentially a biochemical reaction best carried out in large industrial complexes to take advantage of economies of scale.

EDITOR'S CORNER

The Ill-fated San Antonio Conference

Modern professional life is too frequently too similar to a series of episodes from "The Perils of Pauline." Take, for example, the San Antonio conference on "Insects as a Food Resource, which was scheduled for December 10 and was announced in the July issue of the Newsletter.

Everything appeared to be set, with the U.S. Agency for International Development planning to provide funding in the amount of \$15,000, which would largely cover the travel expenses of conference participants.

Things began unraveling in early September when the editor, who was also organizer of the conference, was informed by USAID that it would be unable to follow through on the commitment. This abruptly ended a stretch of several successive weeks in which the editor had been thoroughly enjoying life. Unfortunately for the conference, two strong supporters at AID retired in August and another left Washington on a long-term overseas assignment. The conference apparently simply got lost in the bureaucratic shuffle between two fiscal-year budgets and a new group of administrators for whom it had much lower priority.

According to the ESA national office, the anticipated conference had elicited "numerous inquiries and a lot of interest." The editor is currently in diapause insofar as organizing conferences is concerned, but the program scheduled for San Antonio, or an expanded version of it, could be quickly resurrected for another time and place if a sponsor should suddenly appear on the horizon.

GRD

design. Many of these factors are, of course, highly interactive and we have concentrated on the design and assembly of a functioning process that could, in principle, be scaled up to industrial size. To prove the point to skeptics, we have also manufactured insect-based hot dogs (from confused flour beetle larvae) and tested their consumer acceptability in a very limited way.

Our process consists of two major cycles: conversion and propagation. The variables linking these (egg inoculation rate and adult creation rate) are suitable for process control and allow production to be stable for long periods. The process is based on three common industrial unit operations: solids mixing, sifting and air classification. The feed is wheat flour mixed with 5% brewer's yeast; the organism is the confused flour beetle. The process is operated semi-continuously due to the nature of the reactor. The reactor is a "batch-fed plug-flow" type consisting of 140 shallow trays and four functions are carried out in it: feed conditioning, feed conversion, dormant stage incubation (several stages) and organisms propagation. During several experiments the process was operated continually for up to half a year and produced enough larvae to make one hot dog per day.

We are presently working on three major ways to improve our process:

1. So far, the process has been operated manually, i.e., all the materials handling was done by graduate students; in the next version (under construction) this will be automated, partially with robotics and partially with pneumatic transport
2. The reactor is cumbersome to operate and difficult to automate--a new reactor is being constructed (tower reactor-less floor space, use of gravity for materials flow); it will consist of aerated, packed beds rather than shallow trays and will be operated pneumatically; it will contain 20 times as much material as the old one and produce more than 20 times as much larvae to allow some more product research, e.g., animal feeding studies on a long-term basis.

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THE IDENTITY OF GRASSHOPPERS USED AS FOOD BY NATIVE AMERICAN TRIBES

Prior to the arrival of European influence, grasshoppers were an important item among the insect foods of existing cultures in western North America. This is not surprising as there are several hundred species, and some of them have a tendency, if unchecked, to frequently reach plague proportions. So, they were often available in abundance. There are at least 60 or 70 papers, mostly in the anthropological literature, that report consumption of grasshoppers (or "locusts") by cultures north of Mexico. Nearly all of the reported use was in western North America; there are few reports from east of the Mississippi River.

Taxonomists place North American grasshoppers in about eight families (Otte 1981, 1984, and others), but the one best known to the most people is the family Acrididae, the shorthorned grasshoppers. These are allotted to one or another of several subfamilies. With hundreds of species to choose from, and numerous reports of grasshopper consumption, one might expect to compile a lengthy list of the species known to have been consumed. Not so. Here again we run into the familiar difficulties caused by the low estate in which insect consumption has been held by the European-derived mind. The same ethnographic, ethnohistorical, and archaeological reports that often went into great taxonomic detail about the plants and vertebrate animals encountered were much less precise when it came to insects, being satisfied with such taxonomic precision as "locusts", "crickets", "ants", "caterpillars", etc.

gists. There are great difficulties attendant to studies aimed at elucidating what happened in earlier times (see Sutton 1988 for a discussion). And, besides, while anthropologists are always very precise about the tribal identities and relationships of the cultures they study, Essig listed his eight species of grasshoppers as being consumed by "California Indians." The eight species are tabulated below:

Family Acrididae

Subfamily Oedipodinae

Camnula pellucida Scudder, Clear-winged grasshopper

Subfamily Catantopinae¹

Melanoplus bivittatus (Say), Two-striped grasshopper
Melanoplus devastator Scudder, Devastating grasshopper
Melanoplus differentialis (Thomas), Differential grasshopper
Melanoplus femurrubrum (DeGeer), Red-legged grasshopper
Melanoplus sanguinipes (Fabr.), Lesser migratory grasshopper
Oedaloenotus enigma (Scudder), Valley grasshopper

Subfamily Crytacanthacridinae

Schistocerca shoshone Thomas³, Large green valley grasshopper

1. Species assigned to the subfamily name Catantopinae above will apparently be assigned to the subfamily name Milanopinae in the 3rd volume of Otte's *The North American Grasshoppers* when it appears (see Otte 1981).

<p>In fact only four authors from among those 60-70 papers provide any information on the specific identity of the grasshoppers consumed. The "mother lode" is Essig (1931). In mentioning that Essig was an entomologist, I do not mean to be critical of the level of insect taxonomy practiced by anthropolo-</p>	<p>2. Reported as <i>Melanoplus atlanis</i> (Riley) by Essig. 3. Reported as <i>Schistocerca venusta</i> Scudder by Essig, which is probably synonymous with <i>S. shoshone</i> according to Strohecker et al (1968).</p> <p style="text-align: center;">SEE GRASSHOPPERS, p. 5</p>
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<p>Two Easy Grasshopper Recipes-</p>	
<p>An article caught our eye recently in the Newsletter of the Department of Entomology, University of Minnesota (April 20,1989). Titled "Fried Cow or Fried Locust-What's the Diff ?", and authored by The Creeping Gourmet, it presented two recipes that are so quick and simple that we thought we should pass them along. As acknowledged by Gourmet, they first appeared in Ronald Taylor's book, <i>Butterflies in My Stomach, or Insects in Human Nutrition</i> (1975, Woodbridge Press, Santa Barbara, Calif., pp.107-108).</p>	
<p>Fried Locusts</p> <ol style="list-style-type: none"> pluck off the wings and legs (heads optional) sprinkle with salt pepper, and chopped parsley fry in butter add a dash of vinegar and serve 	<p>Grasshopper Fritters</p> <ol style="list-style-type: none"> pluck off wings and legs (heads optional) dip insects in egg batter and deep fry salt and serve
<p>Although grasshoppers were used extensively as food by Native American tribes in western North America, little is known about which species were preferred---if there was any preference. One way of harvesting the insects was for a number of people to form a large circle around a bed of coals and then drive the hoppers toward the bed of coals, where, hopefully, some would land and be roasted. As there are usually several species of range grasshoppers present at any one time and location, probably any roasted hopper was a good hopper (see above article).</p>	

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<p>Recent Technical Papers</p>	
<p>Kodondi, K.K.; Leclercq, M.; Gaudin-Harding, F. 1987. Vitamin estimations of three edible species of Attacidae caterpillars from Zaire. <i>Internat. J. Vit. Nutr. Res.</i> 57:333-334. Faculte de Pharmacie, Laboratoire de Biochimie, Chatenay Malabry, France.</p>	<p>needed (protein efficiency ratio, true digestibility, etc.), and concludes that because <i>A. venata</i> is univoltine and its host plant (an important timber species) is fast disappearing, mass-rearing would be necessary to enhance its value as a supplementary protein source in rural areas.</p> <p>Luo, Ke. 1989. The status of studies on feed insects in China. <i>Kunchong Zhishi</i> 26(2):118-120. [In Chinese.] Dept of Plant Protection, Beijing Agricultural University.</p>
<p>Among the edible caterpillars in Zaire, those of the giant silk moths (Family Attacidae (or Saturniidae) are the most generally appreciated. Three species, <i>Nudaurelia oyemensis</i>, <i>Imbrasia truncata</i> and <i>Imbrasia epimethea</i>, prepared by the traditional techniques (smoking and drying), were analyzed for vitamins, the results of which are shown in a table. The authors state that values for riboflavin (vitamin B2,) and niacin are high while thiamin (B1) and pyridoxine (B6) are low in comparison with U.S. National Academy of Sciences - National Research Council nutrient requirements (1972). Feeding trials of 4 weeks' duration using 21-day-old Wistar C.F. rats confirmed that, except for thiamin and pyridoxine, the vitamins supplied by the caterpillars are sufficient to allow proper growth of young rats. There have been previous analyses of vitamins in African saturniid caterpillars but this appears to be the first study involving animal trials.</p>	<p>The author summarizes the results of numerous research papers published in China since 1980 on the nutritive value of insects, primarily three species, as feed for poultry, fish, pigs and farm grown mink. The three species are <i>Musca domestica</i> (larvae and pupae), the silk worm, <i>Bombyx mori</i> (pupae), and the yellow meal worm, <i>Tenebrio molitor</i> (larvae). Data on proximate analyses, calcium and phosphorus content of the three insects are presented in a table and compared to earthworm meal and two conventional high-protein feeds, fish meal and bean cake.</p> <p>In at least the majority of the feeding trials reported, experimental diets involved substitution of insect meal for equivalent weights of fish meal, either all or part of it. There is no mention of whether diets were kept isonitrogenous and isocaloric within experiments.</p>
<p>Ashiru, M.O. 1988. The food value of the larvae of <i>Anaphe venata</i> Butler (Lepidoptera: Notodontidae). <i>Ecol Food Nutr.</i> 22:313-320. Forestry Research Institute of Nigeria, Ibadan, Nigeria.</p>	<p>In all of eight reports on laying hens, hens fed fly meal-containing diets fared as well or better than those fed fish meal diets as measured by egg production, egg quality, and feed costs. In one test on pigs fed fly larval diet, the pigs showed increased growth and reduced cost per pound of meat produced. In two reports on first-year grass carp, fish fed fly meal showed increased weight gains and protein efficiency and reduced cost per pound of fish produced.</p>
<p>Interviews with 35 people in widely separated localities of Nigeria revealed that 80% of them were aware that the larvae of <i>Anaphe venata</i> are edible and 69% had either eaten the larvae or had household members who had eaten them. The larvae are prepared by roasting them in hot dry white sand. Forty-six percent of the people interviewed attributed the reduced availability of the larvae in recent years to the logging of the host tree <i>Triplochiton scleroxylon</i>. Dr. Ashiru considers it noteworthy that more than 20 years after a 1963 survey by J.C. Ene, there is no appreciable reduction in people's awareness and actual involvement in entomophagy, although he cautions that this finding might be somewhat biased by the lower average educational level of those interviewed in the present survey. Insect larvae are eaten mainly by the peasants in the rural areas rather than by the educated and urbanized population.</p>	<p>In one report on silkworm pupal meal fed to chicks, weight gains of chicks fed the pupal meal were slightly lower than those fed fish meal, but the cost per pound of meat produced was reduced because the price of pupae is only half that of an equivalent amount of fish meal. In two reports, silkworm pupae were an excellent protein source for commercially reared mink, resulting in improved lustre and quality of fur. Silkworm pupae produced increased weight gains in pigs but also resulted in an odor problem in the meat. The problem was eliminated by removing pupae from the diet one month before slaughter. Chemical methods also show progress in eliminating the offending odor from silkworm pupae.</p>
<p>Results of proximate, amino acid and mineral analyses, and calorific value, are presented in a series of data tables. Proximate analysis of dried, seventh-instar field-collected larvae from which the long setae had been removed by passing over a flame was as follows: moisture 6.61 %, crude protein (N x 25) 60.003%, fat 23.22%, ash 3.21 %. Calorific value,</p>	<p>SEE RECENT TECHNICAL PAPERS, p. 6 p. 6</p>

determined by a ballistic bomb calorimeter, was 6.113 kcal/g. The author notes that more sophisticated studies of the protein quality are

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Abundance is an important factor in determining the choices of food by hunter/gatherer societies (Dufour 1987, and others). The *Melanoplus* species listed above, with the exception of *M. devastator* which is limited to the Pacific Coast states and Nevada, are all widely distributed in North America, are abundant, and destructive to vegetation (Capinera and Sechrist 1982, and others). Three of them are among the four species considered by Henderson (1944) to have been historically of the greatest economic importance to agriculture in Utah, listed in descending order of importance: *Melanoplus sanguinipes* (= *M. mexicanus mexicanus* (Saussure)), *M. packardii* Scudder, *M. bivittatus*, and *M. femurrubrum*. Henderson mentions specifically only three other species for their damage in Utah and they happen to be three more of the species reported by Essig as food: *M. differentialis*, *O. oedalonotus*, and *C. pellucida*.

Others who have provided information on the specific identity of grasshoppers used as food include Ebeling (1986:157) who states that *M. femurrubrum*, *M. devastator*, and *Arphia pseudonietana* (Thomas) (the latter belongs to the subfamily Oedipodinae and brings the total of reported species to nine) were probably eaten in the Owens Valley; Madsen and Kirkman (1988) who reported large-scale use of *M. sanguinipes* in Utah, and Sutton (1988) who has attempted to identify the species most likely used on the basis of their abundance and ecology.

Western tribes used a variety of methods for harvesting grasshoppers. One of the better accounts is that of Chittenden and Richardson (1905, III, pp. 132-33) pertaining to the Soshocos:

They begin by digging a hole, ten or twelve feet in diameter by four or five deep; then, armed with long branches of artemisia, they surround a field of four or five acres, more or less, according to the number of persons who are engaged in it. They stand about twenty feet apart, and their whole work is to beat the ground, so as to frighten up the grasshoppers and make them bound forward. They chase them toward the centre by degrees-- that is, into the hole prepared for their reception.

Their number is so considerable that frequently three or four acres furnish sufficient grasshoppers to fill the reservoir or hole.

The basic procedure described by Chittenden and Richardson appears to have been widely used as a number of early writers have described incorporated it similarly, or variations on it. Sometimes fire was heated, as described by Dixon (1905, pp. 183-84, 190) for the Northern Maidu in the lower Sierra region:

Grasshoppers and locusts were eaten eagerly when they were to be had. The usual method of gathering them was to dig a large shallow pit in some meadow or flat, and then, by setting fire to the grass on all sides, to drive the insects into the pit. Their wings being burned off by the flames, they were helpless, and were thus collected by the bushel. They were then dried as they were. Thus prepared, they were kept for winter food, and were eaten either dry and uncooked or slightly roasted.

A variation of the above methods was related to Essig (1931) by a relative of his who lived in the Sacramento Valley in the early 1850s: "The method then used in that place was to build a large fire which was reduced to a bed of coals. The Indians then formed a large circle and drove the grasshoppers into the coals where they were soon roasted, removed and eaten at once or preserved for the future." Aginsky (1943) reported several methods of grasshopper collection used by the Central Sierra Indians, one of which was simply to burn over the ground and pick them up. Non-firing methods included picking the grasshoppers from the grass and bushes early in the morning before they became active (Downs 1966, p. 35) and fortuitous collecting of grasshoppers that washed up in windrows along the shores of saline lakes (Madsen and Kirkman 1988, and others).

Although only nine species have apparently been reported specifically as food, when one considers the harvest methods used by the Indians, there can be little doubt that dozens of additional species were consumed. Ordinarily, at any given time and place, if grasshoppers are active there is a mixture of species present. For example, the range grasshopper complex at five sites in the shortgrass prairie of southeastern Wyoming was found to be comprised of 16-18 species at each site (Pfadt 1977). For another example, to procure grasshoppers for proximate and mineral analysis, the author and Dr. J.B. Campbell of the University of Nebraska spent several days in August, 1979, sweep-netting in a field near North Platte in western Nebraska and netted a total of 16 species representing 11 genera. If we had tried to drive these hoppers onto a hot bed of coals, I am sure that mixed among our *Melanoplus sanguinipes*, etc., there would have been some *Melanoplus packardii* Scudder, some *Melanoplus foedus* (Scudder), some *Aulocara*, some of the huge wingless *Boopedon* females, some *Dissosteira*, etc., etc., etc. Except for a few aposematic species which might not taste good, the early anthropologists probably had the right idea - a grasshopper is a grasshopper when it comes to eating them.

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hydroxide to solubilize the protein matrix surrounding the microfibrils and to dissolve residual cellular debris adhering to the carapace. The flakes are then washed and demineralized with hydrochloric acid. Crustacean exoskeleton, in contrast to that of most insects, contains calcium, as much as 20%, and this must be removed to yield pure chitin. The purified chitin is then deacetylated by treatment in concentrated sodium hydroxide to produce chitosan (see Figure 1b, page 6). Unfortunately, bulk production of chitin and chitosan in this manner leads to chain breakage and unpredictable alteration of the component sugars. Improved methods are now available that eliminate these problems.

In contrast to chitin, chitosan is soluble in dilute acidic solutions and is the major outlet for chitinous products. Once in solution, it can then be fabricated into gels, films, and powders and then modified by various chemical processes including acylation, aldimination, carboxymethylation, phosphorylation and sulfation to form the desired products.

ent and oxygen permeable. These properties make chitosan-based soft contact lenses potentially useful for extended wear. Limited studies have now demonstrated that chitosan can ameliorate dermatitis in monkeys and humans and can stimulate in a nonspecific manner the immune system of rodents. Sulfated N-carboxymethyl derivatives of chitosan have been demonstrated to block blood clotting *in vitro*. This is not surprising considering that the potent anticoagulant, heparin, is a highly sulfated polysaccharide with a chemical structure not unlike that of the derivatized chitosan.

Chitin and its derivatives have been used in a number of ways. Historically, chitin was first used in wound healing. Koreans have long used the pen of an octopus as a source of chitin for the treatment of abrasions, while Mexicans have used mushrooms with their chitosanaceous cell walls to accelerate laceration wound healing. Advances in biotechnology have capitalized on these observations to provide potentially new approaches to medical problems. For example, chitosan has been used experimentally in the treatment of burns because it forms a tough, water-absorbent, biocompatible film that prevents bacterial invasion. This film can be applied directly to the burn by application of an aqueous solution of chitosan acetate. Since the underivatized chitosan is slowly degraded by the enzyme lysozyme, periodic removal of the film is unnecessary. The treatment of grafting material used to stop life-threatening vascular bleeding with chitosan has also yielded promising results. Hemostatic graft material was treated with chitosan acetate and applied to experimentally induced vascular wounds. Chitosan-treated grafts performed as well as the routinely used blood-treated grafts. In some whole animal studies, chitosan-treated grafts inhibited fibroplasia and stimulated the regeneration of normal tissue elements.

Bioerosion of chitin derivatives offers new approaches to controlled delivery of drugs. For instance, if therapeutic agents are required on a long-term basis, a single implantation of capsules containing the agent admixed with the chitin derivative could serve as gradual release sites. As enzymes hydrolyze the matrix, the drug is slowly released. Another potential use for chitin derivatives is in the production of contact lenses. A lens composed of chitosan derivatives offers the attractive properties of being tough, highly moldable, transparent, water absorb-

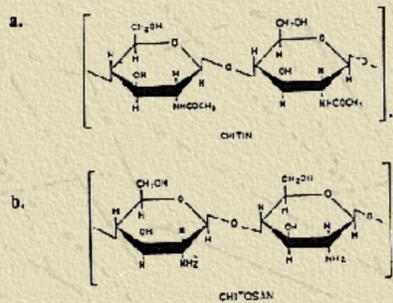


Figure 1: Structure of chitin and one of its derivatives, chitosan. Both compounds are polymers of varying lengths.

In a cholesterol conscious society, the discovery of low toxicity drugs that lower serum cholesterol levels is welcome. Although eating raw insects won't change your serum cholesterol levels significantly, the use of certain chitin derivatives may. A number of studies have demonstrated that rats fed a diet containing 2-5% chitosan can substantially reduce serum cholesterol with few side effects. Chitosans are thought to: (1) bind bile acid and/or cholesterol in the intestinal lumen, thus reducing uptake, and (2) stimulate excretion by interfering with the absorption process. Thus, an inexpensive, nonnutritive agent such as chitosan, capable of inducing hypocholesterolemic activity should be competitive with the more expensive drugs such as cholestyramine.

From an industrial viewpoint, the interaction of chitin derivatives with various toxic metals provides a means of removing pollutants from industrial waste water. Interestingly, derivatives of cellulose, normally used for such purposes, have significantly less capacity for ion binding than does the chitin derivative. On the other hand, the hydrophobic nature of the fibrils makes them less likely to swell, thus permitting high throughput of aqueous waste effluent.

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The extensive use of non-biodegradable plastic in modern societies has generated a waste disposal crisis as well as problems for marine organisms. This point is underscored by the estimate that 30% of the world's ocean fish have tiny pieces of plastic in their stomachs that interfere with digestion. Much of the environmental damage attributable to plastics is caused by precisely those characteristics for which they were developed, namely, their durability over products constructed from natural materials. As noted earlier, chitin derivatives can be cast into filaments and films of high tensile strength owing to their extensive hydrogen bonding in three dimensions. This degree of cross-linking makes them much stronger than cellulose. Despite its strength, materials derived from chitosan can be rapidly degraded by soil or marine microorganisms. Indeed, when chitosan films constructed of the appropriate chainlength were incubated in cold ocean waters, complete decay was observed within a month. Although chitosan represents a promising approach to the problem of biodegradability, the limited supplies of raw product cannot begin to supply the voracious demand for plastics. Until massive sources of chitin become readily available, dependence upon petrochemically-derived polymers remains the reality.

The use of chitin-based derivatives is most widespread in agricultural applications. One west coast company offers chitosan as a seed treatment for the control of nematodes and fungi in wheat, barley, oats and peas. The mechanism by which chitosan suppresses fungi and nematodes is uncertain although several hypotheses have been presented. Unfortunately, the amount of chitosan required to effect a general reduction in soil pathogens is enormous and the nematocidal levels of chitin may be phytotoxic. Added to this

Bade, M.L.; Wick, R.L. 1988. Protecting crops and wildlife with chitin and chitosan. In *Biologically Active Natural Products*, edited by H.G. Cutler, American Chemical Society, Washington, D.C. pp. 450-468.

Hepburn, H.R. 1976. *The Insect Integument*, Elsevier Scientific, Amsterdam.

Kramer, K.J.; Dziadik-Turner, C.; and Koga, D. 1985. Chitin metabolism in insects. In *Comprehensive Insect Physiology, Biochemistry and Pharmacology*, Pergamon Press, Oxford. pp. 75-115.

Muzzarelli, R.; Jeuniaux, C.; Gooday, G.W. 1986. *Chitin in Nature and Technology*, Plenum Press, N.Y.

Neville, A.C. 1975. *Biology of the Arthropod Cuticle*, Springer-Verlag, N.Y.

Zikakis, J.P. 1984. *Chitin, Chitosan, and Related Enzymes*, Academic Press, N.Y.

Directory Again Delayed - -

As of November 1 only about 75 individuals (less than 20% of the *Newsletter* mailing list) had responded to the query in the July *Newsletter* regarding Directory listing. More than 90% of those responding so far have checked "yes" regarding Directory listing (see Address Form, page 9), while less than 10% have checked "no." Responses are still dribbling in at the rate of 6-7 per week, so we have again postponed printing of the Directory. As a reward for promptness, however, those who have responded are being sent, under separate cover, a computer printout of Directory listees as of November 1, 1989. This policy will continue when the printed Directory is distributed, it will be sent only to those who have responded "yes" or "no" regarding Directory listing.

is the problem of variability between chitosan preparations. The source of chitin seems to play an unknown role in the effectiveness as a fungicide or nematocide. Although full-scale agricultural application of chitin-based derivatives is unlikely in the near future, this does not dampen the outlook for utilization of chitin in agriculture. For example, in areas where large-scale insect outbreaks occur, insect bodies might be used as a source of fertilizer as well as a source of chitin. Better methods may be forthcoming in reducing the variability in chitosan preparation and specific fractions of chitosan may be identified as to the active ingredient.

With the many possibilities that chitin-based products offer given the means of mass production and genetic engineering, the future of this biopolymer is bright. For further information about chitin, chitosan, and the many derivatives, see below:



Research Request Department: If someone has an English translation of the long (158 pp.) paper in German by Helmut Reim, 1962, *Die Insektennahrung der Australischen Ureinwohner*, Berlin, Akademie-Verlag, I will gladly pay a reasonable price for a copy. Gene DeFoliart, 545 Russell Laboratories, University of Wisconsin, Madison, WI 53706, USA.

GRASSHOPPERS

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For the backpacker headed for the higher elevations between late June and late August in the western or northern United States or southern Canada, the clear-winged grasshopper, *Camnula pellucida*, is the snack to watch for - According to Essig it is the most abundant species in the high mountain meadows throughout California, and according to Capinera and Sechrist it is common at higher elevations in Colorado. For the more sedentary citizen almost anywhere in the United States, the *Melanoplus* species, *bivattatus*, *differentialis*, *femurrubrum*, and *sanguinipes* frequently move into the suburbs in sufficient numbers to give them pest status, and it is increasingly agreed that biocontrol in the form of predators is preferable to insecticides in the garden. See the recipes on page 3 for how to fix them if you can catch them.

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Edible insects must be gaining in prestige...

Baskets of edible insects are not an unusual sight in the markets of the tropical world. But Dr. Ralph Bram, USDA, Beltsville, MD, who has seen, for example, baskets of the giant water-bug (Belostomatidae) for sale in the Sunday market of Bangkok, wrote recently to say that he had encountered baskets of edible insects in a most unexpected place--Zurich, Switzerland! They were adult beetles. And one more surprise - they were not dipped in chocolate! We would like to carry this suspense further, but to be truthful, the beetles were made entirely of chocolate. Although not versed in European beetle taxonomy, from the documentary colored photograph sent by Dr. Bram, the editor guesses them to be the European chafer or Maybeetle, *Melolontha melolontha*, and they look authentic enough, right down to the details of the tarsal segments, to run easily through a taxonomic key.

We are not sure what this portends for the future of edible insects in Europe and North America, but if chocolate candies are now being shaped to look like real insects, instead of real insects being disguised by dipping them in chocolate, progress is surely being made.

RECENT TECHNICAL PAPERS

from page four

In one report on meal worms fed to chicks, growth and feed/gain ratios were improved compared to chicks fed fish meal. One investigator reports rearing 0.5 kg of meal worms in 1.25 kg of wheat bran at a cost of Chinese ¥ 0.20 (or about U.S. 5 cents).

A number of additional tests involved other insects or animals but none as extensively as those mentioned above. From this paper it is evident that there has been a considerable amount of research on insects as animal feed during the past decade in China.

[Editor's note: Appreciation is expressed to Mr. Shaohua Liu, a pre-doctoral student in the UW Department of Entomology, for providing a translation of this paper.]

Acknowledgement: This issue of *The Food Insects Newsletter* was produced by an all-volunteer team: Catherine Howley (commutes from Milwaukee); Joyce Keesy (commutes from Rockford, Illinois); and Dr. Christine Merritt, UW Department of Entomology.

1989 Sustaining Patrons

The individuals listed below contributed \$5.00 or more to help cover the costs of printing and distributing The Food Insects Newsletter during the past year. We wish to express our thanks.

Dr. Ralph A. Brain (Bethesda, Maryland)	Dr. Stephen V. Landry (Moscow, Idaho)
Robert Collins (Meruchen, New Jersey)	Dr. Karl Maramorosch (New Brunswick, New Jersey)
Patricia Conway (Milwaukee, Wisconsin)	Linda R. (Anzelmo) McElreath (Bethesda, Maryland)
Michael Coventry (Kaleen, Australia)	Dr. James W. Mertins (Ames, Iowa)
Dr. J. Richard Gorham (Washington, D.C.)	Dr. Katharine Milton (Berkeley, California)
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Roberto Hernandez (San Salvador, El Salvador)	Don Pack (Williamsport, Kentucky)
Dr. E. Jane Homan (Madison, Wisconsin)	Dr. David Pimentel (Ithaca, New York)
Alan Kaplan (Berkeley, California)	Dr. Philip J. Scholl (San Antonio, Texas)
Bennett Kaufmann (Silver Springs, Maryland)	Sonoran Arthropod Studies, Inc. [Steve Prchal](Tucson, AZ)
Dr. Marc J. Klowden (Moscow, Idaho)	Dr. Michael Weissmann (Boulder, Colorado)
Robert Kok (St. Anne de Bellevue, Quebec, Canada)	Diana Young (Bangor, Maine)

Program Profile from page two

3. The present major feedstock is wheat flour--we will attempt to formulate an (organism)/(cellulose-based feedstock) system which meets all the process and product requirements and which has adequate kinetic performance.

About 30 years ago microbiologists and engineers founded several sub-disciplines, industrial microbiology and biochemical engineering, which both dealt with fermentation in rather different ways. Their interaction has been extremely fruitful and in more recent years their sub-disciplines have grown closer together into the rather successful field of "biotechnology" which is now the academic focus of a multi-billion dollar industry. Presently, entomologists and engineers are both looking at the industrialization of insect production in a very similar way that the use of microorganisms was being investigated 30 years ago. I think that, again, fruitful cooperation between two

disciplines is not only possible but highly desirable and that it will lead to major industrial innovations. Above, I have attempted to present the engineering point of view in a limited way because if two disciplines are to cooperate they must understand each other's jargon to at least a certain extent. To get entotechnology on its way, the production of insects for food and feed is probably as good a place to start as any; as the technology is developed many other uses will surface.

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