23 November 1956, Volume 124, Number 3230 SCIENCE

Current Status of Insect Control by Radiation

Charles C. Hassett

The losses occasioned by insect pests in stored products amount to well over a billion dollars a year in the United States alone. Losses occur in stored grains before processing, in packaged food products, in clothing and other textiles, and in lumber and wooden articles. Control of the insects responsible for these losses is a large-scale problem, and tremendous savings could be achieved by the development of methods more effective than those currently in use.

The best methods of insect control today depend on the use of various chemical agents, most of which have been developed in recent years. These insecticides have been sensationally successful in use against the pests that affect standing crops and stored unprocessed grains. Toxic chemicals cannot, however, be applied to foods and clothing, or to other finished products that must undergo storage, during which the attacks of insects are costly. This has led to the consideration of various forms of radiant energy for the protection of stored products.

Controls Other Than Chemical

There are several forms of radiation that can be used to kill insects, each having its own characteristics, advantages, and disadvantages. A number of investigators have tested the effects of sound waves above the audible range, especially between 50,000 and 100,000 cycles per second, and have found that they are destructive to living organisms. It is not certain, however, that the apparatus for producing such frequencies is adaptable to large-scale treatment of material containing insects. A more promising form of energy is found in high-frequency radio waves which cause what is known as dielectric heating in nonconducting bodies. Soderholm (*1*) has reported the use of this method on rice weevils and on the pink bollworm. The apparatus used produced electric fields with alternating frequencies of 40 megacycles per second. This raised the temperatures of the material in the field and killed the insects. The heating was not high enough to damage the grain or cottonseed that surrounded the insects. The weevils were killed by 1-second exposure, the bollworms after 14 to 29 seconds in the field.

Frings (*2*) reported success in killing several common insects by the same method in laboratory trials. Baker, Wiant, and Taboada (*3*) have applied radio frequencies of 2450 megacycles per second to grain containing *Tribolium confusum* and *Sitophilus granarius*. This test, like the others, was done on a small scale, but the authors, by combining their data with those of Schaefer and Schwan (*4*) were able to calculate the over-all costs of using dielectric heating at $2.60 per ton of grain processed. All three of these tests were performed with commercial equipment which could be developed into a practical means of treating moderately large quantities of material. The use of radio-frequency heating would seem to be potentially useful for insect control under some conditions, although it is doubtful that it can be used on a very large scale. Neither can it be used on heat-sensitive materials.

New Sources of Radiation

Recent developments in physics have produced several new sources of radiation, some of which seem certain to be applicable to insect control. All derive either from some type of particle accelerator or from the radioactive decay of various elements.

Particle accelerators produce beams of subatomic particles traveling at extremely high speeds. The particles may be electrons, protons, or other kinds of atomic fragments. Only electron accelerators are of interest for insect control, because the others are far too costly and elaborate. The Van de Graaff electrostatic generator and other models of electron accelerators are in common use and are not unduly costly. All electron radiation, however, is limited to relatively thin layers of material or to surface irradiation of thick objects. Electrons penetrate only a few millimeters of most substances, which limits their use considerably, but this disadvantage is balanced somewhat by the relatively light shielding required to protect personnel. Another advantage is that, unlike radioactive radiation, the electron beam can be shut off when it is not wanted, which makes for safer and more convenient operation. All such apparatus is, however, subject to failure of tubes or other parts, which may be costly.

Radioactive elements, often referred to as radioisotopes, offer another, and very useful, source of radiation. There are already in use a number of cobalt-60 units of high intensity, rated in thousands of curies. Cobalt-60 emits strong gamma rays, which, like x-rays, penetrate deeply. Much larger objects can be treated with a gamma source than is possible with any type of electron machine. Heavy shielding must be provided to protect personnel from the effects of this radiation.

The operation of nuclear reactors, or piles, results in the accumulation of very large quantities of radioactive elements of various intensities and with differing decay periods. The safe disposal of these wastes is at present a serious problem, and means are being sought to develop practical ways of concentrating, separating, and applying to use those radioisotopes which possess the proper characteristics. Both gamma and beta (electron) radiation can be extracted from

Dr. Hassett is a member of the physiology division, Directorate of Medical Research, Army Chemical Center, Maryland.

these wastes, or, if desired, the crude waste need only be concentrated and the total radiation used. Still another source of radiation from the uranium reactor has been suggested: this is the use of spent fuel rods from the pile. Any of these sources of radiation, which are now largely useless, could be fabricated into units of suitable size and intensity to furnish radiation for processing large quantities of products of many kinds.

Costs of Control by Radiation

Are the devices described here practical solutions to the problem of killing insects that infest large quantities of food and other packaged products? The answer to this question lies in measuring the amount of radiation that is necessary to kill the insects and in the cost of the equipment and the operating expenses. Baker *et al.* (*3*) calculated that the cost of doing the work by dielectric heating was reasonable. Costs have been estimated for the various other types of radiation treatments. Measurements of the lethal dose by gamma radiation and the dose necessary to prevent reproduction have been made by Hassett and Jenkins (*5*) in experiments at Brookhaven National Laboratory. It was found that a variety of the common pests of stored products, including the carpet beetle, cigarette beetle, rice weevil, powder-post beetle, and others, can be killed rapidly by doses of 65,000 roentgens and rendered incapable of reproducing by 16,000 roentgens. These doses could be delivered by irradiation units using any of the wastes described in the preceding paragraph. Their results were confirmed later by Proctor *et al.* (*6*) on the same insects, with the exception of the powder-post beetle.

Table 1. Estimates of capacity and cost for facilities designed to treat stored products. Some values recalculated for uniformity. Cost estimates include construction and operation.

Reference	Energy source	Capacity	Cost/ton
3	Dielectric heat	1000 lbs/hr	$ 2.60
6	Electron accelerator	2 tons/hr	20.40
8	Cobalt-60	1260 lbs/hr	10.00
9	Spent fuel rods	27 tons/hr	0.75
8	Cesium-137	8 tons/hr	2.53
	Mixed fission products	8 tons/hr	3.23
	Spent fuel rods	8 tons/hr	2.45
	Spent fuel rods	27 tons/hr	0.94

At present there are no cost estimates based on actual operation of equipment for destruction of insects. There are, however, several studies that include cost estimates for this or similar purposes (Table 1). In the Stanford Research Institute report to the U.S. Atomic Energy Commission (*7*), it was estimated that, as soon as an efficient process could be evolved for separating useful istotopes (for example, cesium-137) from bulk fission waste, there would be an economically feasible use for it in sterilizing penicillin.

In 1955, the Brookhaven National Laboratory held a conference to consider the development of methods for prestorage irradiation of potatoes. A dose of 20,000 roentgens has been found to prevent sprouting of stored potatoes, thus extending the safe period of storage considerably. Both electron and gamma-ray irradiation were considered practical. Detailed plans were presented for the irradiation of large quantities of potatoes by both methods. Electron accelerators now on the market need only be adapted to a specific use by adjustment of the beam size and intensity, with provision for material-handling equipment such as conveyors. Proctor *et al.* (*6*), basing their estimate on the use of such an electron accelerator, consider that material can be processed at a reasonable cost (Table 1).

No commercial gamma irradiation units are now operating, but Otto Kuhl, of the Brookhaven National Laboratory, presented plans of a pilot model usable for potatoes or other products (*8*). This consists of a truck and trailer, carrying a cobalt-60 irradiation unit, with accessory conveyor belts and the necessary shielding, to process 15 tons per day (24 hours) at a cost of $10 per ton (5¢ per pound). This includes all costs, amortizing the original cost over 5 years.

The Fission Products Laboratory, University of Michigan (*8, 9*), presented plans for a unit to operate on either cesium-137 or mixed fission products, or even on spent reactor fuel elements. The facility could be fixed or could be built into a railroad boxcar. This unit would process 6400 bushels per day at a cost of 6¢ to 8¢ per bushel, or $2.50 per ton.

All these facilities, whether or not specifically designed for the destruction of insects, could be used to process a wide variety of food products, clothing, or wooden objects. If such material were wrapped in insectproof covers before processing, any existing insects would be killed and no reinfestation could occur. It has been shown by a number of studies that the doses required would have no effect on the taste and vitamin content of foods (*6, 8–10*), and there would be, of course, no residue of any kind, for these radiations do not induce radioactivity. Radiant energy can, therefore, provide a safe, nondestructive, means of ridding many stored products of insect pests.

References and Notes

1. L. H. Soderholm, unpublished report presented at meeting of American Society of Agricultural Engineers, Chicago, 1952.
2. H. Frings, *J. Econ. Entomol.* 45, 396 (1952).
3. V. Baker *et al., J. Econ. Entomol.* 49, 33 (1956).
4. H. Schaefer and H. Schwan, *Ann. Physik* 43, Nos. 1, 2 (1943).
5. C. C. Hassett and D. W. Jenkins, *Nucleonics* 10, No. 12, 42 (1952).
6. B. E. Proctor *et al., Food Technol.* 8, 536 (1954).
7. Stanford Research Institute, *Report to the U.S. Atomic Energy Commission* (1951).
8. Proceedings of a conference on biological, physical, and industrial aspects of potato irradiation, department of biology, Brookhaven National Laboratory, 1955.
9. L. E. Brownell, J. V. Nehemias, J. J. Bulmer, AECU 3050, Engineering Research Inst., University of Michigan, Ann Arbor (1955).
10. V. H. Baker, O. Taboada, D. E. Wiant, *Quart. Bull. Michigan Agric. Expt. Sta.* 36, 448 (1954).