

## A REVIEW OF TRICALCIUM PHOSPHATE AS AN INSECT POPULATION SUPPRESSANT: RESEARCH TO APPLICATION<sup>1</sup>

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In 1964, Majumder and Bano reported on the toxic effects of calcium phosphate salts to insect pests of stored grain. Since 1972, research on these and other inorganic salts as grain and oilseed protectants and as food additives has been conducted at or sponsored by the USDA-ARS Stored-Product Insects Research and Development Laboratory in Savannah, Georgia. (Press et al. 1972, Shaver 1974, Highland 1975, Baker et al. 1976, Baker et al. 1978, Boczek and Ignatowicz 1978, Ignatowicz and Boczek 1978, Ignatowicz and Pankiewicz-Nowicka, 1980, Kruk et al. 1983, Davis et al. 1984, Boczek et al. 1984, Highland et al. 1984, Bookwalter et al. 1985, and Boczek et al. (In press). Two research projects have been sponsored under the Public Law 480 Program 2/: one in Poland entitled "Effect of calcium imbalance on the development of common stored-product arthropods" and one in Egypt entitled "Insect-resistant packages for processed cereals."

Pratt et al. (1972) stated that the use of mineral salts offered a new promising method of insect control. They suggested that commodities could be formulated and possibly could be stored that would be unsuitable or even toxic as insect diets but safe as food for man. To date only one salt, the food additive tricalcium phosphate,  $[Ca_3(PO_4)_2]$  or TCP, has shown promise as an insect population suppressant when added to blended cereal foods. The mechanism for the reported toxic effects of this salt is still largely unexplained.

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1/ This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the US Department of Agriculture nor does it imply registration under FIFRA as amended.

2/ In Poland - PL-ARS-76 [Marie Sklodowska - Currie Grant (FG-Po-360)(JB-28)] and in Egypt (EG-SEA-94).

Bano and Majumder (1965) reported on the development, emergence, external symptoms of toxicity and the histological changes in several stored-product insects induced by adding TCP to their diets. Majumder (1974) reported on interactions of potentiation and antagonism observed between TCP and various organic acids, amino acids, sugars and vitamins. He suggested that some of these reactions possibly could be responsible for the adverse effects of this salt on insect development. Baker et al., (1976) reported that the effect of TCP on Tribolium castaneum (Herbst) and Tenebrio molitor L. was probably due to water loss rather than to disruptive mineral metabolism. In 1978, Baker et al., reported that when using TCP as a 24-hour contact treatment on T. castaneum the branched-chain alkanes, methylheptacosanes and dimethylheptacosanes isolated from cuticular surface extracts were significantly reduced, apparently as the result of absorption by the TCP. They suggested that TCP may have a contact toxicity or cause some metabolic aberration.

The use of TCP in the suppression of stored-product insects is somewhat variable. Most researchers have followed the example of Majumder and Bano and have used 2-3% TCP by weight. The work by Press et al., 1972, suggested that 2% was a marginal dosage and that 3% gave better results. This work also suggested that the diet itself offers some survival value at least for the cigarette beetle, Lasioderma serricornis (Fabricius). In this species, diets of the blended cereal food CSM (cornmeal, soy flour and dry milk) with 2 and 3% TCP resulted in greater population numbers. However, there was also an increase in the number of development days to the adult stage. The increase in developmental times is an observation which is often recorded in the investigation of TCP and ultimately effects the development of population numbers. The survival value of the diet, for the cigarette beetle, was also borne out by the evaluation of TCP in a commercial shipping test (Highland, 1975). Davis et al., (1984) reported on TCP as a legume grain protectant against three bean weevils where mortality was recorded as occurring within 8 hours. Levels of TCP as low as 0.1 and 0.25% by weight dusted on navy beans, Phaseolus vulgaris, or cowpeas, Vigna unguiculata, as a protectant prevented the occurrence of a F<sub>1</sub> generation.

The use of TCP in flour and blended cereal foods has resulted in the complete suppression of all Lepidoptera species tested except for the Mediterranean flour moth, Anagasta kuehniella (Zeller). Boczek et al., (in press) reported little effect of any of each of thirty-two different salts added to the diet of this moth. The only effect observed was on the developmental time of this moth which was extended by TCP at a concentration of 3%.

In the control of Acari, TCP has not been shown to be effective against the mold mite, Tyrophagus putrescentiae (Schrank) (Boczek and Ignatowicz 1978). Most of the salts used commonly as mineral food additives - calcium carbonate [CaCO<sub>3</sub>], calcium dihydrogen phosphate [Ca(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>], tricalcium phosphate [Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>], potassium carbonate [K<sub>2</sub>CO<sub>3</sub>], potassium nitrate [KNO<sub>3</sub>], potassium sulfate [K<sub>2</sub>SO<sub>4</sub>], magnesium chloride [MgCl<sub>2</sub>], sodium chloride [NaCl], sodium bicarbonate [NaHCO<sub>3</sub>], sodium nitrate [NaNO<sub>3</sub>], ammonium hydrogen phosphate [(NH<sub>4</sub>)<sub>2</sub>HPO<sub>4</sub>], ammonium nitrate [NH<sub>4</sub>NO<sub>3</sub>] and ammonium sulfate [(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>] - produce only a

slight effect on fecundity and egg viability (Boczek et al. 1984). Ignatowicz and Pankiewicz-Nowicka (1980) reported that concentrations of TCP (1.5-6.0%) affected the fecundity and longevity of Acarus siro, the flour mite. Egg viability was not affected. Generally A. siro was found to be more susceptible than Tyrophagus putrescentiae.

In the United States, dietary blended food supplements, such as Instant CSM, regular CSM and Wheat-Soy Blend, have been reformulated to contain TCP instead of the former mineral supplements monocalcium phosphate and calcium carbonate (USDA 1975; Bookwalter 1983). The addition of TCP to wheat flour has been shown to be effective in commercial situations, but severe dusting problems were encountered both in the mills during preparation and in the field (Highland 1975). Bookwalter et al. (1985) have investigated the use of TCP in combination with soybean oil in an attempt to solve the problems of dusting and separation. They observed some loss of insecticidal value with use of TCP and soybean oil mixtures.

The use of TCP has found a place among our tools for insect population suppression. The extent of its use in the future will depend upon research into its toxicity to other insect species and its compatibility with other commodities.

#### References

- Baker, J. E., Highland, H. A. and Engle, G. C. (1976) Bulk density of tricalcium phosphate as a significant variable in the suppression of insect populations in flour and wheat soy blend. *Environ. Entomol.* 5, 909-919.
- Baker, J. E., Sukkestad, D. R., Woo, S. M. and Nelson, D. R. (1978) Cuticular hydrocarbons of Tribolium castaneum, Effects of the food additive tricalcium phosphate. *Insect Biochem.* 8, 159-167.
- Bano, A. and Majumder, S. K. (1965) Pathological changes induced by tricalcium phosphate in insects. *J. Invertebr. Path.* 7, 384-387.
- Boczek, J. and Ignatowicz, S. (1978) Effect of tricalcium phosphate on Tyrophagus putrescentiae (Schr.) (Acari: Acaridae). pp 320-327. *In R. Davis (ed.). Proc. 2nd Internat. Wkg. Conf. Stored-Product Entomol.* 1979. Ibadan, Nigeria. 455 pg.
- Boczek, J., Ignatowicz, S. and Davis, R. (1984) Some effects of mineral salts in the diet of the mold mite, Tyrophagus putrescentiae (Schr.). *J. Georgia Entomol. Soc.* 19, 235-248.
- Boczek, J., Wolska, K. and Davis, R. Effects of mineral salts in the diet of the Mediterranean flour moth, Anagasta kuehniella (Zellar). *J. Entomol. Sci.* (In press)
- Bookwalter, G. N. (1983) World feeding strategies utilizing cereals and other commodities. *Cereal Foods World.* 28, 507.
- Bookwalter, G. N., Highland, H. A. and Warner, K. (1985) Tricalcium phosphate-soybean oil in fortified processed cereals to suppress insects, dusting, and separation. *J. Food Sci.* 50, 245-248.

- Davis, R., Boczek, J., Pankiewicz-Nowicka, D. and Kruk, M. (1984) Efficacy of tricalcium phosphate as a legume grain protectant. pp 256-261 In R. B. Mills, V. F. Wright and J. R. Pedersen (Eds.). Proc. 3rd Internat. Wkg. Conf. Stored-Prod. Entomol. 1983. Kansas State Univ., Manhattan. 726 pg.
- Highland, H. A. (1975) Tricalcium phosphate as an insect suppressant in flour and CSM. J. Econ. Entomol. 68, 217-219.
- Highland, H. A., Kamel, A. H., El Sayed, M. M., Fam, E. Z., Simonaitis, R. and Cline, L. D. (1984) Evaluation of permethrin as an insect-resistant treatment on paper bags and of tricalcium phosphate as a suppressant of stored-product insects. J. Econ. Entomol. 77, 240-246.
- Ignatowicz, S. and Boczek, J. (1978) Sterility induced in "copra mite," Tyrophogus putrescentiae by iodine salts. pp 285-290. In J. S. Rodriguez (ed.). Recent Adv. Acarol. Vol I. 1979. Academic Press. New York.
- Ignatowicz, S. and Pankiewicz-Nowicka, D. 1980. Effect of inorganic salts upon biology and development of acarid mites. VI. Effect of tricalcium phosphate and calcium chloride surplus in food upon fecundity, life span and egg viability of flour mite, Acarus siro L. (Acarina, Acaridae). Pol. Pismo Entomol. 50, 541-546.
- Kruk, M., Boczek, J. and Davis, R. (1983) Some effects of selected mineral salts on Tribolium confusum Jacquelin DuVal. J. Georgia Entomol. Soc. 18, 20-27.
- Majumder, S. K. and Bano, A. (1964) Toxicity of calcium phosphate to some pests of stored grain. Nature (London) 202, 1359-1360.
- Majumder, S. K. (1974) The importance of taxonomy and of laboratory studies on the biology, nutrition and physiology of insects infesting stored-products. P. 18-29. In R. Davis (ed.). Proc. 1st Internat. Wkg. Conf. Stored-Prod. Entomol. 1975. Savannah, GA 714 pg.
- Pratt, J. J., Jr., House, H. L. and Monsingh, A. (1972). Insect control strategies based on nutritional principles: A prospectus. pp 651-658. In J. G. Rodriguez (ed.). Insect and Mite Nutrition. North Holland-Amsterdam.
- Press, J. W., Phillips, R. H., Lum, P. T. M. and Miller, A. M. (1972) Tricalcium phosphate as an additive to CSM and all-purpose wheat flour for control of insect infestation. J. Econ. Entomol. 65, 254-257.
- Shaver, K. J. (1974) The dual functionality of tricalcium phosphate as a mineral supplement and insect inhibitor. Proc. IV Int. Congr. Food Sci. Techn., Madrid.
- USDA. (1975) CSM-7 Purchase of corn soya-milk for use in export programs. Agricultural Stabilization and Conservation Service, Commodity Office, Shawee Mission, KS. 66208.