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THE MECHANISM OF STORED GRAIN INSECT CONTROL AND GRAIN QUALITY MAINTENANCE BY LOW DOSAGE PHOSPHINE FUMIGATION

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ABSTRACT

China is a developing country in which the general condition of warehouses for grain storage is not good and highly conducive to storage losses. The conventional storage structure is a horizontal warehouse that holds about 500 tonnes of grain in bulk. The "Triple-Low" grain storage technique was developed and is specially designed for grain conservation in China. The technique is based on the use of plastic liners to seal the grain stacks, low-dosage phosphine (PH_3) fumigations using aluminium phosphide (at 2g AlP/m^3), and maintenance of airtight conditions within the stack for prolonged periods. The cost of this treatment is $0.30/ tonne, and currently some 15 million tonnes are treated by this method each year. In comparison with conventional PH_3 fumigations at AlP dosage of 10g/m^3, the "Triple-Low" treatment represents annual savings of about $1 million. This paper reviews experimental data amassed in the Jiangsu Province over the years 1982-1992. In this Province over fifty million tonnes of grain are stored using low-dosage PH_3 for insect control, with the goal of reducing quantitative losses and maintaining grain quality as expressed by the palatability of cooked rice and especially "stickiness". Texture studies of rice held under the low-PH_3 regime showed that stickiness, viscosity, tryptophane levels, and other textural parameters did not markedly decrease during storage.

TREATMENT MECHANISM

The PH_3 treatment reduces by 53.5-66.1% the citric acid cycle and oxidative phosphorylation of cellular mitochondria of insects (Price, 1980) and grains. Insects cannot survive in the presence of even low PH_3 concentrations and gradually die until complete mortality is achieved. The AlP dosage of 2g/m^3 phosphine produces 100% mortality of all common stored-product insects, while the low levels of respiration of the dormant grain ensure maintenance of organoleptic qualities.

Phosphine can inhibit cytochrome-c at the end of the electron transport chain, thereby influencing the mitochondrial respiration of insects and grain and reducing it by 26.9-31.9%. Phosphine can also restrain the activity of ascorbic acid and reduce it by 25.4-29.1%. A dosage of 0.2 mg/l PH_3 restrains the rate of respiration of grain at a moisture content (m.c.) of 15% and is equivalent to a dosage of 1.5 mg/l PH_3.

EXAMINATION METHOD

Measurement and examination of mitochondrial respiration were carried out with a Seronsen solution of Na_3N_2, 1mM EDTA 10 mM Tris-HCl 10mM KCl (pH 6.2), 10^{-2}M NaN_3, 5 x 10^{-3} M Dieca 5mM $MgCl_2$ 170μM ADP, and $HgCl_2$.

EFFECT OF PHOSPHINE ON MITOCHONDRIAL RESPIRATION OF PADDY

Measurement of the rate of mitochondrial respiration was conducted according to Bendall and Bonner (1971) and Chefurka *et al.*, (1976). Findings showed that the control rate of respiration in normal mitochondria is 4.2 ± 1.1 μl O_2 g^{-1} hr^{-1}, ADP/O=2.1; after fumigation with low dosage of AlP, the control rate of mitochondrial respiration was equal to 2.4 ± 0.7 μl O_2 g^{-1} hr^{-1} ADP/O=1.35. The studies showed that oxidative phosphorylation decreased markedly, resulting in better control of mitochondrial respiration when the grain is moist than when it is dry. Similar results were found by Robinson and Bond (1970).

EFFECT OF PHOSPHINE ON PADDY AND RICE VIABILITY

Experiments indicated that fumigation with a low-dosage of AlP reduced the respiration rate of moist paddy and milled rice by over 50%, but did not effect viability. However, when rice was stored without being covered by plastic liners, the viability of rice stored at 25°C and 15% m.c. decreased markedly.

EFFECT OF PHOSPHINE ON GRAIN MICROORGANISMS

The above respiration experiments on paddy and milled rice also includes the respiration of microorganisms. The proportion by volume of respiration of microorganisms in paddy is about 20% of the total, whereas the proportion in milled rice is 74.7%. Thus low-dosage fumigation with PH_3 can reduce respiration rates of paddy and milled rice to 50.1% and 55.7% of their original rates, respectively, and reduce respiration of microorganisms in paddy and milled rice to 69.8% and 80.2%, respectively.

In conclusion, the studies described above show that low-dosage PH_3 fumigations for insect control and conservation of grain quality is economical, practical, simple, and safe.

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