

**Title** Control of citrus postharvest decay by ammonia gas fumigation and its influence on the efficacy of the fungicide imazalil

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### Abstract

Postharvest green mold and blue mold, caused by *Penicillium digitatum* and *Penicillium italicum*, respectively, were effectively controlled by fumigation of lemons and oranges for 6 h at 22 °C with two applied dosages of 3000  $\mu\text{L L}^{-1}$  of ammonia that was injected initially and again 2 h later. This treatment did not injure oranges, however, it caused the tissue within previously injured areas on the rind of lemons to become darker in color. Fumigation of lemons with 6000  $\mu\text{L L}^{-1}$  of ammonia slightly accelerated the natural transition of rind color from green to yellow. The germination of conidia of *P. italicum* was more sensitive to ammonia than those of *P. digitatum*, although many survived fumigation. About 30% of the conidia of *P. digitatum* and 10% of those of *P. italicum* could germinate after a 6 h fumigation where two injections of 6000  $\mu\text{L L}^{-1}$  of ammonia were applied, one initially and a second 2 h later. Ammonia fumigation controlled an isolate of *P. digitatum* with a high level of resistance to imazalil (IMZ). The influence of ammonia fumigation on the effectiveness of this common postharvest fungicide was examined. When fruit were first immersed in 10 or 30  $\text{mg L}^{-1}$  IMZ (about 10% of typical commercial rates) before ammonia fumigation, a single fumigation with 1500  $\mu\text{L L}^{-1}$  of ammonia was adequate to control both diseases and the increase in effectiveness was usually additive and sometimes synergistic. This effect was probably due in part to the influence of pH on IMZ activity, because the neutral form of IMZ increases with increasing pH and it has markedly higher antifungal activity than the ionized molecule. Fumigation with 1500, 3000, or 6000  $\mu\text{L}$  of ammonia per liter increased the pH ( $\pm\text{SD}$ ) of albedo tissue of pre-existing wounds on oranges and lemons from 5.9 ( $\pm 0.2$ ) before fumigation by 0.6 ( $\pm 0.3$ ), 0.9 ( $\pm 0.4$ ), or 1.3 ( $\pm 0.3$ ) units, respectively. IMZ can be applied immediately after harvest by drenching fruit within harvest bins with aqueous IMZ solutions. Subsequent ammonia fumigation on their arrival to packinghouses may be a feasible practice, since it could employ the existent ethylene degreening chambers present at all packinghouses, if these were modified to be gas tight. Ammonia could replace synthetic fungicides or augment IMZ performance in citrus postharvest decay management. Its capacity to control IMZ resistant isolates of *P. digitatum*, common in citrus packinghouses, is particularly valuable.