Title Integrated control of blue mould using new fungicides and biocontrol yeasts lowers levels of fungicide residues and patulin contamination in apples

Author Giuseppe Lima, Raffaello Castoria, FilippoDe Curtis, Assunta Raiola, Alberto Ritieni and Vincenzo De Cicco

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Abstract

We tested the compatibility of the biocontrol yeasts (*Rhodosporidium kratochvilovae* LS11 and *Cryptococcus laurentii* LS28) with the recently developed fungicides boscalid (BOSC), cyprodinil (CYPR) and fenhexamid (FENH) to create an efficient integrated approach to control blue mould on apples. The fungicide thiabendazole (TBZ), which is presently allowed for postharvest treatment of pome fruit in different countries, was also used as the control. Both the biocontrol agents (BCAs) LS11 and LS28 were compatible *in vitro* with BOSC and CYPR, whereas they were strongly inhibited by FENH. TBZ was compatible with LS28, while it strongly inhibited LS11. *In vitro* assays with some isolates of *Penicillium expansum* showed that the majority were resistant to TBZ, whereas they were all markedly inhibited by BOSC and CYPR. Experiments of integrated control were performed on wounded apples kept at 21 °C up to 7 days. After 4 days of storage, the combination of a low BCA concentration (5×10^6 cfu mL^{-1}) with a low dose (25% of the label dose) of commercial formulates of BOSC or CYPR, resulted in an efficient reduction of blue mould incidence (83–100% less infection with respect to the control). Conversely, the combination of BCAs with TBZ was less effective (not more than 60% of rot reduction). When applied alone at low dosage, LS11, LS28, BOSC, CYPR and TBZ reduced Penicillium rot by 35%, 52%, 67%, 72% and 0%, respectively. After 7 days of storage, only the integrated treatment based on BCAs with BOSC or CYPR resulted in a significant rot reduction (as much as 98%). Treatments based on the utilization of the BCA LS28 or low dosage of CYPR alone were much less effective (10% and 28% rot reduction, respectively), whereas both BCAs integrated with TBZ were ineffective. Furthermore, integrated treatments (BCAs + BOSC or CYPR) resulted in lower fungicide residues and patulin (PAT) contamination in apples. Our data show that the integration of biocontrol yeasts with a low rate of the recently commercialized fungicides BOSC or CYPR could be an effective and safer strategy to control *P. expansum* and keep fungicide residues as well as PAT contamination in apples low.