Cultivation of *Rhodosporidium paludigenum* in gluconic acid enhances effectiveness against *Penicillium digitatum* in citrus fruit

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Abstract

Penicillium digitatum acidifies the extracellular environments of fruit during decay development, this pH fluctuation decreased the efficacy of biological approaches under commercial conditions. Here, we explored the interaction between *P. digitatum* and an antagonistic yeast *Rhodosporidium paludigenum* to investigate potential mechanism behind the battle. *P. digitatum* was found in acidified citrus fruit tissue at pH 4.25 to 3.98 as mold infection progressed. Metabonomic data showed that gluconic, glucaric, and malic acids markedly increased upon infection at pathogen-fruit interaction sites. At concentrations > 1×10^6 cells mL^{-1} in liquid culture containing glucose or fructose instead of lactose, *R. paludigenum* could effectively control green mold. High concentrations of six different acids suppressed yeast growth even in the presence of sufficient glucose. Conversely, at ≤200 mmol L^{-1}, malic and gluconic acids promoted yeast growth in reverse. Cultivation of *R. paludigenum* with gluconic acid enhanced its ability to control green mold. This study provides new insights into the mechanisms by which extracellular acidification caused by acids produced by *P. digitatum* discriminates against competing microbes, thereby enhancing antagonistic yeast biocontrol of green mold in citrus.