Yeast adaptation to early alcoholic fermentation under low pH: effects of bio-activators on fermentation performance, viability, and gene expression

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The initial stages of alcoholic fermentation are critical for ensuring a successful process and are particularly sensitive to environmental stressors such as high sugar concentrations, low pH, oxidative stress, and high temperatures. A rapid adaptation by *Saccharomyces cerevisiae* to these challenging conditions is essential. The present study investigated yeast adaptation during the first 48 hours of alcoholic fermentation under standard (pH 3.5) and low pH (2.9) conditions. The focus is on evaluating the impact of two commercial yeast-based bio-activators on fermentation kinetics, cell viability, and stress-related gene expression. The microbiological monitoring of *S. cerevisiae* populations was conducted through plate counts and flow cytometry, while gene expression was assessed via RT-qPCR. Fermentation kinetics were analysed through micro-fermentation trials in grape must and modified YPD medium, with weight loss and growth curves used to measure lag phase duration. Results showed that the addition of bio-activators significantly improved yeast cell viability, particularly at 14 and 24 hours post-inoculation, under both pH conditions. Low pH extended the lag phase, but this effect was mitigated by bio-activator supplementation. Gene expression analysis revealed enhanced expression of key stress-related genes, including *Sod1* (oxidative stress), *Hsp12* (general stress), and *Grx5* (redox homeostasis), especially under low pH conditions. These findings highlighted the beneficial role of bio-activators in promoting yeast adaptation during the early, stress-intensive phases of alcoholic fermentation, thereby more robust and efficient fermentations under challenging conditions.