Quantum Grey-box Modelling of Oxygen Effects on Metabolic Gene Expressions in E. coli

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Escherichia coli (*E. coli*) exhibits facultative metabolic behaviour, enabling it to adapt to varying levels of oxygen availability. Recent findings indicated that under limited oxygen conditions, gene expressions of metabolic enzymes violated classical total probability law due to potential enzyme interference. In this study, we developed a quantum grey-box model to predict oxygen effects on the gene activities in *E. coli*. The model integrated a white-box component based on classical total probability theory with a black-box component comprising parameterised gates. Implemented on a quantum circuit, the model achieved high accuracy ($r^2>0.99$, $p<0.05$). A key advantage of this model is its ability to systematically encode multiple genes, providing a scalable framework for future investigations. This work provides new insights into in biological systems modelling and advancing our understanding of microbial metabolism.