Frequency Response on the Synthesis of Tryptophan of *B. subtilis* and *E. coli*

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***Short Abstract* — We analyzed the frequency response on the synthesis of tryptophan of *Bacillus subtilis* and *Escherichia coli*. The transfer function was obtained from validated models of *trp* operon to draw the gain plot. External and synthesized tryptophan were established as input and output, respectively. We found that the absence of any of the feedback loops in the *trp* operon, of both bacteria, shifts the cut-off frequency to low frequencies, hence the response time is long. Although, both bacteria regulate the synthesis of tryptophan in a different way, the response to external tryptophan behaves as a low-pass filter.**

***Keywords* — Frequency response, cut-off frequency, *trp* operon.**

I. Introduction

As a temporal stimulus can be decomposed into its sinusoidal components, the frequency response gives an idea of the temporal response to different shapes of stimuli [1]. Besides, the cut-off frequency is related to the time response of a system [2].

Bacteria obtain nutrients from environment or by synthesis. But, sometimes the synthesis is energetically costly. As the case of tryptophan aminoacid, bacteria have evolved to regulate the tryptophan production via *trp* operon [3]. *Bacillus subtilis* has two regulation mechanisms: transcription attenuation and enzyme inhibition. *Escherichia coli* has three regulation mechanisms: two of them are the same as in *B. subtilis* and the other one is the repression [3].

In this work we analyzed the frequency response on the synthesis of tryptophan when *B. subtilis* and *E. coli* are exposed to sinusoidal stimuli of external tryptophan.

II. Methods

We used the validated non-linear ODEs of *trp* operon of *B. subtilis* [4] and *E. coli* [5]. Inspired by [6], we introduce the terms: synthesized, T_S, and external, T_{ext}, tryptophan. The models were linearized in the steady-state with $T_{ext}=0.3T_{S\_max}$ (T_{S_max} is reached when $T_{ext}=0$). Then, we found the transfer function and plotted the gain for each system.

III. Results and Discussion

In wild-type bacteria, *E. coli* has a faster response due to cut-off frequency is higher than *B. subtilis* (Fig. 1). This result was expected because *E. coli* has a faster duplication time than *B. subtilis* [4,5], so this could accelerate the metabolism.

The lack of any of the feedback loops on the *trp* operon, of both bacteria, shifts the cut-off frequency to low frequencies, hence the response time is long. The lowest cut-off frequency is showed in the absence of the inhibition mechanism. However, the obvious difference is observed in the gain when the *trp* operon lacks the inhibition mechanism in *B. subtilis*. This means that the *trp* operon does not response in *B. subtilis* to change in T_{ext}. The difference in the organization of *trp* operon, in both bacteria, or other things that we are not considering in the models could be the factors for this discrepancy between both systems.

IV. Conclusion

The lack of any of the feedback loops in the *trp* operon shifts the cut-off frequency to low frequencies, this result in a long response time. Despite the difference between both bacteria to regulate the synthesis of tryptophan, the response to external tryptophan behaves as a low-pass filter.

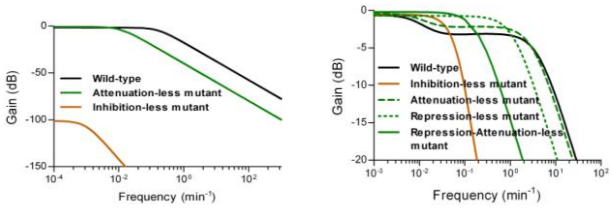

Figure 1. The gain of tryptophan behavior in *B. subtilis* (left) and *E. coli* (right). Wild-type and mutants lack any of the feedback loops are showed.

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