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Research on the duplication and death probability of the DNA of Escherichia coli within different generational time periods

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Abstract. Since the discovery of Escherichia coli during the 17th century, scientists have made substantial efforts to investigate the trends in the advanced combination probability of the Escherichia coli culture. This paper puts forward a combination method for models, via Escherichia coli. Here this paper develops a Markov-chain model for its population in different generational time periods and predicts the chance for duplication and loss from their stationary phase. Understanding the Duplication rate of Escherichia coli is crucial for various fields, including microbiology, medicine, and biotechnology. Our hypothesis believes that there is a correlation between the generational time intervals and the probability of Escherichia coli l duplication. This research contributes to our understanding of its Duplication dynamics and provides valuable information for various applications including the development of antimicrobial strategies, optimization of Escherichia coli l growth in biotechnological process, and the study of its evolution.

Keywords: Escherichia coli, DNA, Duplication and Death Probability

1. Introduction

E. coli has always been a problem during childhood. Whenever people drank milk, the following day would result in a horrible stomach. Where people researched and found that Escherichia coli was one of the main reasons for my stomachaches [1]. Escherichia coli is a Gram-negative, facultative anaerobic, rod-shaped, coliform bacterium of the genus Escherichia that is commonly found in the lower intestine of warm-blooded organisms. Commonly related to human illness symptoms such as, diarrhea, stomach cramps, and fever [2]. Escherichia coli l Duplication is a complicated phenomenon influenced by various factors, such as growth rates, division rates, and environmental conditions. The historical perspective of research on DNA Duplication in Escherichia coli dates back to the mid-20th century when the pioneering work of scientists such as Matthew Meselson and Franklin Stahl provided crucial insights into the semiconservative nature of DNA Duplication. Based on their findings “In semi-conservative Duplication, each two parental DNA strands acts as a template for new DNA strands to be synthesized. However, after Duplication, each parental DNA strand base pairs with complementary newly syntheses strand, and both double-stranded DNAs include one parental or “old” strand and one daughter or “new” strand.” Meselson and Stahl experiment proved that DNA replicates semi-conservatively, which means that each of its strands is dependent for the new synthesis, which acts as a template. Other pioneering work related to the Escherichia coli l DNA, includes Melvin L. DePamphilis’s research on elucidating the molecular mechanisms regulating DNA Duplication, particularly during dearly embryonic

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development. His work has provided valuable insights into the complexities of DNA Duplication and its regulation in multicellular organisms [2].

2. Research question

Do different generational time periods affect the probability of Duplication and death or loss of the DNA of E. coli? The research aims to quantify the likelihood of successful DNA Duplication in E. coli populations with varying Generational time periods under different concentrations of tannin. This objective involves examining how the generation time heterogeneity influences the Duplication probability at the individual cell level. Also, to seek the probability of DNA damage or degradation leading to cell death in E. coli populations.

In this research, people will be proposing a model for the duplication and death or loss probability in E. Coli. One such mathematical model that has proven highly effective in studying dynamic systems is the Markov-chain model. (4)A Markov-chain model is a mathematical framework that describes the probabilistic transitions between different states over time, in this research the heterogeneous Generational time period. By adopting the Markov-chain model to present the Duplication process of Escherichia coli, this paper can gain a deeper understanding of the Duplication probability within a specific Generational time period under different concentrations of tannin [3].

The Markov-chain allows us to capture the inherent randomness and variability of Escherichia coli l Duplication. It considers the different states involved in the Duplication process, such as, single cells, division events, and potential cell death. In addition, the model applies transition probabilities that reflect the rates at which Escherichia coli progresses from one state to another, accounting for factors that influence Duplication dynamics.

This research aims to bridge experimental observations and theoretical understanding by combining empirical data on Escherichia coli l Duplication with the predictive power of a Markov-chain model. Through the duplication probability and the random and spontaneous nature of Escherichia coli l, this paper can unravel the underlying pattern behind it. Moreover, this investigation provides valuable insight into the fundamental principles of Escherichia coli l growth and division.

Hypothesis: The Duplication probability of the DNA of the Escherichia coli is influenced by the longer timeframe, which would mean that in a shorter generational time period the probability that the DNA of the Escherichia coli will replicate is relatively low, while the probability of death of the DNA of the Escherichia coli would occur more frequently [4].

3. Data collection

When growing exponentially by binary fission, the increase in bacterial populations is by geometric progression. If this paper starts with one cell when it divides there are 2 cells in the first generation, 4 cells in the second generation, 8 cells in the third generation, and so on. The generation time is the time interval required for the cells to divide [5].

G (generation time) = (time, in hours)/n (number of generations)

$G=t/n$

t=time intervals in hours

B= number of bacteria at the beginning of a time interval

B= number of bacteria at the end of the time interval

n=number of generation (number of times the cell population doubles during the time interval)

$b= B \times 2^n$

Solve for n :

$\log b = \log B + n\log 2$

$n= (\log b - \log B) / \log 2$

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n= (log b - log B) / 0.301

n= 3.3 log b/B

G = t / n

Solve for G

G = t / (3.3 log b/B)

In this research, this paper would calculate the generation time of an Escherichia coli population of a typical adult human body. Thoroughly revised estimates show that the typical adult human body consists of about 30 trillion to 38 trillion E. coli bacterial DNA cells. This paper assumes that the time for the growth from 30 trillion to 38 trillion of E.coli bacterial DNA cells is 2 hours [6].

$$G = \frac{120}{3.3\ x \log \frac{3.8\ x\ 10^{13}}{3.0\ x\ 10^{13}}} = 354(3.s.f) \quad (1)$$

Based on the calculations, this paper was able to obtain an estimate of a 6 hour generation time.
Percentage error=(6- 5.90) / 5.90 | =1.69%

4. Calculations

Probability of Escherichia coli l DNA Duplication in different generation times

This paper propose a model in which the rate of Duplication of DNA Escherichia coli by using the (6)probability density function," In probability theory, a probability density function (PDF), density function, or density of an absolutely continuous random variable, is a function whose value at any given sample (or point) in the sample space (the set of possible values taken by the random variable) can be interpreted as providing a relative likelihood that the value of the random variable would be equal to that sample.", after heterogeneous generation time (r), the generation time in which the DNA Escherichia coli multiplies forms its stationary phase (T). B0 is the stationary state at the start at time zero, where the probability of the Escherichia coli in DNA Duplication in a heterogeneous generation time period per hour can be modeled by:

B(T) = r x e^(-r x T)

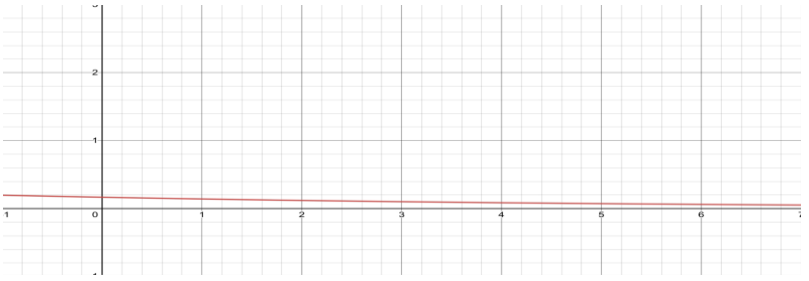

Figure 1. Probability density of the duplication of E coli

The graph demonstrates a exponential graph, the x-axis represents the generational time period and the y-axis represents the probability of E. coli duplication [7]. The probability of the duplication of DNA Duplication within a 2-hour interval is determined by the area under the exponential graph between the x-axis values 0 to 2, this paper integrate Figure 1 over that interval. The probability, denoted can be calculated as follows:

$$\int_0^2 \frac{1}{6} e^{\left(-\frac{1}{6}T\right)}\, dT \quad (2)$$

It's important to note that the exponential distribution assumes independence between Duplication events and a constant average of Duplication. These assumptions may not always hold in real biological

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systems. Therefore, it's crucial to consider the limitations and context-specific factors that may influence the Duplication dynamics of Escherichia coli when using such models.

In Figure 1, it shows the probability of Duplication and death or loss in a 2-hour generation time. As probability cannot be a negative number this paper can take the domain of Figure 1 as [0, infinity] and after this paper used the integral formula to obtain the area under Figure 1 between the area density under values 0 to 2 this paper can obtain the value of 0.283(3.s.f) as the probability that the DNA Escherichia coli replicates itself, afterwards this paper can use the value of this to calculate the probability that the DNA Escherichia coli losses its number of DNA as, [1-0.283=0.717]. Based on these results this paper can determine a Markov Chain for 4 Generational time period of 2 hours:

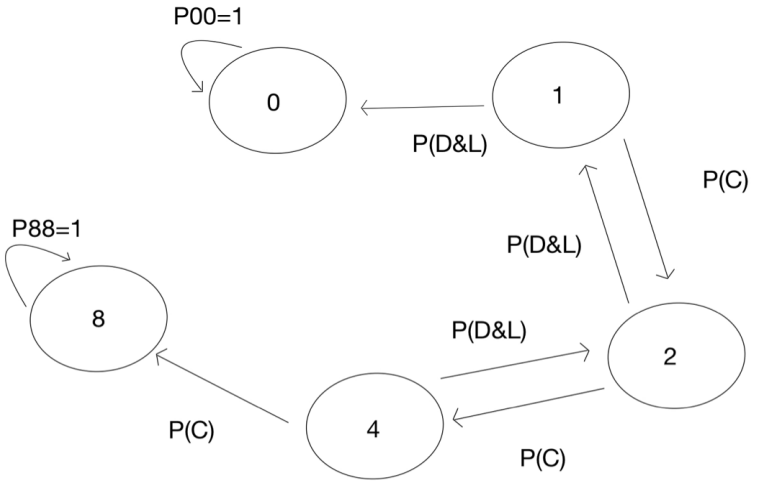

Figure 2. Markov-Chain model

$$\begin{pmatrix} 1 & 0.717 & 0 & 0 & 0 \\ 0 & 0 & 0.717 & 0 & 0 \\ 0 & 0.283 & 0 & 0.717 & 0 \\ 0 & 0 & 0.283 & 0 & 0 \\ 0 & 0 & 0 & 0.283 & 1 \end{pmatrix}$$

$$\left(\begin{array}{ccc|cc} 0 & 0.717 & 0 & 0 & 0 \\ 0.283 & 0 & 0.717 & 0 & 0 \\ 0 & 0.283 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0.283 & 0 & 1 \end{array}\right)$$

Figure 3. The Markov Chain and transition matrix for the probability of replication of E coli

Based on the Markov Chain and Transition Matrix, the probability of each transition from one stage to a larger one is 0.283 and the probability of each transition from one larger state to one smaller state

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is 0.717. The probability of any transition from the state of 0 or 4 will result in zero and the probability of it not replicating or losing the DNA Escherichia coli is 1 [8].

This model uses the Stationary Distribution of a Markov to represent the long-term probability of being in each state. It is obtained by a system of linear equations and provides insights into the steady-state behavior of the chain. This paper can arrange the Markova chain into different groups, states 0 and 8 are absorbing states and the other states are transients.

5. Results

Table 1. The different probability of duplication and loss of death

Generation time	Probability of Duplication	Probability of loss or death
2 hour	0.283	0.717
3 hour	0.393	0.607
4 hour	0.487	0.513
5 hour	0.565	0.435

The analysis revealed a low Duplication probability within the 2-hour generation time. The fixed and relatively short generation time doesn't allow the Escherichia coli to complete DNA Duplication with a low likelihood. It could probably be due to the average generation time of the Escherichia coli. The Duplication probability was close to 30%, indicating a rare event occurring within the specified time interval. This suggests that the Escherichia coli was highly inefficient in replicating their DNA within the given timeframe [9]. On the other hand, the analysis of death probabilities within the 2-hour generation time indicated that cell death occurs frequently, at a relatively high probability. This suggests that Escherichia coli had a low chance of surviving and completing Duplication within the specified time frame. The combination of low Duplication probability and high death probability with the 2-hour generation time resulted in inefficient Escherichia coli l growth dynamics. The Escherichia coli was unable to replicate their DNA and maintain low cell viability within each generation. This allowed the population to decrease in size over successive generations.

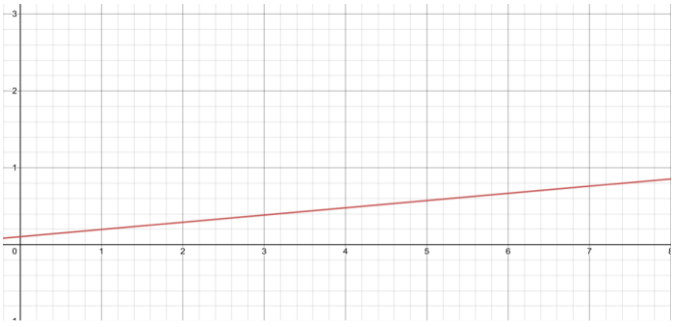

Figure 4. PMCC curve in relation to the generation time with the probability of duplication

In the longer generation time period, there is an increase in the probability that the E. coli Bacterial DNA replicates and a decrease in the probability the E. coli Bacterial DNA loss or death. Based on the diagram it shows that there is a positive and strong correlation between the generation time and the probability of duplication [10]. The y-axis represents the duplication probability and the x-axis represents the generational time period.

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The findings of this research on the Duplication and death probabilities of Escherichia coli l DNA within a homogeneous population with a fixed 2-hour generation time show reasonable results. The low Duplication probability indicates that the Escherichia coli was less efficient in completing DNA Duplication within this short time frame. This suggests that the genetic property of Escherichia coli was viable only within a longer time frame.

The low death probability within the 2-hour generation time suggests that the culture conditions provided during this period were unfavorable for cell survival and Duplication. It implies that the Escherichia coli is not compatible with the environmental conditions, which contributes to the low viability of the Escherichia coli l population.

Whereas, the results shown in the longer generation time suggest the culture conditions provided during the longer periods were more favourable for cell survival and Duplication. It implies that with a longer generation time, Escherichia coli is more compatible with the environmental conditions, which shows the higher viability of the Escherichia Coli population.

Since the study only focuses on a specific generation time, the study neglects other components that might affect the Duplication and death or loss probability. Further research is needed to explore the dynamics of Duplication and death probabilities in populations with varying Generational time periods.

Also, future studies could investigate the long-term consequences to these probabilities on population growth and explore how they may vary under hanging environmental conditions.

6. Conclusion

The research provided valuable insights into the Duplication and death or loss probabilities of Escherichia coli l DNA within a homogeneous population with different generation times. The low Duplication probability and high death or loss probability observed within a short timeframe demonstrate the inefficiency of DNA Duplication and the unfavorable conditions supporting Escherichia coli l survival. A longer timeframe shows that there is larger population growth and a high probability for E. coli bacterial DNA Duplication and survival. However, Further research is required to explore the dynamics of Duplication and death probabilities in populations with different Generational time periods and to investigate the long-term consequences on popular growth and survival.

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