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Homotopy Analysis Method on Listeria Infection Model Caused by Pre-Cooked Package Food

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Abstract In this study, the Listeria infection model involving the fractional derivatives in the Caputo sense is considered and studied through two different techniques called the Homotopy analysis method (HAM) and Runge-Kutta 4^{th} order (RK4) method. HAM is a semi-analytical approach, and the RK4 method is a numerical method proposed for solving fractional order systems of ordinary differential equations (ODEs). We have developed a semi-analytical solution in terms of a series of polynomials by HAM and a numerical solution by the RK4 method for the model. First, we solved the model through HAM by choosing the preferred control parameter and also applied the RK4 method. The model solved by projected methods is compared with the NDSolver solution. The nature of the model is analyzed using different parameters, and the calculations are performed using Mathematica software. The obtained results are expressed in graphs and tables.

Keywords Homotopy analysis method, Runge-Kutta method, Caputo derivative, Listeria infection model, convergence

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1. Introduction

Differential equations have numerous applications, such as describing objects' motion, including projectiles, oscillations, and collisions in classical mechanics; the behavior of electric circuits and electromagnetic waves in electromagnetism, and calculating an item's temperature over time using Newton's law of cooling. Population increase and saturation are modeled using the logistic equation. The SIR model comprehends the transmission of illnesses. The Lorenz system simulates how air circulation and fluid convection behave. We can compute acceleration and velocity. Design and enhance control systems for processes using electricity, mechanical, and chemical elements. Signal handling in audio, picture, and video processing, analyzes and filters signals. Population dynamics examines how different species interact, considering theories of competition and predator-prey relationships. The

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study of epidemiology models the transmission of illnesses, taking into account the effects of immunization and therapeutic approaches. Lotka-Volterra formulae simulate the behavior of predator-prey networks. Hodgkin-Huxley formulae explain how nerve impulses in neurons behave.

Fractional calculus (FC) is a branch of classical calculus that deals with non-integer (fractional) order differentiation and integration procedures. The notion of fractional operators was created nearly concurrently with the introduction of classical operators. In 1695, renowned scientists like the Marquis de l'Hospital and G. W. Leibniz expanded the definition of the semi-derivative. As a result, numerous prominent mathematicians, such as Letnikov, Grünwald, Riemann, Laplace, Liouville, and Euler, became interested in this topic. The theory of FC has advanced quickly since the 19th century, primarily serving as a basis for several practical fields, such as fractional dynamics, fractional differential equations, and fractional geometry. These days, FC has many different uses. It is reasonable to state that practically every field of contemporary science and engineering, in general, is impacted by the schemes and tools of FC. Bioengineering, mechanical and electrical engineering, control theory, robotics, statistical and chemical physics, optics, acoustics, viscoelasticity, rheology, and other fields, for instance, have numerous and productive uses. In general, one may contend that processes in the real world are fractional order systems. These new fractional-order models are frequently more accurate than integer-order ones, meaning they have more degrees of freedom than the corresponding classical model. This is the primary factor contributing to the success of FC applications. This topic is fascinating because fractional integrals and derivatives are non-integer or non-local quantities. To describe the non-local and spread effects frequently found in technological and natural events, all fractional operators take into account the complete history of the process under consideration. As a result, FC is a great collection of instruments for characterizing the memory and inherited characteristics of different materials and processes. The articles [1, 2] provide a clear explanation of the FC.

Listeriosis, or Listeria infection, is caused by the bacterium Listeria monocytogenes. This is a dangerous disease that primarily affects older people, infants, expectant mothers, and persons with weakened immune systems. Numerous environmental elements contain Listeria bacteria, including soil, water, and some animals. Food contamination is a common way for people to get infected with Listeria. Common sources of disease include soft cheeses, hot dogs, deli meats, unpasteurized dairy products, and smoked fish. These foods, even when refrigerated, can harbour Listeria [3].

Muscle aches, headaches, nausea, fever, and diarrhea are just a few symptoms that can be produced by listeriosis [4]. Meningitis, an inflammation of the membranes surrounding the spinal cord and brain, and septicemia, a blood infection, are among the complications that might arise from severe circumstances [5]. Due to the possibility of miscarriage, death, early delivery, or illness in the unborn child, some populations—including pregnant women—are more vulnerable to severe listeriosis [6]. Individuals with compromised immune systems with organ transplants, AIDS/HIV, cancer, or older people may be at a higher risk.

Antibiotics are a treatment option for listeriosis. If you think you may have a Listeria infection, you should see a doctor every once, especially if you are in a high-risk category. Adopting sensible food safety practices is essential to prevent Listeria contamination. Fruits and vegetables should be cleaned, dairy products should