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Fractional Order Dynamical Behavior of Dengue Hemorrhagic Fever with Saturation Factor

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Abstract In this study, we propose a modified fractional order derivative in the scope of Caputo to investigate the dynamics of Dengue fever transmission. The existence, uniqueness and boundedness of the fractional model were established using a fixed-point approach. The stability analysis of the model was done with respect to the reproduction number which was found to be stable locally and globally at infection free and endemic state respectively. The fractional order (DHF) model was estimated using the fractional Adams-Bashforth predictor-corrector technique. Additionally, the numerical validation was done to ascertain the impact of various parameters on the dynamics as a whole, as well as the effect of vaccines on the model. The graphical solutions show that the fractional order (α) and vaccinations affect the dynamics of the model when they are varied within the model. The findings indicate that saturation of infectious individuals in the system helps to flatten out the infection transmission.

Keywords Fractional order, stability, dengue fever, Adam's Bashforth, Banach and Schauder's theorem

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1. Introduction

The dengue virus is the primary cause of dengue fever, sometimes referred to as a vector-borne illness. It has flavivirus serotypes, ranging from (DENV 1-4). This disease poses a threat to the majority of countries worldwide. The Eastern Mediterranean, Americas, Africa, and particularly the Western Pacific and South-East Asian regions are the areas most severely impacted by dengue fever worldwide. With thousands of fatalities and over 390 million cases, dengue fever is regarded as the worst vector-borne disease after malaria [5] [17] [39]. Approximately 100 nations are at risk of contracting dengue fever globally, according to a 2012 estimate. The disease is carried by a variety of mosquito species, including Aedes and particularly Aegypti [25]. In contrast to other dengue fevers, which often produce only modest morbidity and death, classical dengue fever, also known as break bone fever, heals its victims in one to two weeks after the fever first arises [13].

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Dengue hemorrhagic fever (DHF) or the shock syndrome (SS) can strike some individuals [15]. The World Health Organization (WHO) reports a larger number of (DHF) each year worldwide [37]. The primary method of transmission of the dengue virus to humans is via the bites of female mosquitoes carrying the virus [9]. There is currently no known efficient remedy for the dengue virus, with the exception of fluid substitution therapy, which can be started early. Traditional therapeutic methods are also possible. [10]. In addition to the lack of therapy for dengue virus infections, there is currently no effective vaccine available to vaccinate vulnerable persons. Despite the lack of an efficient dengue virus vaccine on the market, the WHO recommended some advancement in the field of dengue vaccine development. Regarding the dengue fever vaccine, a study that was released in 2015 said that the first vaccine was created in Mexico. [38]. There are several mathematical models in the research [24], [22] [16], [36], that address the dengue dynamics. The aforementioned references present several viewpoints on the dengue infection dynamics, including dynamic analysis, vaccine, and optimum control analysis. [33] contains a few recent scientific publications that provided actual data on dengue infection. In [1], a mathematical framework of an infection with dengue was created, addressing the disease using actual data from Pakistan and providing some practical methods for eradicating mosquito-borne disease. Analysis of the dynamics of dengue with identical strains and their reinfection has been found in [2]. A basic discussion of dengue modeling in both deterministic and stochastic approaches is done in [8]. In [35] a hybrid system for dengue prediction is examined. In [21], the authors examined the dynamics of dengue disease and its mutual infection with the Zika virus, demonstrating the protective effects of immunization against dengue hemorrhagic fever (DHF).

Many academics have used fractional differential equations to demonstrate a variety of infectious and non-infectious diseases in the modern era [31], [30], [4], [40]. Omame et al. investigated the analytical solution of a fractional order mathematical framework for a tumor displaying mutations in cells. [37]. The study [28] investigates bifurcation and optimal control in co-infection scenarios of ZIKA and SARS-CoV-2. Andrew et al. [29] used a fractional approach to investigate the dynamics of complex systems. The paper in [28] provides basic rules for modeling complicated systems, which facilitates the creation of axiomatic methods in the field. Atede et al. [3] focused on Nigerian actual data as a base of study and investigated a fractional-order vaccination model for COVID-19 that took ecological propagation into consideration. Studies of TB in relation to internal reactivated and foreign re-infection have been conducted using Frégal-order models [7].

1.1. Objective

This work attempts to examine the dynamics and management of dengue hemorrhagic fever (DHF) transmission in the population using a fractional-order model and also attempts to show how the fractional order variable and memory indices influence the dynamics of the disease.

1.2. Preliminaries and definitions

We include some notations, definitions, and established results that are required for the sequel. This study uses Liouville-Caputo's fractional derivative.