JOSTMED 18 (3), SEPTEMBER, 2022 ISSN: 0748 – 4710

JOURNAL OF SCIENCE, TECHNOLOGY, MATHEMATICS AND EDUCATION (JOSTMED)

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PUBLISHED BY:
DEPARTMENT OF SCIENCE EDUCATION
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA, AFRICA

INVESTIGATION OF THE DISPERSAL RATE OF CURRY AND THYME

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Abstract
This is a study of the rate of dispersal of curry and thyme in a medium using the coefficient of diffusion of curry leaves and thyme leaves. The study was carried out by solving the diffusion equation using the method of separation of variables with appropriate boundary conditions and the coefficient of diffusion applied for curry and thyme.The result shows that curry leaves diffuse faster than thyme leaves under the same conditions. The research establishes why nutritionists and cooks would choose curry ahead of thyme when considering appropriate spices for cooking in order to attract attention.

Keywords: Curry, Coefficient of Diffusion, Species, Thyme.

Introduction

The curry tree, also known as the neem tree is a tropical tree and native to Asia. Its leaves are used in many dishes across Asia and even in Africa. The curry tree grows best in well-drained soil that does not dry out and yet in sunny regions or places with partial shade, preferably away from the wind. The leaves are most widely used in southern and west coast Indian cooking, normally fried along with vegetable oil, mustard seeds, and chopped onions in the first stage of the preparation. According to nutrition experts, curry leaves are a rich source of carotenoids, beta-carotene, calcium and iron (Parmar & Kaushal, 1982). Similarly, the dried aerial portions of various species of the scented perennial evergreen herb genus *Thymus* in the mint family *Lamiaceae* are used to make thyme. Thyme grows well in a warm, sunny area with well-drained soil. It is often planted in the spring and thereafter becomes perennial. It can be multiplied through seed, cuttings or division of the plant's rooted portions. It does well in dry conditions. The plant grows naturally on mountain altitudes and can withstand very cold temperatures. It is propagated by cuttings and thrives on dry hillsides. After flowering, it can be trimmed to prevent it from becoming woody (Peter, 2012).

The diffusion coefficient, which is also known as diffusivity is the rate of diffusion of an amount of substance from a region of high concentration to low concentration in a specified time. The velocity of movement of one substance through the other substance, for instance, the velocity of movement of ink in water at a specified time is the diffusion coefficient.

The curry leaves on the curry tree are known to flourish in well-drained soil, yet in sunny regions. These quite conflicting requirements make it difficult to actually propagate the curry tree in certain regions of the world. Thyme leaves, on the other hand, are consumed dried especially when used for culinary purposes. This has led to the study of the diffusion coefficient of curry leaves and also that of thyme leaves in order to discover which of the leaves diffuses faster than others. The unique scent which has led to an increase in world demand for curry and thyme leaves has led to the need for more research to be done on the diffusion rate of the two leaves. The idea of comparing the diffusion coefficients will help us draw an analysis on the rate of diffusion of the two leaves. ref

Curry leaves (*Murraya koenigii L.*) are the aromatic leaves of the small tree of Rutaceae family with an origin in Southwest Asia. In Ghimire and Magar (2018), the effect of temperature on the drying of the aromatic leaves was investigated. The experimental data was compiled into six thin-layer mathematical modeling. The models were highlighted and studied in terms of coefficient of determination (R^2), chi-square ($\chi 2$) and also root mean square error (RMSE).

Similarly, Curry (Murraya koenigii., Rutaceae) leaves were dehydrated via two drying methods in (Angothu & Waghray, 2022) thus, Conventional drying at 40, 50, and 60°C having an air velocity of 5.2 m/s and Vacuum assisted conventional drying having 250, 400 and 600mmHg were utilized to dry up the curry leaves. The dehydrated leaves were experimented for their colour retention.

Solid-liquid extraction by batches of total polyphenol content gotten from curry leaves (Murraya koenigii L.) was researched in Patil *et al.* (2021). The investigation shows that the result of several solvent concentrations and temperatures that were had on total polyphenol constituents was experimented by performing experiments in batches. The experimental results gave that the movements of solid-liquid batch extraction were affected by several solvent concentrations and temperatures.

Choo *et al.* (2020) researched on comparison between the anti-diabetic and anti-aging properties of Curry (Murraya koenigii) leaves by utilizing the dehydration method of hot-air drying.

The procedures for dehydrating agricultural products are important to ensure the quality of the final product and to check if the process is feasible. Lima *et al.* (2021) carried out the dehydration of pear by continuous and intermittent methods ($\alpha = 2/3$) at two temperatures that are different, looked into the two methods, and compared and explained the methodologies using mathematical models and diffusion models to check the time saving and the energy for effective processing.

The reason for the indispensability of the two leaves is the basis for this research work. Both leaves possess health benefits when consumed in several dishes across the globe. While some areas of the world even claim that both curry leaves and thyme leaves have healing properties. Consequently, the increasing global demand for the two leaves has made this research work a necessity.

Mathematical Formulation

A partial differential equation in three dimensions is evolved and used to study the rate of diffusion of particles of curry and thyme leaves. The equation is solved using the method of separation of variables and appropriate boundary conditions imposed. The coefficients of diffusion of curry and thyme leaves are applied in the solution to determine the rate of dispersion of the two leaves when subjected to the same conditions.

Consider

$$\frac{\partial u}{\partial t} = D\nabla^2 u \tag{1}$$

where $u =$ the function representing the diffusing object and $D=$ coefficient of diffusion.

In three dimensions, the equation will be

$$D\nabla^2 u = D\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) \qquad (2)$$

with$t$ = time,

Considering the diffusion of the scent of the leaves along x-plane only while assuming the diffusion is constant along y and z planes, we have

$$\frac{\partial u}{\partial t} = D\frac{\partial^2 u}{\partial x^2}, \quad 0 < x < 3, \ t > 0 \qquad (3)$$

Given that the boundary conditions are

$$\left(\begin{array}{c} u(0,t) = u(3,t) = 0 \\ u(x,0) = 5sin4\pi x - 3sin8\pi x + 2sin10\pi x \\ |u(x,t)| < M \end{array}\right) \qquad (4)$$

where the last condition states that it is bounded for $0 < x < 3, \ t > 0$.

Using the method of separation of variables (MSV) and considering the boundary conditions in equation (4), we assume

$$u(x,t) = X(x)T(t) \qquad (5)$$

then

$$XT' = X''T \qquad (6)$$

$$\frac{X''}{X'} = \frac{T'}{DT} = -\lambda^2 \qquad (7)$$

Each side must be a constant which we call $-\lambda^2$ (if we use $+\lambda^2$, the resulting solution obtained does not satisfy the boundedness condition for real values of λ). Then

$$X'' + \lambda^2 X = 0, or \ T' + \lambda^2 DT = 0 \qquad (8)$$

with solutions

$$X = A_1 cos\lambda x + B_1 sin\lambda x, \quad T = C_1 e^{-\lambda^2 Dt} \qquad (9)$$

then solution of the PDE is

$$u(x,t) = X(x)T(t) = C_1 e^{-\lambda^2 Dt} (A_1 cos\lambda x + B_1 sin\lambda x) \qquad (10)$$

Assume $A = A_1 C_1, \quad B = B_1 C_1$

$$u(x,t) = e^{-\lambda^2 Dt} (Acos\lambda x + Bsin\lambda x)$$

Since

$u(0,t)=0$,

$$e^{-\lambda^2 Dt}(A)=0 \text{ or } A=0$$

Then

$$u(x,t)=Be^{-\lambda^2 Dt}\sin\lambda x \quad (11)$$

Similarly,

$$u(3,t)=0,\ Be^{-\lambda^2 Dt}\sin 3\lambda=0 \quad (12)$$

If $B=0$, the solution is identically zero, so we must have

$$\sin 3\lambda=0 \text{ or } 3\lambda=m\pi \quad (13)$$

Implying

$$\lambda=\frac{m\pi}{3} \text{ where } m=0,\pm1,\pm2,\ldots \quad (14)$$

Thus, a solution is

$$u(x,t)=Be^{-\frac{m^2\pi^2}{9}Dt}\sin\frac{m\pi}{3}x \quad (15)$$

Also, by the principle of superposition,

$$(x,t)=\sum_{m=1}^{\infty}B_m e^{-\frac{m^2\pi^2}{9}Dt}\sin\frac{m\pi}{3}x \quad (16)$$

From which

$$(x,0)=\sum_{m=1}^{\infty}B_m\sin\frac{m\pi}{3}x \quad (17)$$

To make the solution (17) fit the initial condition (4), all the terms in the infinite Fourier series are not required. The only required terms are:

$$m=12 \text{ with coefficient } B_{12}=5,$$

$$m=24 \text{ with coeffucient } B_{24}-3$$

and the term for which

$$m=30 \text{ with coefficient } B_{30}=2$$

Substituting these into (16), the required solution is

$$u(x,t)=\ 5e^{-16\pi^2 Dt}\sin 4\pi x\ -3e^{-64\pi^2 Dt}\sin 8\pi x+\ 2e^{-100\pi^2 Dt}\sin 10\pi x \quad (19)$$

Results and Discussion

Graphical representation

The graphs obtained using the coefficients of diffusion $D_{curry} = 2.64\times10^{-12}\, m^2/s$ and $D_{thyme} = 7.6\times10^{-9}\, m^2/s$ for the diffusion coefficient of curry and thyme respectively are presented in Figures 3.1 and 3.2.

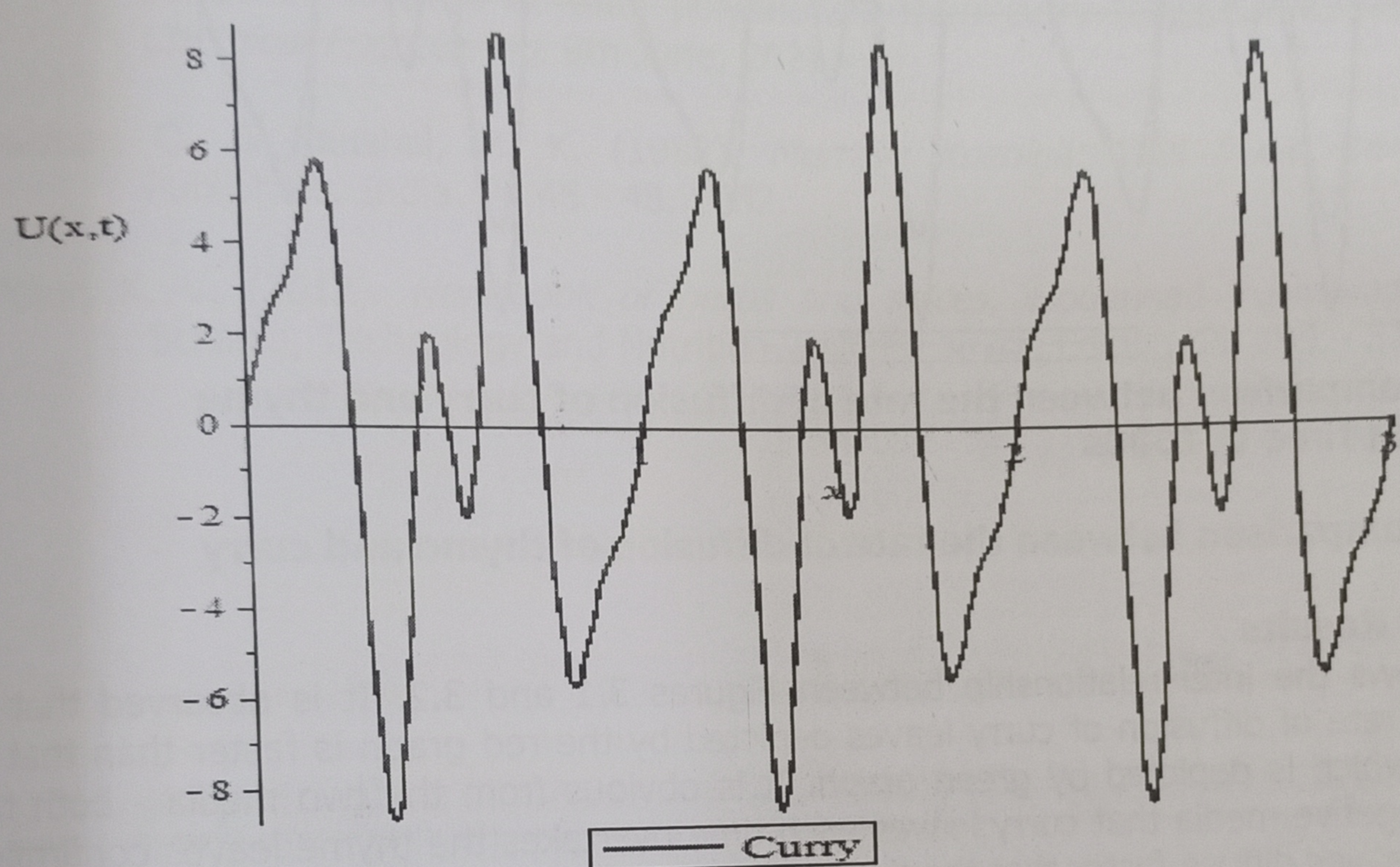

Figure 3.1: Diffusion of Curry along x=3m at time t=1000s

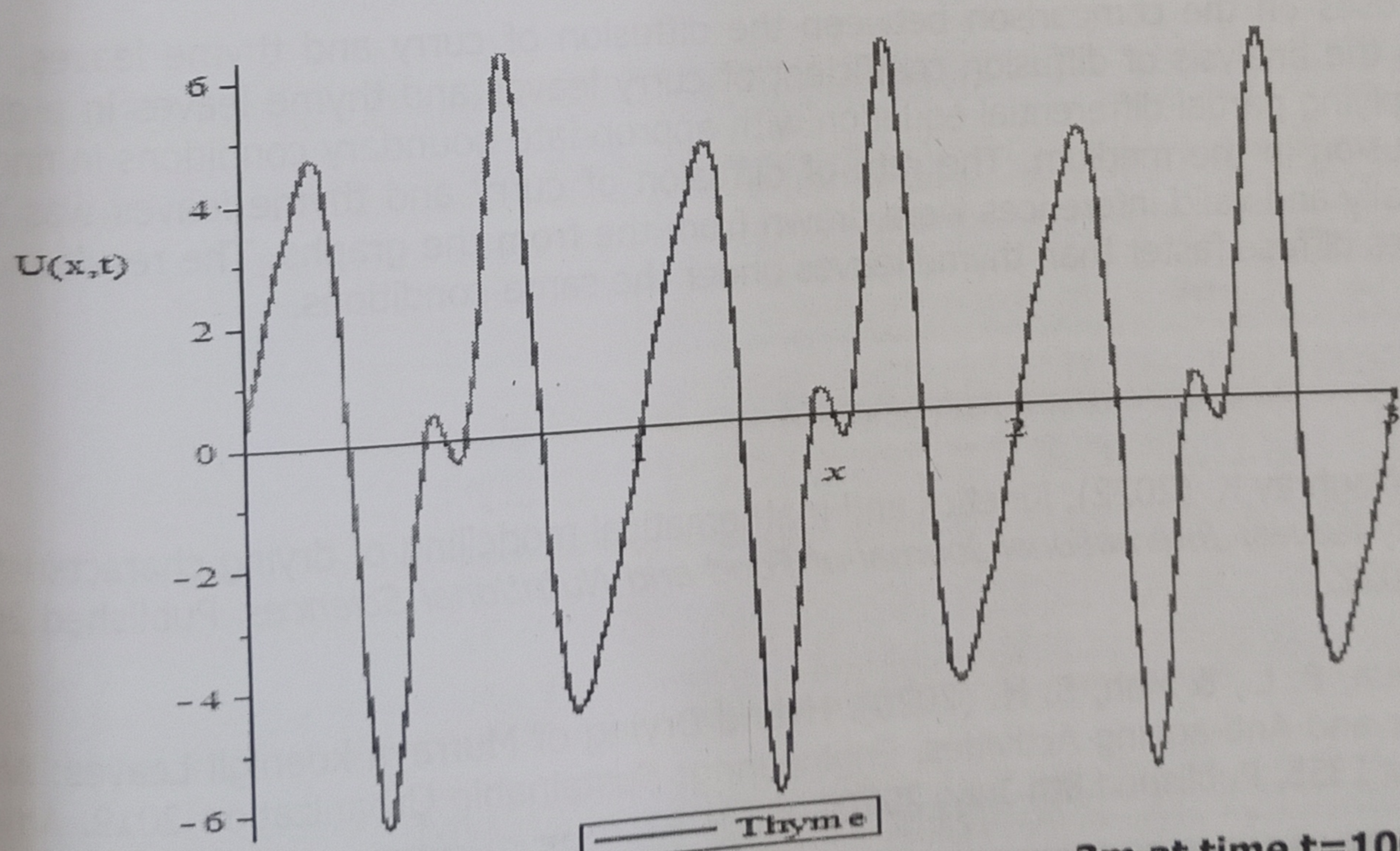

Figure 3.2: Diffusion of thyme along x=3m at time t=1000s

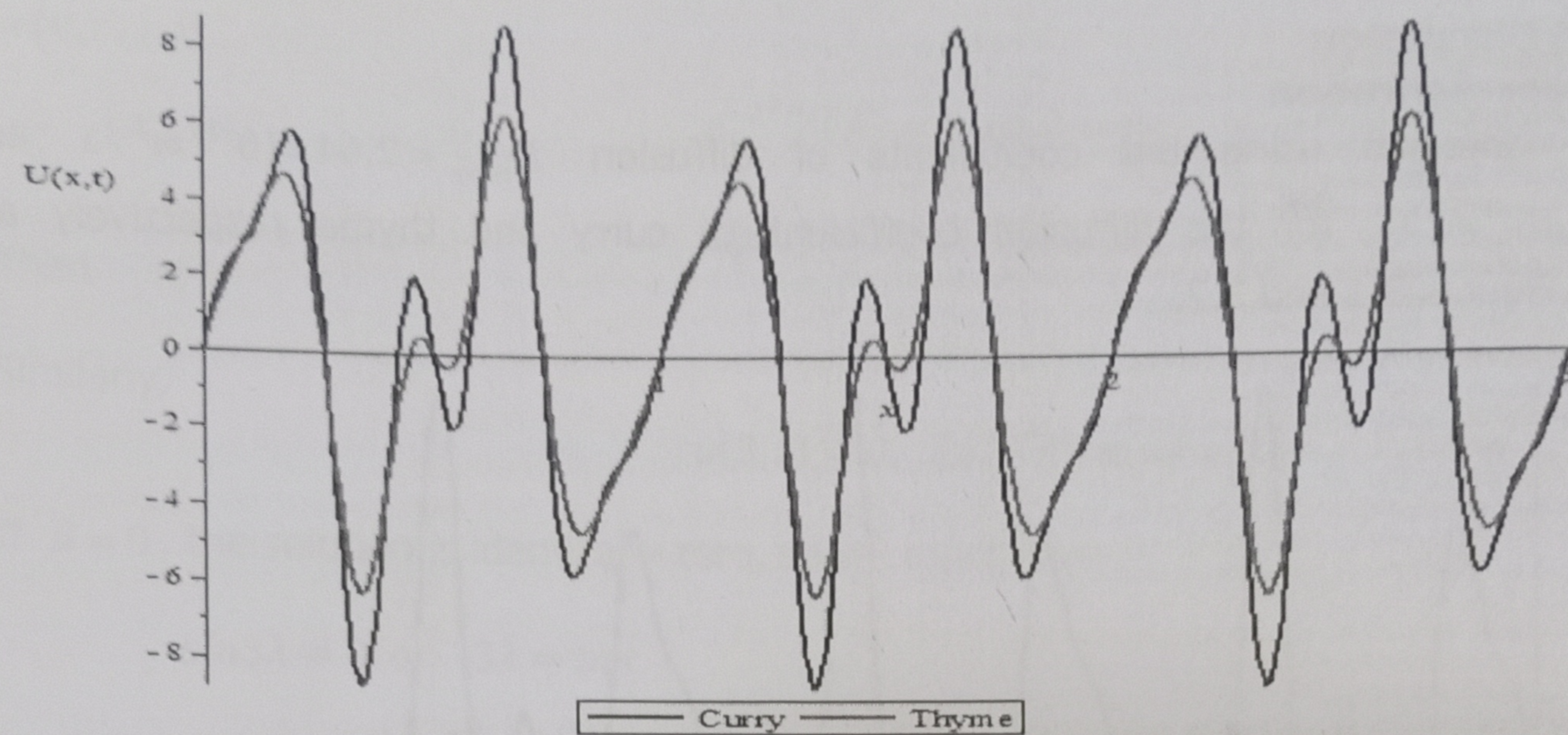

Figure 3.3: Comparison between the rate of diffusion of curry and thyme along x=3m at time t=1000s

Figure 3.3: Comparison between the rate of diffusion of thyme and curry

Discussion of Results

Figure 3.3 shows the inter-relationship between Figures 3.1 and 3.2. It is observed that at constant time, rate of diffusion of curry leaves depicted by the red graph is faster than that of thyme leaves which is depicted by green graph. It is obvious from the two media - both the positive and negative media that curry leaves each time overtakes the thyme leaves confirming that the curry leaves diffuse faster that the thyme leaves.

Conclusion

This study focuses on the comparison between the diffusion of curry and thyme leaves. The study explores the analysis of diffusion coefficient of curry leaves and thyme leaves in a given medium by applying partial differential equation with appropriate boundary conditions in finding its rate of diffusion in the medium. The rate of diffusion of curry and thyme leaves was also shown graphically and valid inferences were drawn from the from the graphs. The result shows that curry leaves diffuse faster than thyme leaves under the same conditions.

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