Predictive Model on Dynamics of Natural Ecosystem and Organic Foods as Effective Prevention and Control Measures Against Covid-19 Infection

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Abstract

In this work a mathematical model is formulated based on systems of differential equations to predict the dynamics of natural ecosystem and organic foods as prevention and control measures against covid-19 infection. People living in a natural ecosystem and feed on fresh organic foods are in a position to develop natural immunity as a result of being exposed to the virus which reside in the animals within the ecosystem and also from the fresh natural nutrients of the organic foods that are consumed. The existence of the steady states is examined and the basic reproduction number $R_0$ is computed using the next generation matrix approach. Stability analysis shows that the infection free equilibrium (IFE) is locally asymptotically stable (LAS) when $R_0 < 1$, however, it is not globally asymptotically stable (GAS) even when $R_0 < 1$. This is an indication of the existence of backward bifurcation which exists at $R_0 = 1$. Because of the nature of covid-19 virus which spreads very fast even from a single infective, a small perturbation at $R_0 = 1$ causes disease explosion leading to high levels of infection. Numerical simulation of the model shows that more infections and deaths occur in the population of individuals without natural immunity. From the study it can be concluded that in settings where the ecosystem is not extensively destroyed and interfered with and the inhabitants are constantly exposed to the virus and consume the fresh organic foods, the body develops natural immunity and is able
to develop protection against infection to a greater extent and even those who are infected are able to fight the invading virus and recover. Results of this study will sensitize the global population to reconcile modernization, urbanization and environmental conservation in order to prevent viral and bacterial pandemics.

**Introduction**

Ecosystem is the Biological community of interacting organisms, non-living particles and their physical environment [4]. Over the past 50 years, humans have rapidly and extensively changed the ecosystem. This is largely to meet their desire to improve infrastructure, increase urbanization, manage the global population increase and also due to increased demand for fuel and food [6]. These changes have contributed positively to human wellbeing, however, they have been achieved at a growing cost in the form of high degree of degradation of the natural ecosystem. Forests have been cleared, wild animals driven away from their habitat, from where there was some level of interaction between human beings and animals [Footprint]. Some animals like bats and small birds like weaver birds and doves even shared shelter and some foods like fruits and grains with human beings. At certain times some of the small animals like tortoise, bats, frogs and small birds were children’s play toys. Children at their early age already had had close contact with these animals and that meant that any pathogen carried by these animals could have easily entered the children’s system. And, we can assume that the body was in a position to start an immune reaction and fighting the pathogens and later develop some form of immunity at that early stage of life. Immunity is usually developed gradually so that in case of exposure the pathogen is eliminated or the illness is not of severe magnitude because the body already has protective antibodies to resist the attack by the pathogens. Individuals growing up in an environment where a certain pathogen is prevalent gradually develop immunity against the infection by the pathogen. A child exposed to the virus earlier in life develops stronger immune system and is less likely to become sick due to the infection by these viruses in hers or his later years [herd immunity rough]. The immune system mitigates the challenges posed by the infecting virus extremely well [1]. The small doses of the virus train the immune system to recognize and combat the viral infection. The system learns to recognize the virus as invaders and then produces antibodies which will try to neutralize the virus if it re-infects before it can spread and cause illness. This is natural active immunity and can lead to lifelong protection [Herd immunity trends].

Most fresh, organic foods (fruits, vegetables and proteins) are now not easily available because of the organization of the human settlement. We no longer live within reach of farms from where we can avail fresh foods. Our bodies are thus deprived of the natural antidotes/ingredients that come from a diet that contains plenty of fresh fruits and vegetables such as kales, berries, broccoli, kiwis, garlic, ginger and
spices that contain phytonutrients which are plant chemicals that protect our bodies from diseases by increasing our immune function. This reduces development of the immune system and increases our vulnerability to diseases like covid-19. Natural immunity can be boosted by certain nutrients found only in fresh healthy foods [herd immunity trends]. The organically grown foods contain significantly fewer contaminants than their conventional counterparts as well as significantly richer nutrient content. However pressure to feed large urban populations have forced authorities in most parts of the world to discard organic farming and embrace conventional methods which are faster and give higher yields (GMOs). Otherwise the population of people with herd immunity would therefore be high, thus reducing the pool of people who can catch the disease and in turn reducing the risk of the disease spreading to the so far unaffected. Currently, most people in the world feed on processed foods whose nutritional value have been altered and may impair the immunity of the body. With appropriate action it would be possible to reverse the effects of degradation on many ecosystems and rebuild the natural architecture. It is possible to conserve the world’s ecosystems and natural resources while still ensuring the population is fed and infrastructure is still being developed.

In this study we have analysed a mathematical model of the effect of destruction of the natural ecosystem and its effects on the human immune system against infectious diseases like covid-19.

**Model description, formulation and analysis**

The total human population is partitioned into five stages, $S_1$ are the susceptible who live in a natural ecosystem and to some degree have been exposed to the virus and also feed on fresh organic foods hence have developed natural immunity, $S_w$ are also susceptible who do not live in a natural ecosystem and have low immunity, $I_M$ are the individuals infected with covid-19 virus but with mild sickness and the majority easily recover. $I_{SS}$ are those who get severely sick on infection and $R$ are the recovered persons. $\Lambda_a$ is the rate of recruitment into susceptible with natural immunity, while $\Lambda_b$ is the rate of recruitment into susceptible without natural immunity. $\beta$ and $h$ (very small) are the rates of becoming mildly sick by those with natural immunity and those without natural immunity respectively. $\theta$ is the recovery rate of those who get mildly sick and $\alpha$ is the rate at which $S_1$ rid themselves off the virus without showing any signs of sickness. $\rho$ is the rate at which the mildly sick may get severely sick, but $\rho$ is very small. The susceptible with low immunity get severely sick at the rate of $\phi$ and recover at very low rate of $\gamma$ but die at the rate of $\mu$ from covid-19 infection. Here

$$\beta = \frac{\Lambda_a(I_M + I_{SS})}{N_H}$$  \hspace{1cm} (1)
and

$$\phi = \frac{\lambda_1 (\rho I_M + I_{SS})}{N_H}$$  \hspace{1cm} (2)$$

$$\lambda_1$$ and $$\lambda_2$$ are effective contact rates with $$S_I$$ and $$S_W$$ respectively. It is been assumed that the probability of becoming susceptible again after recovery is zero and the deaths are only due to covid-19 infection.

![Diagram of the model](image)

(ovid-19 and organic food)

And from the above definitions we have the following model.

$$\frac{dS_I}{dt} = \Lambda_a - \beta S_I - \alpha S_I$$

$$\frac{dS_W}{dt} = \Lambda_b - \phi S_W - h S_W$$

$$\frac{dI_M}{dt} = \beta S_I - \rho I_M - \theta I_M$$

$$\frac{dI_{SS}}{dt} = \phi S_W + \rho I_M - \eta I_{SS} - \mu I_{SS}$$

$$\frac{dR}{dt} = \theta I_M + \eta I_{SS} + \alpha S_I$$

(3)

The infection free equilibrium (IFE) is given by
$I_0 = (S_t(t), Sw(t), IM(t), ISS(t), R(t)) = (S_{I0}, Sw(t), 0, 0, R(t))$.

**Analysis of the infection free equilibrium**

The basic reproduction number is the average number of secondary infections due to a single infectious individual introduced in a fully susceptible population during the entire period of infectivity. The next generation matrix approach is used to calculate the basic reproduction number $R_0$.

The rate of secondary infection increase may be denoted by the $i^{th}$ disease compartment by $f$ and $v$ the rate of disease progression to $i^{th}$ compartment. From the model (3), taking the derivatives with respect to the state variables for the transmission and transition terms, the matrices $F$ and $V$ can be found by

\[
F = \left( \frac{\partial f_i(I_0)}{\partial x_j} \right) \\
V = \left( \frac{\partial v_i(I_0)}{\partial x_j} \right)
\]

Taking the rates of appearance of new infection in each compartment defined as curl $f$

\[
f = \begin{bmatrix} \beta S_1 \\ \phi S_w \end{bmatrix}
\]

and differentiating with respect to the diseased stages to get

\[
F = \begin{bmatrix} \lambda_1 & \lambda_2 \\ \lambda_2 \rho & \lambda_2 \end{bmatrix}
\]

Likewise taking curl $v$ the rate of transfer of individuals in and out of a particular compartment by any other means

\[
v = \begin{bmatrix} \rho IM_t + \theta IM_t \\ -\rho IM_t + \eta ISS + \mu ISS \end{bmatrix}
\]

and differentiating with respect to the diseased stages to get

\[
V = \begin{bmatrix} \rho + \theta & 0 \\ -\rho & \eta + \mu \end{bmatrix}
\]

$R_0$ is the spectral radius of $FV'$ which in this case is

\[
R_0 = \frac{\lambda_1 (\eta + \mu + \rho)}{(\rho + \theta)(\eta + \mu)}
\]

**Theorem 1:** If $R_0 < 1$, then the IFE of the system (3) is locally asymptotically stable (LAS) and it is unstable when $R_0 > 1$. The stability nature determines the extent to which the disease will disappear from the population.

**Proof:** To prove the results we evaluate the Jacobian matrix of the model (3) at infection free equilibrium $J(I_0)$ and it’s given by
Two of the eigenvalues of the above Jacobian matrix \( J(I_0) \) are negative \(-\rho\) and \(-(\eta + \mu)\). For the rest of the eigenvalues we take the 3x3 matrix \( B = \begin{bmatrix} \rho & \lambda_2 & 0 \\ \theta & \eta & 0 \\ 0 & 0 & \eta \end{bmatrix} \).

For Routh-Hurwitz criteria, it is sufficient to prove that trace \((\text{Tr})\) of matrix \( B \) is negative and the determinant is positive if \( R_0 < 1 \). Thus trace of the matrix \((B)\) is 
\[
\lambda_1 + \lambda_2
\]
and determinant of \( B \) is zero, hence the IFE is locally asymptotically stable.

**Global Asymptotic Stability (GAS) of the Infection Free Equilibrium (IFE)**

**Lemma 1**: The infection Free Equilibrium (IFE) of the model (3) is globally asymptotically stable (GAS) if \( R_0 < 1 \) and unstable if \( R_0 > 1 \). From the above results since Trace \( J(I_0) > 0 \) but the Det \( J(I_0) = 0 \) which doesn’t satisfy the prescribed threshold criteria based on Gerald (2012), then the IFE does not satisfy the criteria for Globally Asymptotic Stability (GAS).

**Proof**: Proof of the above lemma is based on using comparison theorem [cite]. The equation of the infected components in the model (3) is written as

\[
\begin{bmatrix}
\frac{dI_M}{dt} \\
\frac{dI_S}{dt}
\end{bmatrix} = (F-V) \begin{bmatrix} I_M \\
I_S
\end{bmatrix} - \frac{S}{N_H} \begin{bmatrix} \lambda_1 & \lambda_2 \\
\lambda_2 \rho & \lambda_2
\end{bmatrix}
\]

\[
F-V = \begin{bmatrix} \lambda_1 - \rho - \theta & \lambda_1 \\
\lambda_2 \rho + \rho & \lambda_2 - \eta - \mu
\end{bmatrix}.
\]

The eigenvalues are all positive and thus the \( I_0 \) is globally asymptotically unstable despite \( R_0 < 1 \). Since covid-19 is highly infectious there is backward bifurcation at \( R_0 \).
There occurs a sudden, abrupt and explosive exchange between IFE and the endemic equilibrium and once \( R_0 > 1 \) the disease invades at high levels equivalent to pandemic levels as illustrated in figure 1. Covid-19 will then be endemic and spreads from one person to the other during the course of illness and social interactions of the individuals.

![Figure 1](image1)

**Figure 1:** Despite \( R_0 < 1 \), the IFE is not globally asymptotically stable (GAS).

**Numerical Simulations:** Simulations are used to give graphical projection of the results of the model. The simulations are done with varying initial conditions.

![Figure 2](image2)

**Figure 2:** The simulation of rates of infection in the two susceptible groups show that there is more infection in the susceptible without natural immunity which keeps on rising. For \( S_I \) there is a slight rise which reduces very fast and there after the infection rates are very low. Those with natural immunity are able to fight the virus and resist infection or just become mildly sick and recover even without treatment.

![Figure 3](image3)

**Figure 2:** This is the simulation of the infected population of \( S_I \) and \( S_W \) in a longer period (months). The \( S_W \) who are infected rise sharply and then falls drastically.
Since they don’t have natural immunity, they are highly vulnerable to infection and similarly they easily become severely sick and are likely to die. And so the graph drops due to high rates of death. While the graph of $S_i$ rises gradually due to low rates of infection and the drop is mostly due to recoveries with few deaths of those who become severely sick.

**Figure 3:** Simulation of the rate recovery of different stages of the disease. The mildly sick recover the curve flattens because of death of the few who become seriously sick and most likely die.

**Discussion**

Cocid-19 is a highly infectious viral disease which gets pandemic within a very short time in the community. Majority of patients have mild to moderate symptoms and transmit the disease effectively to one another in the community if there is no control. The asymptomatic patients with Covid-19 infection continue infecting others and they will continue transmit it to others. The model developed show that the living in the natural ecosystem and consumption of organic foods are preventive and control measures against covid-19 infection. People who live in the natural ecosystem are in a position to develop natural immunity as a result of being continuously exposed to the virus which reside in the animals within the ecosystem. More so, feeding on the fresh organic foods containing fresh natural nutrients are important in enabling them to have a better immunity to contain the virus.

**Conclusion**

It is believed that living in the natural ecosystem and eating organic foods are effective prevention and control measures against Covid-19. This will enable most of the infected patients to progress to recovery. Results of this study will sensitize the global population to reconcile modernization, urbanization and environmental conservation in order to prevent viral and bacterial pandemics.
References


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