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Mathematical Model on The Control of Intestinal Torsion in Pigs

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ABSTRACT

An institutional based research at Federal College of Education (Technical) Ekiadolor, Benin City, Edo State, Nigeria, examined a pig farm in the Ovia North East Local Government Area, investigating a mathematical model on the control of intestinal torsion in pigs through vaccination and fibre-rich nutritional feeds. It results in the application of a four-compartment mathematical model for pig intestinal torsion, which is made up of the classes S, I, V, and R for the Susceptible, Infected, Vaccinated and Recovered classes. This model is used to solve for the reproduction number (R0) using the Next Generation Matrix (NGM), to solve the positivity model, to solve for the existence and uniqueness of the model, and to plot the model graphs using Maple.

Keywords : Intestinal Torsion, Mathematical Model, Vaccination and Reproduction Number

I. INTRODUCTION

Pigs with intestinal torsion, also known as volvulus, have a serious gastrointestinal condition that can cause serious health problems like colic, ischemia, and even death. This illness is characterised by intestinal twisting, which can result in tissue necrosis and impede blood flow. It's critical for swine producers to comprehend intestinal torsion's causes, signs, and treatment options. Nutritional management is one of these tactics that is essential to preventing this illness [1]. Numerous reasons can lead to intestinal torsion. It is frequently linked to abrupt dietary changes in pigs, high feed consumption, or feeding techniques that encourage quick consumption [2]. Stress, the environment, and some breeds' innate anatomical predispositions are other contributing variables. Abdominal pain resulting from the acute onset of torsion may appear as rolling, resistance to movement, or distress signals.

The following are some of the clinical signs that pigs suffering from intestinal torsion may exhibit: Abdominal distension, Colic (indicated by kicking at the belly or lying down frequently), Anorexia, Lethargy and Vomiting or abnormal faecal output [3]. The diagnosis of intestinal torsion usually involves clinical examination and may be supported by imaging techniques such as ultrasound or radiography to confirm the presence of torsion. An effective strategy for intestinal torsion prevention involves a multifaceted approach, with nutritional management being a cornerstone of the approach [4]. Alternating abruptly between diets is one of the main causes of intestinal torsion. The producers should gradually alter the diet to reduce this risk. It is necessary to gradually introduce new meals over a period of a week or longer to enable the pig's digestive tract to adjust without becoming overburdened. For example, a gradual transition from a grower to a finisher diet can reduce the chance of torsion.

Gastrointestinal health is significantly influenced by the diet's makeup. Fibre-rich diets can lower the risk of torsion and assist control intestinal motility.

Because fibre slows down digestion, it encourages a continuous release of nutrients and reduces the chance that meals will be consumed quickly. Due to their high calorie density, diets designed for growing pigs may find this to be especially crucial. The frequency of feedings has a major impact on the risk of intestinal torsion. Pigs should not be fed one or two large meals during the day; instead, they should be provided many smaller meals. This method not only promotes improved digestion but also lessens the possibility that pigs would overeat in one sitting, which is a typical cause of torsion. Additionally, utilising feeding methods that promote slower eating—like slow feeders or troughs with access restrictions can also help reduce the risk.

Drinking enough water is essential for gut health. Pigs' gastrointestinal problems, such as torsion, can be avoided and digestion can be aided by providing them with continuous access to clean, fresh water. Torsion risk can rise due to reduced intestinal motility brought on by dehydration. Encouraging water intake can also aid in normalising digestive processes and softening the diet.

Animal stress levels should be taken into account while developing nutritional solutions. Numerous gastrointestinal problems are known to be influenced by stress. Reducing overcrowding, making sure housing is pleasant, and offering environmental enrichment are examples of actions that minimise stress and can improve general health and lower the incidence of intestinal torsion.

Probiotics and prebiotics can help maintain gut health and stave off gastrointestinal problems when added to the diet. Probiotics improve digestion and nutrient absorption by bringing good bacteria into the gut. These good bacteria eat prebiotics, which encourages their growth and activity. When combined, they can support the preservation of a balanced gut flora, which is necessary for healthy intestinal function.

Pigs that are at risk can be identified through routinely assessing growth rates and body condition. Pigs that are overly overweight or growing too quickly may be more prone to digestive problems. Intestinal torsion risk can be decreased by modifying the meal to provide a balanced growth rate.

1.1 Problem Statement:

To research on intestinal torsion in pigs in Ovia North East Local Government Area of Edo State and also to solve the mathematical model that shows the control of the disease through the graphical representation.

1.2 Objectives of the study:

The objective of this research is to:

i. research on the intestinal torsion condition in pigs that are in Ovia North East, Edo State.
ii. solve the model mathematically
iii. solve the positivity of the model.
iv. solve the existence and uniqueness of the model
v. solve for the reproduction number (R_0)
vi. represent the result graphically (maple 18)

Pig intestinal torsion is a significant illness that needs to be managed by farmers, especially in terms of nutrition. Producers can greatly lower the incidence of this illness by putting tactics like progressive dietary modifications, modifying feed composition, optimising feeding techniques, guaranteeing an adequate water supply, and stress management into practice. Probiotic integration along with growth rate monitoring improves gut health and resilience even more. Pig producers can increase productivity and profitability in their operations while also improving animal welfare by giving priority to nutritional interventions. In order to prevent intestinal torsion and maintain the health and productivity of pigs throughout their growth phases, it is imperative to comprehend the relationship between diet and gastrointestinal health.

Diagram 1

II. METHODS AND MATERIAL

2.1 Computation of Disease Equilibrium

A four compartment mathematical model was designed for *Intestinal Torsion in Pigs* which comprises of the Susceptible Class = S, Infected Class = I, Vaccinated Class = V and Recovery Class = R which is gives as follows:

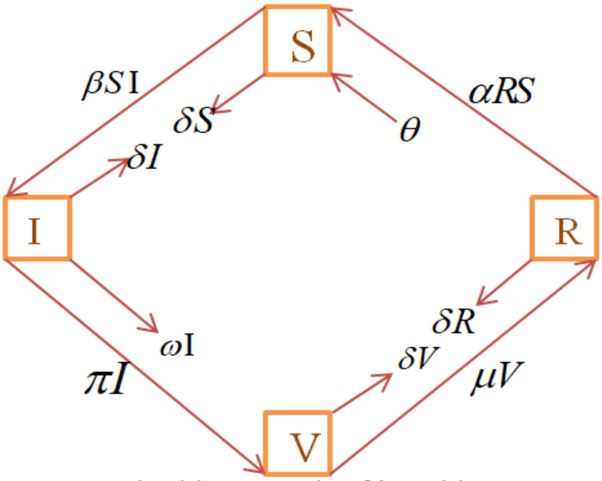

Diagram 2: Pictorial Representation of the Model

TABLE 1
MODEL INTERPRETATION

model parameters	Interpretation
Θ	birth rate of pigs into the susceptible class-s
Β	movements of pigs to infected class-i (contact rate)
Π	movement of pigs to vaccinated class-v
Μ	movement of pigs to recovery class-r
Α	movement of pigs to susceptible class-s
δ	natural death
ω	advancement rate from infected to another state or new disease

$$\frac{ds}{dt}=\theta-\left(\delta+\frac{\beta I}{N}-\alpha R\right)S \quad (1)$$

$$\frac{dI}{dt}=\frac{\beta SI}{N}-(\delta+\pi+\omega)I \quad (2)$$

$$\frac{dV}{dt}=\pi I-(\mu+\delta)V \quad (3)$$

$$\frac{dR}{dt}=\mu V-(\alpha S+\delta)R \quad (4)$$

2.2 DISEASE FREE EQUILIBRIUM (DFE) POINT:

$$\frac{dS}{dt}=\frac{dI}{dt}=\frac{dV}{dt}=\frac{dR}{dt}=0 \quad (5)$$

Then

$$\theta-\left(\delta+\frac{\beta I}{N}-\alpha R\right)S=0 \quad (6)$$

$$\frac{\beta SI}{N}-(\delta+\pi+\omega)I=0 \quad (7)$$

$$\pi I-(\mu+\delta)V=0 \quad (8)$$

$$\mu V-(\alpha S+\delta)R=0 \quad (9)$$

At I = 0

$$S_0=\frac{\theta}{\alpha R+\delta} \quad (10)$$

$$DFE=\{S_0,\mathrm{I}_0,V_0,R_0\}=\left\{\frac{\theta}{\alpha R+\delta},0,0,0\right\}$$

2.3 ENDEMIC EQUILIBRIUM POINT

There is presence of intestinal torsion.

From (6)

$$\theta-\left(\delta+\frac{\beta I}{N}-\alpha R\right)S=0$$

$$S=\frac{\theta}{\left(\delta+\frac{\beta I}{N}-\alpha R\right)} \quad (11)$$

From (8)

$$\pi I-(\mu+\delta)V=0$$

$$I=\frac{(\mu+\delta)\mathrm{V}}{\pi} \quad (12)$$

From (8)

$$\pi I-(\mu+\delta)V=0$$

$$V=\frac{\pi I}{(\mu+\delta)} \quad (13)$$

From (9)

$$\mu V-(\alpha S+\delta)R=0$$

$$R=\frac{\mu V}{(\alpha S+\delta)} \quad (14)$$

$$EE=\{S,I,V,R\}=$$

$$\left\{\frac{\theta}{\left(\delta+\frac{\beta I}{N}-\alpha R\right)},\frac{(\mu+\delta)V}{\pi},\frac{\pi I}{(\mu+\delta)},\frac{\mu V}{(\alpha S+\delta)}\right\}$$

2.4 REPRODUCTION NUMBER (R_0)

At the disease free equilibrium when infection is at zero that is I = 0, the equilibrium value for susceptible population is at S^*

From (2)

Let $\frac{dI}{dt}=0$ then $\beta SI-(\delta+\pi+\omega)I=0$

If $I\neq 0$, then $\beta S=(\delta+\pi+\omega)$

Such that $$S^*=\frac{\delta+\pi+\omega}{\beta} \quad (15)$$

To determine the rate of infected pigs, the rate newly infected pigs in the model is given by: βSI

The number of new infections generated by one infected pig (Reproduction Number R_0) can be solved using: $R_0=\frac{New\text{ infections per unit time}}{\text{Re}moval\text{ Rate}}$

Removal Rate = $\delta+\pi+\omega$

$$R_0=\frac{\beta S^*}{\delta+\pi+\omega}$$

Substitute the equilibrium value S^* in equation (15)

Put (15) into R_0

Then $R_0 = 1$

Therefore

The Basic Reproduction Number is R_0 in the model

$$R_0=\frac{\beta S^*}{\delta+\pi+\omega} \quad (16)$$

2.5 POSITIVITY OF THE MODEL

$$S' = \theta - \left(\delta + \frac{\beta I}{N} - \alpha R\right)S \qquad (17)$$

$$I' = \frac{\beta SI}{N} - (\delta + \pi + \omega)I \qquad (18)$$

$$V' = \pi I - (\mu + \delta)V \qquad (19)$$

$$R' = \mu V - (\alpha S + \delta)R \qquad (20)$$

From (17)

$$\frac{ds}{dt} = \theta - \left(\delta + \frac{\beta I}{N} - \alpha R\right)S$$

$$\frac{ds}{dt} \geq \theta - \left(\delta + \frac{\beta I}{N} - \alpha R\right)S$$

Such That $S_0 > 0$

$$S(\mathrm{t}) \geq e^{\left(\delta + \frac{\beta I}{N} - \alpha R\right)\mathrm{t}}.S_0 \qquad (21)$$

From (18)

$$\frac{dI}{dt} = \frac{\beta SI}{N} - (\delta + \pi + \omega)I$$

$$\frac{dI}{dt} \geq \frac{\beta SI}{N} - (\delta + \pi + \omega)I$$

Such That $I_0 > 0$

$$I(\mathrm{t}) \geq \mathrm{e}^{\left(\frac{\beta S}{N}\right)\mathrm{t} - (\delta + \pi + \omega)\mathrm{t}}.I_0 \qquad (22)$$

From (19)

$$\frac{dV}{dt} = \pi I - (\mu + \delta)V$$

$$\frac{dV}{dt} \geq \pi I - (\mu + \delta)V$$

Such that $V_0 > 0$

$$V(\mathrm{t}) = \mathrm{e}^{-(\mu+\delta)\mathrm{t}}.V_0 \qquad (23)$$

From (20)

$$\frac{dR}{dt} = \mu V - (\alpha S + \delta)R$$

$$\frac{dR}{dt} \geq \mu V - (\alpha S + \delta)R$$

Such that $R_0 > 0$

$$R(\mathrm{t}) \geq e^{-(\alpha \mathrm{s} + \delta)\mathrm{t}}.\mathrm{R}_0 \qquad (24)$$

Thus, for all t > 0, all the solution set {S(t) I(t) V(t) and R(t)} of the system of equation (17) to (20) are all positive.

TABLE 2. MODEL PARAMETER VALUES

model parameters	Values
θ	1000
β	0.1
π	0.01
μ	0.1
α	0.001
δ	0.015
ω	0.05
S_0	10
I_0	7
V_0	5
R_0	3

2.6 EXISTENCE AND UNIQUENESS SOLUTION OF THE MODEL

The system of equations be denoted as follows:

$$f_1 = \theta - \left(\delta + \frac{\beta I}{N} - \alpha R\right)S \qquad (25)$$

$$f_2 = \frac{\beta SI}{N} - (\delta + \pi + \omega)I \qquad (26)$$

$$f_3 = \pi I - (\mu + \delta)V \qquad (27)$$

$$f_4 = \mu V - (\alpha S + \delta)R \qquad (28)$$

The partial derivative of equation (25) to (28) gives the following:

From equation (25)

$$\left|\frac{\delta f_1}{\delta S}\right| = \left|-\left(\delta + \frac{\beta I}{N} - \alpha R\right) S\right| < \infty, \left|\frac{\delta f_1}{\delta I}\right| = 0 < \infty,$$

$$\left|\frac{\delta f_1}{\delta V}\right| = 0 < \infty, \left|\frac{\delta f_1}{\delta R}\right| = 0 < \infty$$

From equation (26)

$$\left|\frac{\delta f_2}{\delta S}\right| = \left|\frac{\beta I}{N}\right| < \infty, \left|\frac{\delta f_2}{\delta I}\right| = \left|-(\delta + \pi + \omega)\right| < \infty,$$

$$\left|\frac{\delta f_2}{\delta V}\right| = 0 < \infty, \left|\frac{\delta f_2}{\delta R}\right| = 0 < \infty$$

From equation (27)

$$\left|\frac{\delta f_3}{\delta S}\right| = 0 < \infty, \left|\frac{\delta f_3}{\delta I}\right| = |\pi| < \infty, \left|\frac{\delta f_3}{\delta V}\right| = \left|-(\mu + \delta)\right| < \infty,$$

$$\left|\frac{\delta f_3}{\delta R}\right| = 0 < \infty$$

From equation (28)

$$\left|\frac{\delta f_4}{\delta S}\right| = |-\alpha R| < \infty, \left|\frac{\delta f_4}{\delta I}\right| = 0 < \infty, \left|\frac{\delta f_4}{\delta V}\right| = |\mu| < \infty,$$

$$\left|\frac{\delta f_4}{\delta R}\right| = \left|-(\alpha S + \delta)\right| < \infty$$

As shown above, the partial derivative of equation (25) to (28) exist, they are finite and bounded. Therefore SIVR has a unique solution.

2.7 Analytical Solution using Homotopy Pertubation Method

From (1) to (4)

$$\frac{ds}{dt} = \theta - \left(\delta + \frac{\beta I}{N} - \alpha R\right) S \qquad (1)$$

$$\frac{dI}{dt} = \frac{\beta SI}{N} - (\delta + \pi + \omega) I \qquad (2)$$

$$\frac{dV}{dt} = \pi I - (\mu + \delta) V \qquad (3)$$

$$\frac{dR}{dt} = \mu V - (\alpha S + \delta) R \qquad (4)$$

Using the following initial condition on (1) to (4)

$\{S(0) = S_0, I(0) = I_0, V(0) = V_0, R(0) = R_0\}$ (29)

Assume that

$$\left.\begin{aligned} S &= a_0 + ra_1 + r^2 a_2 + \ldots \\ I &= b_0 + rb_1 + r^2 b_2 + \ldots \\ V &= c_0 + rc_1 + r^2 c_2 + \ldots \\ R &= d_0 + rd_1 + r^2 d_2 + \ldots \end{aligned}\right\} \quad (30)$$

Applying HPM on equation (1) to (4) gives the following

$$(1-r)\frac{dS}{dt} + r\left(\frac{dS}{dt} + (\delta + KI - \alpha R) S - \theta\right) = 0$$

Where K = $\dfrac{\beta}{N}$

$$(1-r)\left(a_0^1 + ra_1^1 + r^2 a_2^1 + \ldots\right) + r\begin{pmatrix} \left(a_0^1 + ra_1^1 + r^2 a_2^1 + \ldots\right) \\ + \begin{bmatrix} k\left(b_0 + rb_1 + r^2 b_2 + \ldots\right) \\ -\alpha\left(d_0 + rd_1 + r^2 d_2 + \ldots\right) \\ +\delta \end{bmatrix} \\ \left(a_0 + ra_1 + r^2 a_2 + \ldots\right) - \theta \end{pmatrix}$$

$$= 0$$

i.e.

$$\left(a_0^1 + ra_1^1 + r^2 a_2^1 + \ldots\right) + \begin{bmatrix} \delta r + k\left(rb_0 + r^2 b_1 + r^3 b_2 + \ldots\right) \\ -\alpha\left(rd_0 + r^2 d_1 + r^3 d_2 + \ldots\right) \end{bmatrix}$$

$$\left(a_0 + ra_1 + r^2 a_2 + \ldots\right) - \theta r = 0$$

Expanding and collecting the coefficients of like powers of r gives

$$\left.\begin{aligned} &r^0 : a_0^1 = 0 \\ &r^1 : a_1^1 + \delta a_0 + kb_0 a_0 - \alpha d_0 a_0 - \theta = 0 \\ &r^2 : a_2^1 + ka_0 b_1 + kb_0 a_1 - \alpha d_1 a_0 - \alpha d_0 a_1 = 0 \end{aligned}\right\} \quad (31)$$

Similarly, applying HPM on (2) gives

$$(1-r)\frac{dI}{dt} + r\left(\frac{dI}{dt} + (\delta + \pi + \omega) I - KSI\right) = 0$$

$$(1-r)\left(b_0^1+rb_1^1+r^2b_2^1+...\right)+r\begin{pmatrix}\left(b_0^1+rb_1^1+r^2b_2^1+...\right)\\+\left(\delta+\pi+\omega\right)\\\left(b_0+rb_1+r^2b_2+...\right)\\-k\left(a_0+ra_1+r^2a_2+...\right)\\\left(b_0+rb_1+r^2b_2+...\right)\end{pmatrix}=0$$

$$\left(b_0^1+rb_1^1+r^2b_2^1+...\right)+\left(\delta+\pi+\omega\right)\left(rb_0+r^2b_1+r^3b_2+...\right)$$
$$-k\left(ra_0+r^2a_1+r^3a_2+...\right)\left(b_0+rb_1+r^2b_2+...\right)=0$$

Expanding and collecting the coefficients of like powers of r gives:

$$\left.\begin{aligned}&r^0:\mathrm{b}_0^1=0\\&r^1:\mathrm{b}_1^1+(\delta+\pi+\omega)\,\mathrm{b}_0-ka_0b_0=0\\&r^2:\mathrm{b}_2^1+(\delta+\pi+\omega)\,\mathrm{b}_1-ka_0b_1-ka_1b_0=0\end{aligned}\right\}\quad(32)$$

Also,

$$(1-r)\frac{dV}{dt}+r\left(\frac{dV}{dt}+(\mu+\delta)V-\pi I\right)=0$$

i.e

$$(1-r)\left(c_0^1+rc_1^1+r^2c_2^1+...\right)+r\begin{pmatrix}\left(c_0^1+rc_1^1+r^2c_2^1+...\right)\\+\left(\mu+\delta\right)\\\left(c_0+rc_1+r^2c_2+...\right)\\-\pi\left(b_0+rb_1+r^2b_2+...\right)\end{pmatrix}=0$$

$$\left(c_0^1+rc_1^1+r^2c_2^1+...\right)+\left(\mu+\delta\right)\left(rc_0+r^2c_1+r^3c_2+...\right)$$
$$-\pi\left(rb_0+r^2b_1+r^3b_2+...\right)=0$$

Collecting like powers of r gives

$$\left.\begin{aligned}&r^0:\mathrm{c}_0^1=0\\&r^1:\mathrm{c}_1^1+(\mu+\delta)\,\mathrm{c}_0-\pi b_0=0\\&r^2:\mathrm{c}_2^1+(\mu+\delta)\,\mathrm{c}_1-\pi b_1=0\end{aligned}\right\}\quad(33)$$

Finally,

$$(1-r)\frac{dR}{dt}+r\left(\frac{dR}{dt}+(\alpha S+\delta)R-\mu V\right)=0$$

$$(1-r)\left(d_0^1+rd_1^1+r^2d_2^1+...\right)+r\begin{pmatrix}\left(d_0^1+rd_1^1+r^2d_2^1+...\right)\\+\left(\alpha+\left(a_0+ra_1+r^2a_2+...\right)+\delta\right)\\\left(d_0+rd_1+r^2d_2+...\right)\\-\mu\left(c_0+rc_1+r^2c_2+...\right)\end{pmatrix}=0$$

$$\left(d_0^1+rd_1^1+r^2d_2^1+...\right)+\left(\alpha+\left(ra_0+r^2a_1+r^3a_2+...\right)+\delta r\right)$$
$$\left(d_0+rd_1+r^2d_2+...\right)-\mu\left(rc_0+r^2c_1+r^3c_2+...\right)=0$$

Collecting like powers of r

$$\left.\begin{aligned}&r^0:\mathrm{d}_0^1=0\\&r^1:\mathrm{d}_1^1+\alpha a_0d_0+\delta-\mu c_0=0\\&r^2:\mathrm{d}_2^1+\alpha a_1d_0+\alpha a_0d_1-\mu c_1=0\end{aligned}\right\}\quad(34)$$

Solving (31) and (34) by direct integration method for r^0 gives

$a_1^0=0$

$a_0=A$ (applying initial condition)

$$\left.\begin{aligned}&a_0=S_0\\&b_0=I_0\\&c_0=V_0\\&d_0=R_0\end{aligned}\right\}\quad(35)$$

Where S_0, I_0, V_0 *and* R_0 are all constants

Using (35) into (31-34) by method of direct integration for r gives the following

$$a_1=\left(\theta+\alpha d_0a_0-kb_0a_0-\delta a_0\right)t$$

$$a_1=\left(\theta+\alpha S_0R_0-kS_0I_0-\delta S_0\right)t \qquad (36)$$

Similarly

$$b_1=\left(ka_0b_0-\left(\delta+\pi+\omega\right)b_0\right)t$$

$$b_1=\left(kS_0I_0-\left(\delta+\pi+\omega\right)I_0\right)t \qquad (37)$$

Also

$$c_1=\left(\pi b_0-\left(\mu+\delta\right)c_0\right)t$$

$$c_1=\left(\pi I_0-\left(\mu+\delta\right)V_0\right)t \qquad (38)$$

then

$$d_1=\left(\mu c_0-\alpha a_0d_0\right)t$$

$$d_1=\left(\mu V_0-\alpha S_0R_0\right)t \qquad (39)$$

Using (35) and (36 - 39) into (31 - 34) and integrating directly with respect to time for r² gives

$$a_2 = \frac{1}{2}\left(\alpha d_0 a_1 + \alpha a_0 d_1 - k a_1 b_0 - k a_0 b_1\right) t^2$$

$$a_2 = \frac{1}{2}\left(\begin{array}{l} \alpha\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) R_0 + \alpha S_0\left(\mu V_0 - \alpha S \right. \\ -k\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) I_0 - k S_0\left(k S_0 I_0 - (\right. \end{array}\right.$$

Similarly

$$b_2 = \frac{1}{2}\left(k a_1 b_0 + k a_0 b_1 - (\delta + \pi + \omega) b_1\right) t^2$$

$$b_2 = \frac{1}{2}\left(k\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) I_0 + k S_0\left(k S_0 I_0 - (\delta + \pi + \omega) I_0\right)\right) t^2 \quad (41)$$

also

$$c_2 = \frac{1}{2}\left(\pi b_1 - (\mu + \delta) c_1\right) t^2$$

$$c_2 = \frac{1}{2}\left(\pi\left(k S_0 I_0 - (\delta + \pi + \omega) I_0\right) - (\mu + \delta)\left(\pi I_0 - (\mu + \delta) V_0\right)\right) t^2 \quad (42)$$

Finally

$$d_2 = \frac{1}{2}\left(\mu c_1 - \alpha a_0 d_1 - \alpha a_1 d_0\right) t^2$$

$$d_2 = \frac{1}{2}\left(\begin{array}{l} \mu\left(\pi I_0 - (\mu + \delta) V_0\right) - \alpha S_0\left(\mu V_0 - \alpha S_0 R_0\right) \\ -\alpha\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) R_0 \end{array}\right) t^2 \quad (43)$$

From(30)

$$\left.\begin{array}{l} S = a_0 + r a_1 + r^2 a_2 + \ldots \\ I = b_0 + r b_1 + r^2 b_2 + \ldots \\ V = c_0 + r c_1 + r^2 c_2 + \ldots \\ R = d_0 + r d_1 + r^2 d_2 + \ldots \end{array}\right\} \quad (30)$$

Let

$$\left.\begin{array}{l} \lim_{r\to 1} S(t) = \lim_{r\to 1}\left(a_0 + r a_1 + r^2 a_2 + \ldots\right) = a_0 + a_1 + a_2 + \ldots \\ \lim_{r\to 1} I(t) = \lim_{r\to 1}\left(b_0 + r b_1 + r^2 b_2 + \ldots\right) = b_0 + b_1 + b_2 + \ldots \\ \lim_{r\to 1} V(t) = \lim_{r\to 1}\left(c_0 + r c_1 + r^2 c_2 + \ldots\right) = c_0 + c_1 + c_2 + \ldots \\ \lim_{r\to 1} R(t) = \lim_{r\to 1}\left(d_0 + r d_1 + r^2 d_2 + \ldots\right) = d_0 + d_1 + d_2 + \ldots \end{array}\right\} \quad (44)$$

this implies

$$\lim_{r\to 1} S(t) = \lim_{r\to 1}\left(a_0 + r a_1 + r^2 a_2 + \ldots\right) = a_0 + a_1 + a_2 + \ldots$$

$$S(t) = S_0 + \left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) t + \frac{1}{2}\left(\begin{array}{l} \alpha\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) R_0 \\ + \alpha S_0\left(\mu V_0 - \alpha S_0 R_0\right) \\ -k\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) I_0 \\ -k S_0\left(k S_0 I_0 - (\delta + \pi + \omega) I_0\right) \end{array}\right) t^2 \quad (45)$$

$$\lim_{r\to 1} I(t) = \lim_{r\to 1}\left(b_0 + r b_1 + r^2 b_2 + \ldots\right) = b_0 + b_1 + b_2 + \ldots$$

$$I(t) = I_0 + \left(k S_0 I_0 - (\delta + \pi + \omega) I_0\right) t + \frac{1}{2}\left(\begin{array}{l} k\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) I_0 \\ + k S_0\left(k S_0 I_0 - (\delta + \pi + \omega) I_0\right) \end{array}\right) t^2 \quad (46)$$

$$\lim_{r\to 1} V(t) = \lim_{r\to 1}\left(c_0 + r c_1 + r^2 c_2 + \ldots\right) = c_0 + c_1 + c_2 + \ldots$$

$$V(t) = V_0 + \left(\pi I_0 - (\mu + \delta) V_0\right) t + \frac{1}{2}\left(\begin{array}{l} \pi\left(k S_0 I_0 - (\delta + \pi + \omega) I_0\right) \\ -(\mu + \delta)\left(\pi I_0 - (\mu + \delta) V_0\right) \end{array}\right) t^2 \quad (47)$$

$$\lim_{r\to 1} R(t) = \lim_{r\to 1}\left(d_0 + r d_1 + r^2 d_2 + \ldots\right) = d_0 + d_1 + d_2 + \ldots$$

$$R(t) = R_0 + \left(\mu V_0 - \alpha S_0 R_0\right) t + \frac{1}{2}\left(\begin{array}{l} \mu\left(\pi I_0 - (\mu + \delta) V_0\right) \\ -\alpha S_0\left(\mu V_0 - \alpha S_0 R_0\right) \\ -\alpha\left(\theta + \alpha S_0 R_0 - k S_0 I_0 - \delta S_0\right) R_0 \end{array}\right) t^2 \quad (48)$$

III.RESULTS AND DISCUSSION

Figure 1 shows sensitivity analysis of Susceptible Class against time for different values of infectious rate β, it was observed that as the infectious rate increases the susceptible class decreases.

Figure 2 shows the graph of sensitivity analysis of α on Susceptible Class against time for different value of α on back to susceptible class, it was well observed that recovered pigs reduces as transmission rate back to susceptible class increases.

Figure 3 depicts the sensitivity analysis of Birth Rate θ on Susceptible Class against time and it was observed that the susceptible class increased in population as birth rate increases.

Figure 4 displays sensitivity analysis of Contact Rate β on Infected Class against time, showing the rate of infectious Pigs increases and the infected class increases.
Figure 5 shows sensitivity analysis of Natural Death Rate δ on Infected Class, it was observed that infected class reduces as natural death rate increases Figure 6 depicts sensitivity analysis of Vaccination Rate π on Infected Class against time. It was observed that the vaccinated class reduces as the rate of vaccinated pigs moved towards recovery.
Figure 7 shows sensitivity analysis of Death Rate due Infection ω on Infection Class against time different values of ω on Infection Class and it was observed that infected pigs death increased as ω increases.

Figure 8 shows sensitivity analysis of Vaccination Rate π on Vaccinated class against time for different values of π on Vaccinated class and it was observed that vaccinated class increased as the recovery rate increases.

Figure 9 depicts sensitivity analysis of Recovery Rate μ on Vaccinated Class against time for different values of μ on Vaccinated Class and it was observed that the recovery class increased as vaccinated class increases.

Figure 10 shows sensitivity analysis of Natural Death Rate δ on Vaccinated class against time for different value of δ on Vaccinated class.

Figure 11 displays sensitivity analysis of α on Recovery Class against time for different values of α on Recovery Class and it was observed that recovery class increased as the vaccination class decreases.

Figure 12 depicts sensitivity analysis of Natural Death Rate δ on Recovery Class against time for different value of Natural Death Rate δ Intestinal torsion in pig reduces the population of pigs and they likely move back to the susceptible class if the nutritional feeds and appropriate vaccinations are not properly administered.

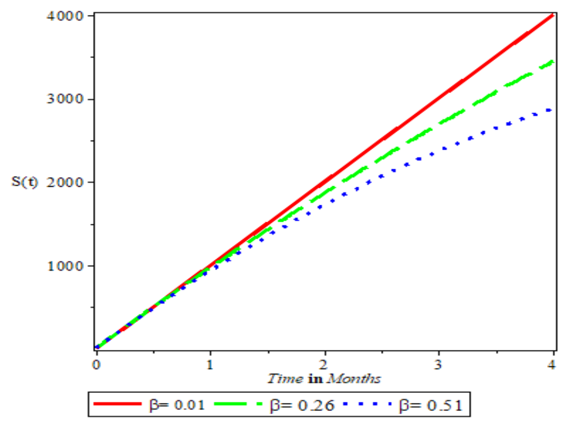

Fig 1: Variational Impact of Contact Rate β on S - Class

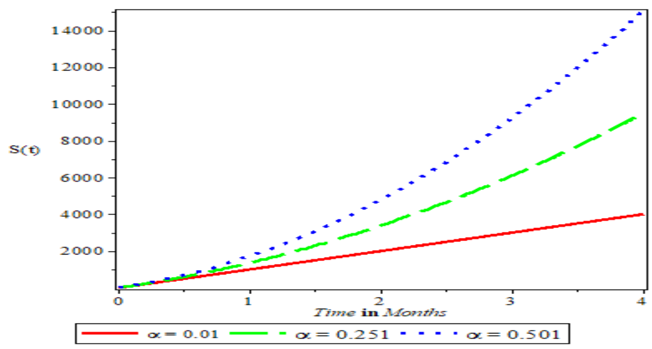

Fig 2: Variational Impact of α on S – Class

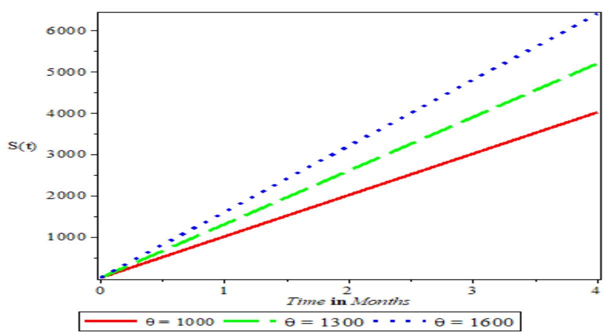

Fig 3: Variational Impact of Birth Rate θ on S – Class

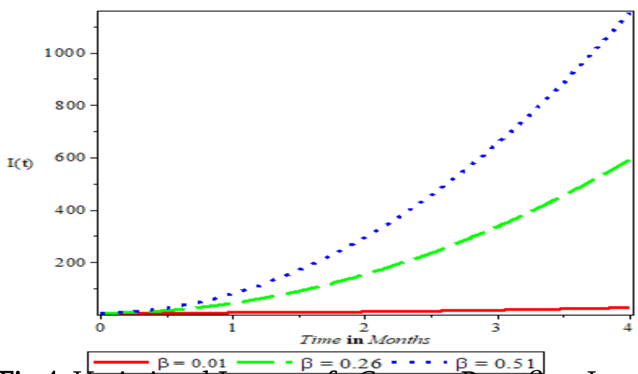

Fig 4: Variational Impact of Contact Rate β on I - Class

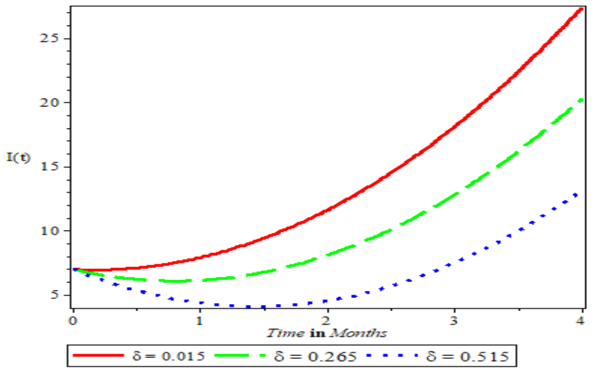

Fig 5: Variational Impact of Natural Death Rate δ on I - Class

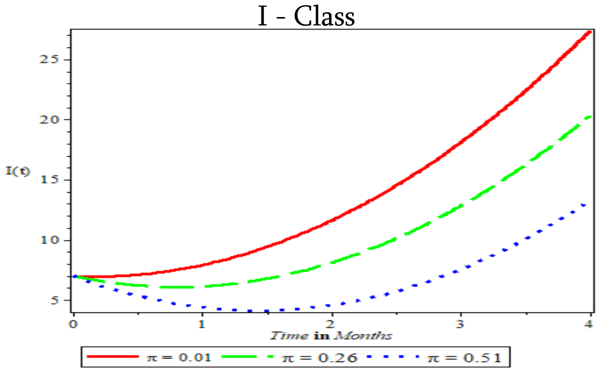

Fig 6: Variational Impact of Vaccination Rate π on I - Class

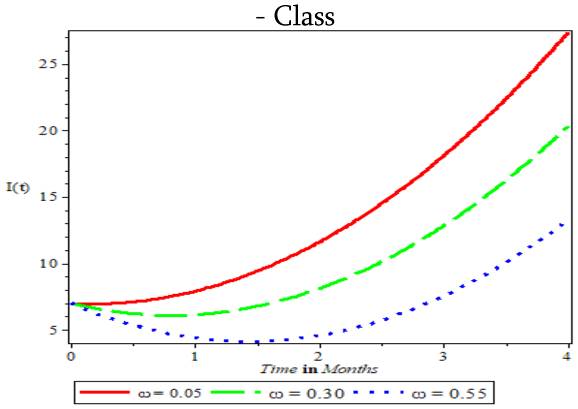

Fig 7: Variational Impact of Death Rate due Infection ω on I- Class

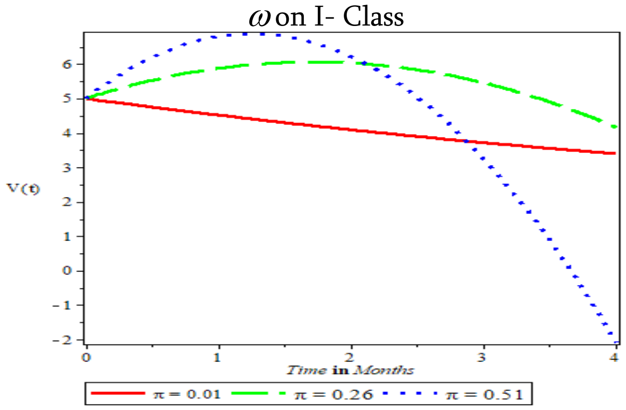

Fig 8: Variational Impact of Vaccination Rate π on V- class

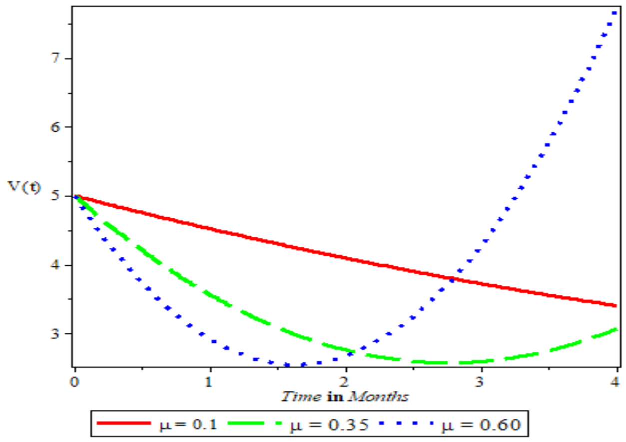

Fig 9: Variational Impact of Recovery Rate μ on V- Class

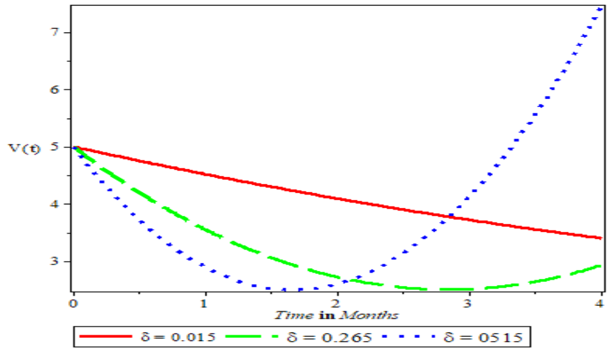

Fig 10: Variational Impact of Natural Death Rate δ on V-class

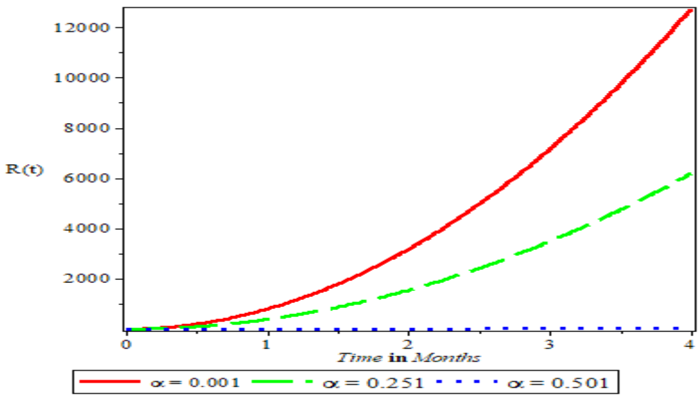

Fig 11: Variational Impact of α on R - Class

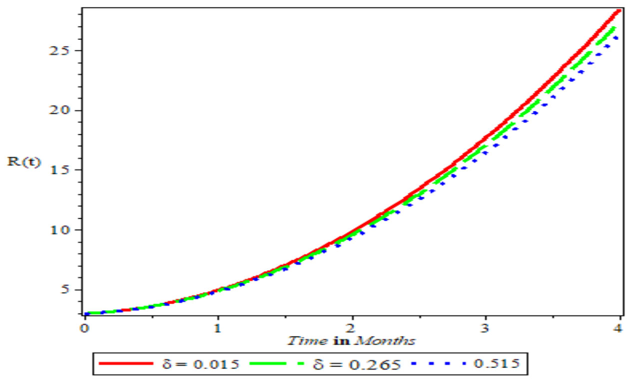

Fig 12: Variational Impact of Natural Death Rate δ on R- Class

IV.CONCLUSION

Utilising a proven mathematical model (SIVR) to regulate intestinal torsion in pigs by means of a focused nutritional feed immunisation approach has shown a great deal of promise. During the course of a four-month implementation period, the model successfully forecasted the results concerning the health of pigs and the occurrence of torsion, enabling proactive modifications to feeding programs. This method improved the pigs' overall resistance to intestinal problems while also optimising their nutritional intake. Pigs Farmers can increase sustainable farming methods, lessen financial losses, and enhance animal welfare by combining nutritional tactics with quantitative modelling. Subsequent investigations ought to concentrate on enhancing these models and investigating their suitability for various agricultural settings and circumstances.

V. REFERENCES

[1]. Britt, J. R., & Harlan, L. (2010). "The Impact of Feeding Practices on the Incidence of Gastrointestinal Disorders in Pigs." Veterinary Journal, 184(1), 15-23.

[2]. De Almeida J.M.K.M, Maduireira, M.S., & Ribeiro R.M.A.F. (2018). “Modelling Pig Production System.” Journal of Livestock Science, Volume: 212 page: 75-86 DOI: 10.1016/j.livsci.2018.04.015

[3]. Gonzalez, A., & Coe, M. (2011). "Nutrition's Role in Preventing Intestinal Disorders in Swine." Swine Health and Production, 19(1), 25-30.

[4]. Hampson, D. J. (1994). "Alterations in the Gut Microflora of Weaned Pigs and Their Relationship with Disease." Journal of Animal Science, 72(1), 203-211.

[5]. Kjaer, J.B., & Sorensen, J. T. (2000). "Animal Welfare and Nutrition: A Case Study of Pig Production." Animal Welfare, 9(3), 321-330.

[6]. Krakowski, L. (2015). "Gastrointestinal Disorders in Pigs: Nutrition and Management." Journal of Swine Health and Production, 23(5), 255-261.

[7]. Meyer, H. (2004). "Intestinal Volvulus in Pigs."Veterinary Clinics of North America: Food Animal Practice, 20(2), 345-356.

[8]. NRC (National Research Council). (2012). Nutrient Requirements of Swine. 11th ed. National Academies Press.

[9]. Stein, H. H., & Shurson, G. C. (2009). "The Role of Dietary Fiber in the Nutrition of Swine." Journal of Animal Science, 87(12), 480-490.

[10]. Singh, R.K., Goyal, A.K. & Goyal S.K. (2016) “Mathematical Modelling of Pig Growth Curve” Journal of Mathematical and Computational Application (MCA), Volume 21, Issue 2, Page 14, DOI: 10.3390/mca23010014

[11].