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Kinetic Modeling of Banana Trunk Biomass Hydrolysate for Ethanol Production

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- **Abstract**

This work aims at determining the rate of change of biomass, glucose yield and ethanol that can be produced in the Hydrolysis Processes for Ethanol from Banana Trunk Biomass. The methodology of consecutive reaction in which the result of one reaction becomes the reactant for the other reactions yielded an optimum glucose of 403.172636g/l at day two with the ethanol yield being inversely proportional to the biomass consumption.

Keywords: Modeling, Kinetic, Banana Trunk Biomass, Ethanol, Hydrolysate.

1. Introduction

Ethanol is a liquid fuel that can be produced from the hydrolysis of starch and fermentation of glucose. It is a volatile, colorless, and flammable chemical (Graeme, 2010). Ethanol can be produced from coarse grain such as corn and millet; sugarcane, cassava, biomass containing cellulose such as agricultural waste, municipal waste, woody materials, forest residues, by – product of organic materials, herbaceous material (Egwim*et a*l., 2015).Lignocellulosic materials such as agricultural residues (wheat straw, corncob and paddy straw); Energy crops (switch grass and fast-grow trees) and forest resources have been recognized as renewable for industrial applications to produce ethanol and other biofuels (Chin, et. al., 2011)
Banana Trunk Biomass can be used as a raw material for ethanol production because it contains sugar with high level of glucose or precursors to glucose (Badger, 2002; Egwim*et a*l., 2015). Historically, fermentation products were mainly food products, but in recent years an increased interest has been observed in the production of bulk chemicals (ethanol and other solvents), specialty chemicals (Pharmaceuticals, industrial enzymes), biofuels and food additives (flavor modifiers) Fermentation processes are also used in agriculture.

According to Nyor et al., (2018), banana trunk biomass is a renewable polymer abundant in nature particularly in Nigeria; as Nigeria is ranked among the highest producers of banana in West Africa. The biomass is often wasted after harvesting the Banana fruit. Currently there are trends in hydrolyzing banana trunk polymers, using enzyme processes to produce fermentable sugars and the fermentable sugar is further converted into ethanol. This is a cheaper way of producing ethanol and it can be used as renewable fuel.

We must understand the dynamic and static behavior of ethanol production in order to control and optimize the production of ethanol (Paz and Cardona, 2011). Mathematical models are convenient and cost effective in the modeling of biological growth. It helps us to learn more about the real life phenomenon by manipulating a model's variables and observing the results once the models are developed properly. In developing fermentation process, Kinetic modeling has been regarded as an important step since models help in both process control and research efforts, where they will be most effective in reducing process costs and increasing product quality (Olaoye and Kolawole 2013)..

1.1 Problem Statement

The rising demand for ethanol consumption calls for optimal production model since it has been found to be an alternative source of sustainable energy and in high demand in industries.

1.2 Aim of the Study

The aim of this study is to determine the concentration of the biomass, glucose yield and ethanol that can be produced in the Hydrolysis Processes for Ethanol from Banana Trunk.

2. Literature Review

Banana truck contains high amount of cellulose and lignocellulosic plant material, about 200 tons /ha is wasted yearly (Soffner, 2001). The production of ethanol from biomass seems to be an interesting alternative to traditional fossil fuel and industrial chemical, which can be utilized as a sole fuel in vehicles with dedicated engines or in pharmaceutical industries and food processing industries. Ethanol is currently produced from sugars, starches and cellulosic materials. However due to the concomitant growth in demand for human feed such as starches and sugars there is an urgent need for potentially less competitive and perhaps less expensive feedstock such as lignocellulose materials as main resources for ethanol production in the near future (Taherzadeh and Karimi, 2007).

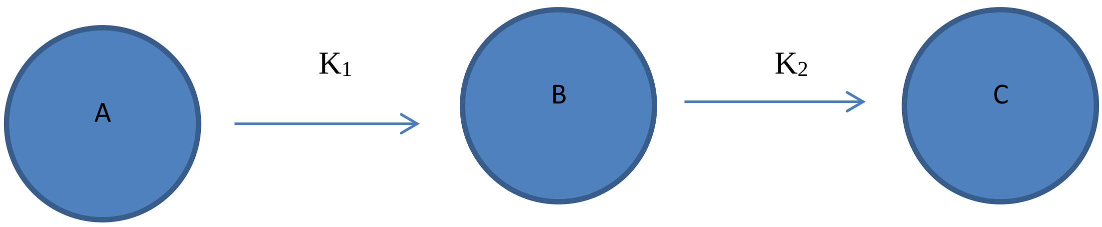
According to Olaoye and Kolawole (2013), logistic model can be used to illustrate the kinetics of biomass conversion with respect to time while the modified Gomperta model can be used to test the kinetics of ethanol production at a steady temperature. It has also been observed that results from mathematical models were not significantly different when compared with the experimental results. Literature supports that the utilization of mathematical model will contribute to a better understanding of effects of various factors, affecting production of ethanol.

Farah et al (2011), Used computer simulation of four different kinetic models which are: Monod, Contois, Modified Monod and Teisser to investigate *S. cerevisiae* growth kinetics and ethanol productivity. It was observed that Teisser model gave marginally better fit than other models tested as it obtained the highest correlation coefficient of 0.96299. They concluded that ethanol batch fermentation is a non-growth associated process based on Leudking-Piret model.

3. Methodology

3.1 Mathematical process

In the production of ethanol from banana trunk biomass, we consider a pattern of a consecutive reaction where the product of one reaction becomes the reactant for the other reactions. (Martinopa, 1987; Yu, 2014 and Olaoye and Kolawole 2013).



The ODEs that describe the rate of change of each reactants with time is written as

$$\frac{d[A]}{dt} = -K_1[A](1)$$

$$\frac{d[B]}{dt} = K_1[A] \; - K_2[B](2)$$

$$\frac{d[C]}{dt} = K_2[B](3)$$

were,

[A] = biomass concentration

[B] = glucose concentration

[C] = ethanol concentration

We consider an initial value problem in which we consider time t=0, for the above reaction,

$$[A] = [A_0], [B] = 0, [C] = 0$$

$$A_0 = [A] + [B] + [C] \qquad (4)$$

Integrating equation (1),

$$\int \frac{dA}{dt} = \int -k_1 A \qquad (5)$$

Applying separation of variable,

$$\int \frac{dA}{A} = -k_1 \int dt \qquad (6)$$

Integrating from A_0 to A and 0 to t,

$$\int_{A_0}^{A} \frac{dA}{A} = -k_1 \int_0^t dt \; (7)$$

$$\ln A - \ln A_0 = -k_1 t \; (8)$$

$$[A] = A_0 e^{-k_1 t} (9)$$

Substituting equation 9, into equation 2, we obtain,

$$\frac{dB}{dt} = k_1 A_0 e^{-k_1 t} - k_2[B](10)$$

Adding $k_2[B]$to both sides of (10), we obtain,

$$\frac{dB}{dt} + k_2[B] = k_1 A_0 e^{-k_1 t}(11)$$

Using integrating factor method,

$$B.IF = e^{\int f(x)dx} = e^{\int f(x)dx}.y(x)dx + C$$

$$e^{\int k_2 dt}.[B] = e^{\int k_2 dt}.k_1[A_0]e^{-k_1 t} + C \qquad (12)$$

We obtain,

$$e^{k_2 t}[B] = \frac{k_1 A_0}{k_2 - k_1} e^{(k_2 - k_1)t} + C \qquad (13)$$

At t=0, $[B] = [B_0]$

$$e^{k_2(0)}[B_0] = \frac{k_1 A_0}{k_2 - k_1} e^{(k_2 - k_1)0} + C \qquad (14)$$

We obtain the constant c as,

$$C = B_0 - \frac{k_1 A_0}{k_2 - k_1} (15)$$

Substitute the value of constant c, into equation13, we have,

$$e^{k_2 t}[B] = \frac{k_1 A_0}{k_2 - k_1} e^{(k_2 - k_1)t} + B_0 - \frac{k_1 A_0}{k_2 - k_1} (16)$$

Diving both sides by $e^{k_2 t}$

$$[B] = \frac{k_1 A_0}{k_2 - k_1} e^{(-k_1)t} + B_0 e^{-k_2 t} - \frac{k_1 A_0}{k_2 - k_1} e^{-k_2 t} (17)$$

Let $B_0 = 0$, we have,

$$[B] = \frac{k_1 A_0}{k_2 - k_1} (e^{-k_1 t} - e^{-k_2 t})(18)$$

From equation 4,

$$[C] = A_0 - [A] - [B] (19)$$

hence,

$$[C] = A_0 - A_0 e^{-k_1 t} - \frac{k_1 A_0}{k_2 - k_1}(e^{-k_1 t} - e^{-k_2 t}) (20)$$

Simplifying equation 20, we obtain,

$$[C] = A_0 \left(1 + \frac{k_1 e^{-k_2 t} - k_2 e^{-k_1 t}}{k_2 - k_1}\right) (21)$$

Equation 9, 18 and 21 was solved using maple to determine the concentration of the biomass, glucose yield and ethanol produced.

4. Result and Discussion

The result generated from the maple simulation at $k_1 = 1.5 \; and \; k_2 = 0.8$ has its initial values as:

$$A(t) = 1000e^{-\frac{3}{2}} \qquad (22)$$

$$B(t) = -\frac{15000}{7} e^{-\frac{3}{2}t} + \frac{15000}{7} e^{-\frac{4}{5}t} \qquad (23)$$

$$C(t) = \frac{12000}{7} e^{-\frac{3}{2}t} - \frac{40000}{7} e^{-\frac{4}{5}t} + 1000^1 \qquad (24)$$

This yields TABLE 1.

TABLE 1: CONCENTRATION OF BANANA TRUNK BIOMASS, GLUCOSE YIELD AND ETHANOL PRODUCED WITH TIME at $k_1 = 1.5, k_2 = 0.8$

TIME (DAYS)	A (MG/ML)	B (MG/ML)	C(MG/ML)
0	1000	0	0

1	223.1301601	241.037404	51.120712
2	49.78706837	403.172636	221.0914746
3	11.10899654	393.17633	425.1240519
4	2.478752177	312.6635423	602.8217373
5	0.55308437	224.6273454	736.7569533
6	0.123409804	152.3327072	830.1731604
7	0.027536449	99.70608923	892.4013873
8	0.006144212	63.77847551	932.6680666
9	0.001370959	40.17213176	958.2296083
10	0.000305902	25.0353831	974.246118

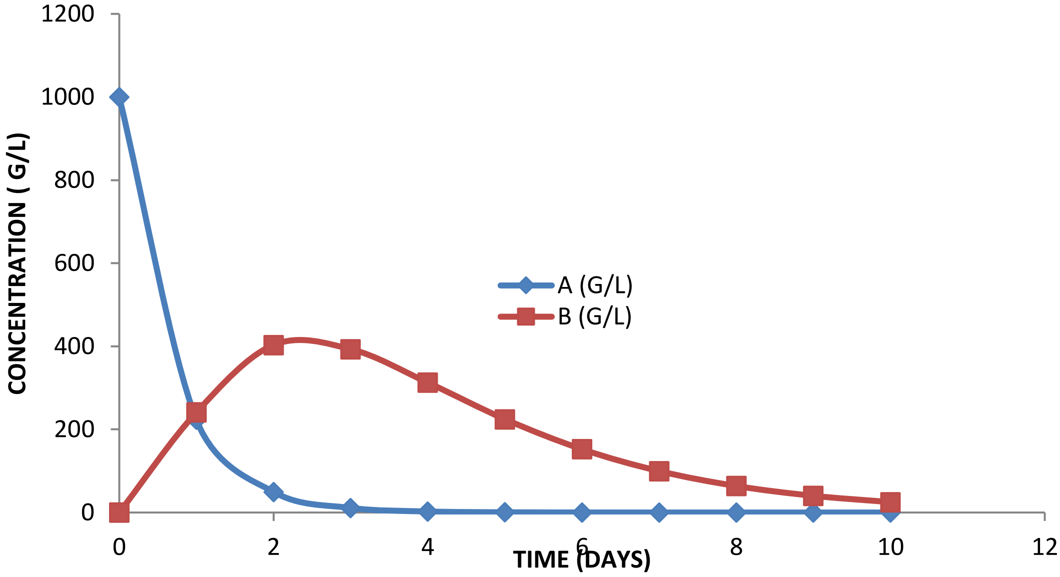


FIGURE 1: A GRAPH OF THE RATE OF CHANGE OF BANANA TRUNK BIOMASS AND GLUCOSE YIELD WITH TIME

Figure 1 shows the dynamics of banana trunk biomass and glucose yield. The banana trunk biomass decreases at the rate of $\alpha = 1.5$ from the initial value of 1000g/l to 0.000305902 g/l at day 10. The glucose yield increases from day one at the rate of 0.8 to an optimum yield of 403.172636g/l at day two.

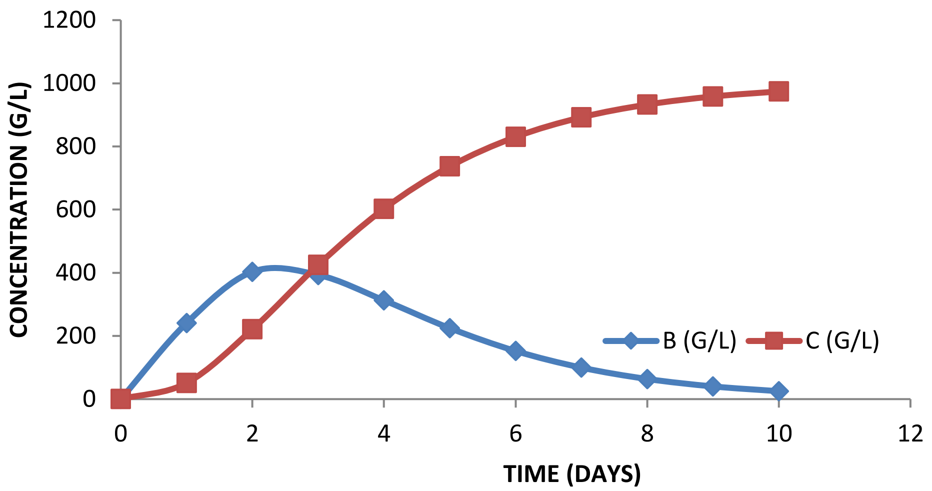


FIGURE 2: A PLOT OF THE RATE OF CHANGE OF GLUCOSE AND ETHANOL WITH TIME

The plot of glucose yield and ethanol production is given in Figure 2. As the glucose yield increases the ethanol also increases until after day 2 when it starts decreasing due to the utilization of the available glucose for the ethanol production.

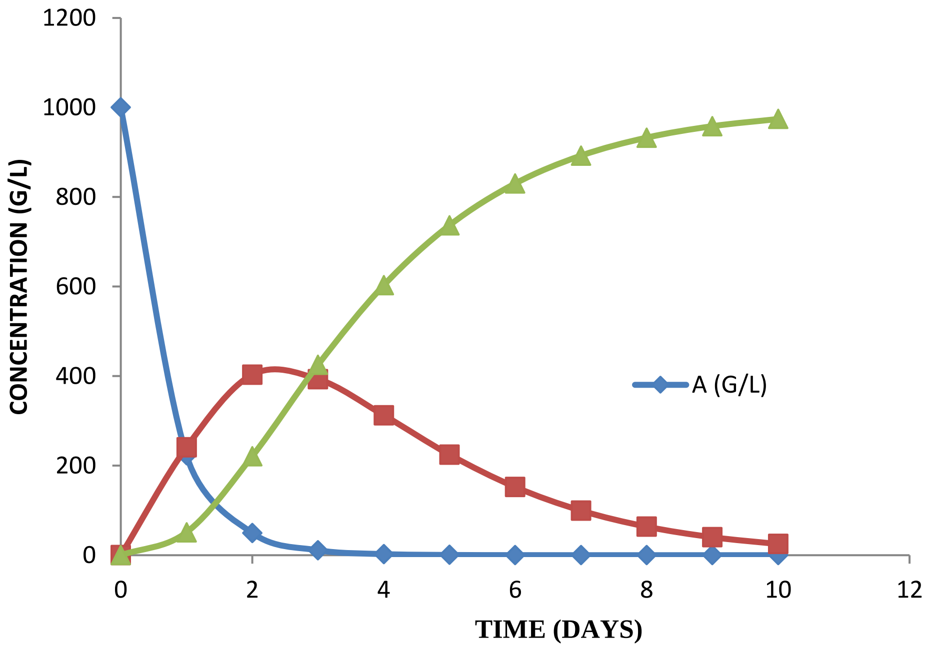


FIGURE 3: A PLOT OF THE RATE OF CHANGE OF BANANA TRUNK BIOMASS, GLUCOSE AND ETHANOL PRODUCTION WITH TIME.

The graph for the kinetics of ethanol produced from banana trunk biomass is given in figure 3. The rate of change of ethanol with time is inversely proportional to that of biomass.

5. Conclusion

In conclusion the initial value problem for the production of ethanol from banana trunk biomass was obtained. The models obtained were used to determine glucose yield and ethanol production using maple software. The rate of production of glucose from the biomass is 1.5 and of ethanol from glucose is 0.8. The optimum glucose yield was 403.172636g/l at day two. The ethanol yield is inversely proportional to the biomass consumption. The work also concludes that at day 2 almost all the biomass was consumed in the process.

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Applying Generalised Additive Models (GAMS) On Insurance Data Using R

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ABSTRACT

The motor insurance data compiled by the Swedish committee on the analysis of risk premium of automobile insurance was examined here. Generalised Additive Models (GAMs) were applied on this data set. The scatter plot smoother was used to estimate explanatory variables. To estimate the arbitrary smoothers in the additive model, the back-fitting algorithm was adopted. The 'gam' package in R was employed to fit the GAMs, which is