*Biomedical Science and Engineering, 2015, Vol. 3, No. 1, 15-22*
Available online at http://pubs.sciepub.com/bse/3/1/4

DOI:10.12691/bse-3-1-4

# Assessment Evaluation of Bio-Ethanol Yield for Energizing Prosthetics Production Plant Based on Bacterial Growth and Shaking Rate

**C. I. Nwoye[1,*], P. C. Agu[2], B. C. Chukwudi[3], S. O. Nwakpa[1], I. A. Ijomah[1], N. E. Idenyi[4]**

[1]Department of Metallurgical and Materials Engineering, Nnamdi Azikiwe University, Awka, Nigeria
[2]Department of Metallurgical and Materials Engineering, Federal University of Technology, Owerri, Nigeria
[3]Department of Mechanical Engineering, Imo State University, Owerri, Nigeria
[4]Department of Industrial Physics, Ebonyi State University, Abakiliki, Nigeria
*Corresponding author: nwoyennike@gmail.com

*Received August 17, 2014; Revised October 25, 2014; Accepted June 25, 2015*

**Abstract** This paper presents an assessment evaluation of bio-ethanol yield based on the bacteria growth (BG) and shaking rate (SR) during bioprocessing of sugar cane molasses with *Saccharomyces cerevisiae.* Critical computational analysis of generated experimental results indicates that the bio-ethanol yield response typified an empirical model which is exponential-linear in nature. The model was validated prior to evaluation of the yield response coefficient and predictive analysis of generated results. The validity of the derived model expressed as; $\zeta = 4.6335e^{[0.0068(\vartheta/\tau)]} + 0.00012\lambda - 0.00004\varepsilon$ was rooted on the core model expression $\zeta - 0.00012\lambda = 4.6335e^{0.0068(\vartheta/\tau)} - 0.00004\varepsilon$ where both sides of the expression are correspondingly approximately equal. Results of ethanol yield were generated using regression model and its trend of distribution was compared with that from derived model for the purpose of verifying its validity relative to experimental results. The results of the verification process show very close dimensions of covered areas and alignment of curves designating ethanol yield, which precisely translated into significantly similar trend of data point's distribution for experimental (ExD), derived model (MoD) and regression model-predicted (ReG) results. Ethanol yield per unit input ratio SR/ BG were evaluated from experimental, derived model & regression model predicted results as 0.0496, 0.0573 & 0.0565 rpm/ O.D respectively. Standard errors incurred in predicting ethanol yield for each value of SR, BG & SR/ BG considered as obtained from experiment, derived model and regression model were 0.13369, 0.9674 and 1.3380%, 1.3096, 1.3615 and 1.5300 % & 1.3701, 0.5969 and 1.1459 x $10^{-5}$ respectively. The operationally viable deviation range of model-predicted ethanol yield from the experimental results was 0.9 -13.47 %. This translated into 86.53-99.1 % operational confidence and reliability level for the derived models, as well as 0.86 - 0.99 yield response coefficient of ethanol to the input ratio SR/ BG. Consequently, in order to obtain high confidence level, the derived model considers input parameter value; 50 rpm (shaking rate) very extraneous. This was as a result of 23.66% deviation associating the use of this input parameter value.

***Keywords:*** *Bio-Ethanol yield, input ratio of shaking rate and microbial growth, bioprocessing sugar cane molasses, Saccharomyces cerevisiae*

**Cite This Article:** C. I. Nwoye, P. C. Agu, B. C. Chukwudi, S. O. Nwakpa, I. A. Ijomah, and N. E. Idenyi, "Assessment Evaluation of Bio-Ethanol Yield for Energizing Prosthetics Production Plant Based on Bacterial Growth and Shaking Rate." *Biomedical Science and Engineering*, vol. 3, no. 1 (2015): 15-22. doi: 10.12691/bse-3-1-4.

## 1. Introduction

The renewed growing need and demand for a cheap fuel, usable in the transportation system; for conveying goods and services as well as running industrial machines has resulted to successful processing and usage of agricultural products, such as cassava and molasses, for ethanol production which is 99.5% pure alcohol by volume [1]. Ethanol production from agro-products and wastes was also anchored on the fact that increased fossil-fuel demand, due to the increased global energy consumption, and the attendant limitations of fossil carbon reservoir compelled human beings to consider alternative energy source, biofuel which is renewable and produced with quasi-zero $Co_2$ [2].

Reported has shown [3] that the vast majority of ethanol for use as fuel, is produced by fermentation: when certain species of yeast (such as Saccharomyces cerevisiae) metabolize sugar in the absence of oxygen, they produce ethanol and carbon dioxide. The overall chemical reaction conducted by the yeast may be represented by the chemical equation

$$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2CO_2 \qquad (1)$$

The researcher [3] showed that a fermenting strain of Saccharomyces cerevisiae could be utilized for alcoholic fermentation using sugarcane molasses. The scientist optimized fermentation of molasses with respect to temperature, pH and sugar concentration. Results of the process revealed a temperature of 30°C, pH 6.0 and 20% sugar concentration as optimum for fermentation. Under optimized conditions, S.cerevisiae produced 11.6% of ethanol. Immobilization resulted in 10.4% ethanol after 48 hours and the same yeast cells were reused to carry out fermentation. The reuse of immobilized cells gave 7.9% ethanol yield. Ethanol production capacity of novel Xylose-fermenting yeast, Scheffersomyces shehatae UFMG-HM52.2 was evaluated under batch fermentation conditions using sugarcane bagasse hemicellulosic hydrolysate as carbon source and found very laudable and recommendable [4]

Alcoholic fermentation has been carried out using a number of sugary materials depending upon their availability and suitability in particular geographic situations. Various raw materials like sugarcane juice and molasses [5,6] sugar beet, beet molasses [6,7], Sweet sorghum [8] and starchy materials like sweet potato [9] Corn cobs and hull [10,11], cellulosic materials like cocoa, pineapples and sugarcane waste [12] and milk/cheese/whey using lactose hydrolyzing fermenting strains [13,14] have been reported. Amongst these, simple sugar bearing materials are the easiest to process, since the yeast ferment these directly while other carbohydrates like starch/cellulose have to be first hydrolyzed to fermentable sugars using current and sound commercial technologies (physio-chemical/enzymatic preparation) before they can be fermented to yield ethanol.

Studies [15] show that ethanol production from wheat starch. Hydrolyzed wheat starch was used as a substrate for ethanol production using 2 strains of S.cerevisiae. Wheat flour slurry (25%w/v) was gelatinized and conditions were standardized for saccharification and fermentation of wheat starch for ethanol production.

Ethanol in India and other developing countries is mainly produced by fermentation of dilute molasses at ambient temperature of 25-35$^{o}$C employing Saccharomyces cerevisiae [8,16].

A researcher [17] studied the effect of pretreatment of sugarcane molasses for ethanol production by yeast. The effect of pretreatment of molasses with $H_2SO_4$ and $K_4Fe(CN)_6$ on ethanol production by different yeast strain was studied in order to find an effective method to reduce the load of various inhibitory substances and to select a suitable yeast strain for fermentation of pretreated molasses. Pretreatment resulted in decreased level of inhibitory substances like Ca, Cu, and Fe in the molasses solution with improved ethanol production. The inhibitory effect of these constituents was confirmed by supplementation of synthetic medium with residues from different pretreatments and the inhibitory level for various constituents was found to be Ca>0.5%, iron> 46ppm and Cu >5.4ppm. The fermentable carbohydrates in molasses are sucrose and other sugars mainly glucose and fructose.

In fermentation of the various ethanol producing micro-organism yeast belonging to Saccharomyces cerevisiae have been used most commonly. Scientists [18] have isolated yeast from spoiled high sugar foods. Another scientist [19] compared the rates of growth and ethanol production by 11 different strains of Zymomonas, with some strains being more tolerant of high sugar or ethanol concentration and high incubation temperature than others. One of the most promising ethanol producing organisms is the bacterium Zymomonas mobilis which is used to make palm wines. This bacterium can produce upto 1.9 mol of ethanol from each mole of glucose fermented.

Following a comparative study [20] carried out on ethanol production from molasses using Saccharomyces cerevisiae & Zymomonas mobilis, yeast was found to be more ethanol tolerant and produced more ethanol at sugar concentration above 15% (v/v).

A yeast, S. cerevisiae was also isolated [21] from palm wine, which produced increased amounts of ethanol in yeast extract peptone dextrose medium. Later research [22] revealed isolation of new strains of S.cerevisiae on basal medium containing 48% sucrose from fermenting sample collected from Brazilian alcohol factories. Isolated strains fermented concentrated sugarcane syrups as well as high sucrose solution in synthetic medium with conversion efficiency of 89-92%.

Fermentation efficiencies less than 90% are quite common though it should be 95% on an average. Secondly, exact conditions of temperature, pH and nutrients, which are essential for yeast fermentation, are not vigorously maintained.

An empirical model was derived [23] for assessment evaluation of the concentration of ethanol yield during microbial treatment of sugar cane molasses. The model expressed as;

$$y = 0.8008\gamma^3 - 4.9018\gamma^2 + 7.639\gamma - 6.8815\beta^2 + 15.636\beta - 0.8113 \quad (2)$$

shows that the concentration of ethanol produced during the bio-treatment process is dependent on the inoculums size and the growth of microbes attacking the substrate. Ethanol productions per unit inoculums size and microbial growth are -1.86% / O.D and -1.6397% / O.D & - 4.5146 and –3.9798 % $(O.D)^{-1}$ as obtained from experiment & derived model respectively. Statistical analysis of the results indicate that the variance and standard deviation as obtained from experiment and derived model are 5.2674 and 2.2951 as well as 4.8777 and 2.2086 respectively, indicating proximate agreement. Deviational analysis indicates that the maximum deviation of the model-predicted ethanol yield from the corresponding experimental value is less than 14%. The validity of the model was found to be rooted on the expression $0.204\ y = 0.1634\ \gamma^3 - \gamma^2 + 1.5584\ \gamma - 1.4039\ \beta^2 + 3.1898\ \beta - 0.1655$ where both sides of the expression are correspondingly approximately almost equal. Optimization of ethanol production was based on variation in microbial growth while the inoculum size and all other process parameters were assumed constant. The optimization model; $y = 31.272\beta - 13.763\beta^2 - 5.9758$ which was constituted by only the parameter for microbial growth indicates that the optimum ethanol production; 13.9198% would be obtained at an optimum microbial growth of 1.1361 (O.D). The validity of the optimization model was found to be rooted on the expression equations $0.1673\ y + 1 = 5.2331\ \beta - 2.3031\ \beta^2$.

An empirical model [24] was successfully derived for predictive analysis of the concentration of ethanol yield

during bio-treatment of sugar cane molasses. The model expressed as;

$$\beta = 0.0342\alpha - 0.00005\alpha^2 + 9.176\gamma - 2.6721\gamma^2 + 0.9035 \quad (3)$$

shows that the concentration of ethanol produced during the bio-treatment process is dependent on the shaking rate of the reaction vessel and the growth of microbes attacking the substrate. Ethanol production per unit shaking rate are 0.0320 and 0.0391 % $(rpm)^{-1}$ as obtained from experiment and derived model respectively. Similarly, ethanol production per unit growth of microbes are 7.1429 and 8.7290 % $(O.D)^{-1}$ as obtained from experiment and derived model respectively. Statistical analysis of the results indicate that the variance and standard deviation as obtained from experiment and derived model are 10.1588 and 3.1873 as well as 11.6728 and 3.4166 respectively, indicating proximate agreement. The validity of the model was found to be rooted on the expression $0.1090\ \beta - 0.0985 = 0.0037\alpha - 5.45 \times 10^{-6}\ \alpha^2 + \gamma - 0.2912\ \gamma^2$ where both sides of the expression are correspondingly approximately almost equal. Optimization of ethanol production was based on variation in shaking rate only while the microbial growth and all other process parameters were assumed constant. The optimization model; $\beta = 0.0684\ \alpha - 0.0001\ \alpha^2 + 4.3607$ which was constituted by only the shaking rate parameter indicates that the optimum ethanol production; 16.0571% would be obtained at an optimum shaking rate of 342 rpm. The validity of the optimization model was found to be rooted on the expression $0.2293\ \beta - 1 = 0.0157\ \alpha - 2.29 \times 10^{-5}\ \alpha^2$.

Successful analysis and prediction of ethanol yield was carried out [25] during biodegradation of sugar cane molasses. Validity of the derived model expressed as;

$$\alpha = 5.4247\ln\beta - 0.0477\gamma^2 + 2.9656\gamma - 35.8559 \quad (4)$$

was rooted on the expression $0.3372\ (\alpha + 35.8547) = 1.8292\ \ln\beta - 0.0161\ \gamma^2 + \gamma$ where both sides of the expression are correspondingly approximately equal. The model shows the dependency of produced ethanol on the treatment temperature and the growth of microbes attacking the substrate. Ethanol yield per unit temperature rise during the process are 15.3889 and 17.3578% / $^0$C as obtained from experiment and derived model respectively. Similarly, ethanol production per unit growth of microbes are – 0.1847 and – 0.2083 % $(O.D)^{-1}$ as obtained from experiment and derived model respectively. Statistical analysis of the results indicate that the variance and standard deviation as obtained from experiment and derived model are 8.1440 and 2.8538 as well as 7.4053 and 2.7213 respectively, indicating proximate agreement.

The present work aims at taking an assessment evaluation of bio-ethanol yield (for energizing prosthetics production plant) based on the input ratio of shaking rate and microbial growth during bioprocessing of sugar cane molasses with *Saccharomyces cerevisiae.* [1] reported that the produced bio-ethanol is cheap; 99.5% pure and applicable for running industrial machines such as machines for prosthetics production. Therefore this work shows the relationship between the biofuel yield (which are supplied directly to the prosthetics plant) and the process inputs: bacterial growth and shaking rate of reaction vessel affecting the yield.

# 2. Materials and Methods

A weighed quantity of prepared sugar cane molasses was put in a reaction vessel containing the appropriate *Saccharomyces cerevisiae*. Details of the experimental procedure and associated process conditions are as stated in the past report [1]. Analysis of the bio-ethanol production was carried out based on the input ratio of shaking rate and microbial growth using a derived and validated empirical model.

## 2.1. Model Formulation

Experimental data obtained from research work [1] were used for this work. Computational analysis of the data [1] shown in Table 1, gave rise to Table 2 which indicate that;

$$\zeta - S\wp \approx Ne^{K(\vartheta/\varkappa)} - S_e\,\varepsilon \quad (5)$$

Introducing the values of S, K and N into equation (5) reduces it to;

$$\zeta - 0.00012\wp = 4.6335e^{0.0068(\vartheta/\varkappa)} - 0.00004\varepsilon \quad (6)$$

$$\zeta = 4.6335e^{0.0068(\vartheta/\varkappa)} + 0.00012\wp - 0.00004\varepsilon \quad (7)$$

S = 0.00012, K = 0.0068, N = 4.6335 and $S_e$ = 0.00004 are empirical constants (determined using C-NIKBRAN [26].

Where

($\vartheta$) = Shaking rate (SR) (rpm)
($\varkappa$) = Microbial growth (BG)
($\zeta$) = Ethanol yield conc. (%)
($\vartheta/\varkappa$)= input ratio SR/ BG
($\wp$) = Treatment temperature ($^0$C)
($\varepsilon$) = Reaction time (hrs)

**Table 1. Variation of ethanol yield concentration with shaking rate (SR), microbial growth (BG) and input ratio SR/ BG [1]**

| ($\vartheta$) | ($\varkappa$) | ($\vartheta/\varkappa$) | ($\zeta$) |
|---|---|---|---|
| 0 | 0.43 | 0 | 4.93 |
| 50 | 0.70 | 71.4286 | 6.09 |
| 100 | 0.92 | 108.6957 | 10.72 |
| 150 | 1.11 | 135.1351 | 11.51 |
| 200 | 1.53 | 129.8701 | 12.95 |
| 250 | 1.55 | 161.2903 | 12.93 |

# 3. Boundary and Initial Condition

Consider sugar cane molasses interacting with microbes. The atmosphere in the reaction vessel was not contaminated i.e (free of unwanted gases and dusts). Range of shaking rate, microbial growth and input ratio SR/ BG used: 0-250 rpm, 0.43-1.55 and 0 – 161.2903 respectively. Furthermore, reaction time and treatment temperature used maintained constant as 72hrs and 30°C respectively. Mass of wastes used and other process conditions are as stated in the experimental technique [1].

The prevailed boundary conditions are: anaerobic atmosphere to enhance microbial action on the sugar cane molasses. At the bottom of the particles, a zero gradient for the gas scalar are assumed and also for the gas phase at the top of the waste particles. The biodegraded waste was stationary. The sides of the waste particles are taken to be symmetries.

# 4. Results and Discussion

## 4.1. Model Validation

Equation (7) is the derived model.

**Table 2. Variation of ζ - 0.00012 $\mathcal{S}$ with $4.6335e^{0.0068(\vartheta/\varkappa)} - 0.00004\varepsilon$**

| ζ- 0.00012 $\mathcal{S}$ | $4.6335e^{0.0068(\vartheta/\varkappa)} - 0.00004\varepsilon$ |
|---|---|
| 4.9264 | 4.6306 |
| 6.0864 | 7.5279 |
| 10.7164 | 9.6998 |
| 11.5064 | 11.6111 |
| 12.9464 | 11.2029 |
| 12.9264 | 13.8721 |

The validity of the model is strongly rooted on equation (5) where both sides of the equation are correspondingly approximately equal. Table 2 also agrees with equation (5) following the values of ζ - 0.00012 $\mathcal{S}$ and $4.6335e^{0.0068(\vartheta/\varkappa)} - 0.00004\varepsilon$ which were precisely evaluated from the experimental results in Table 1. Furthermore, the derived model was validated by comparing the ethanol yield predicted by the model and that obtained from the experiment [1]. This was done using the 4th Degree Model Validity Test Techniques (4th DMVTT); computational, graphical, statistical and deviational analysis [27].

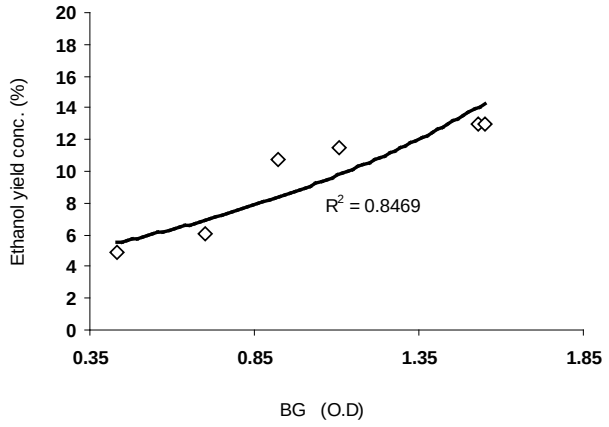


**Figure 1.** Coefficient of determination between ethanol yield and microbial growth as obtained from experiment [1]

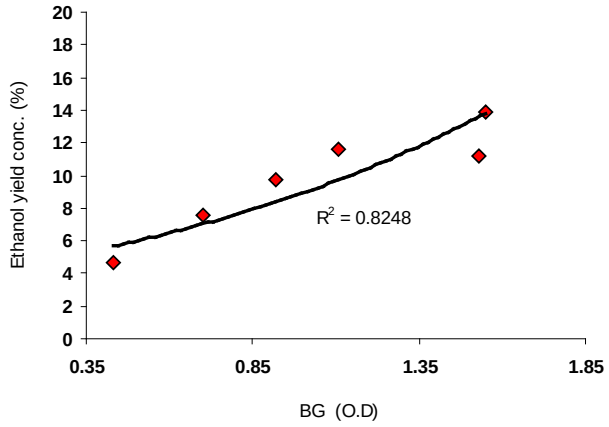


**Figure 2.** Coefficient of determination between ethanol yield and microbial growth as predicted by derived model

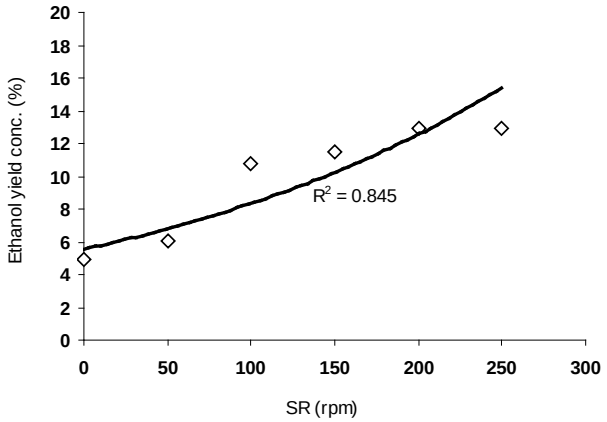


**Figure 3.** Coefficient of determination between ethanol yield and shaking rate as obtained from experiment [3]

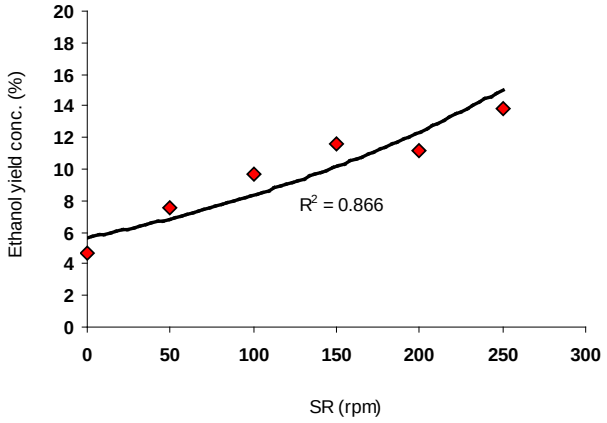


**Figure 4.** Coefficient of determination between ethanol yield and shaking rate as predicted by derived model

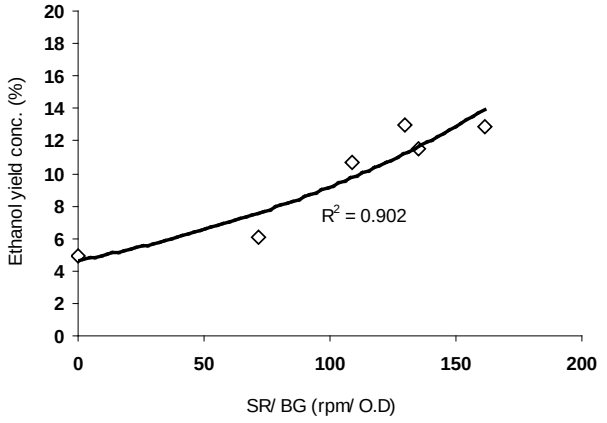


**Figure 5.** Coefficient of determination between ethanol yield and shaking rate- microbial growth ratio as obtained from experiment [1]

### Statistical Analysis

*Standard Error (STEYX)*

The standard errors incurred in predicting ethanol yield for each value of SR, BG & SR/BG considered as obtained from experiment and derived model were 1.3369, 1.3096 & 1.3701% and 0.9674, 1.3615 & 0.5969 % respectively. The standard error was evaluated using Microsoft Excel version 2003.

*Correlation (CORREL)*

The correlation coefficient between ethanol yield and SR, BG & SR/BG were evaluated (using Microsoft Excel Version 2003) from results of the experiment and derived

model. These evaluations were based on the coefficients of determination $R^2$ shown in Figure 1-Figure 6.

$$R = \sqrt{R^2} \quad (8)$$

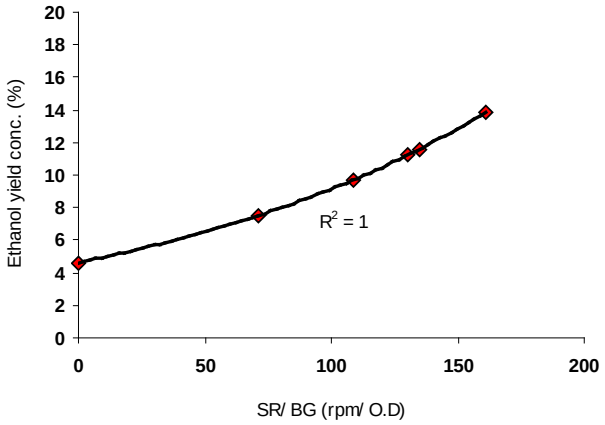


**Figure 6.** Coefficient of determination between ethanol yield and shaking rate- microbial growth ratio as predicted by derived model

The evaluated correlations are shown in Tables 3-5. These evaluated results indicate that the derived model predictions are significantly reliable and hence valid considering its proximate agreement with results from actual experiment.

**Table 3. Comparison of the correlations evaluated from derived model predicted and experimental results based on shaking rate**

| Analysis | Based on SR | |
|---|---|---|
| | ExD | D-Model |
| CORREL | 0.9192 | 0.9306 |

**Table 4. Comparison of the correlations evaluated from derived model predicted and experimental results based on microbial growth**

| Analysis | Based on BG | |
|---|---|---|
| | ExD | D-Model |
| CORREL | 0.9203 | 0.9082 |

**Table 5. Comparison of the correlations evaluated from derived model predicted and experimental results based on input ratio SR/ BG**

| Analysis | Based on SR/ BG | |
|---|---|---|
| | ExD | D-Model |
| CORREL | 0.9497 | 1.0000 |

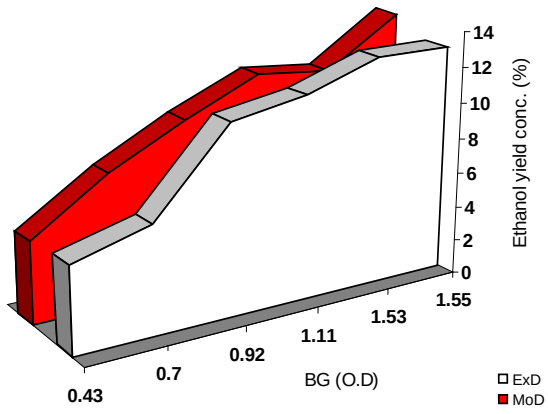


**Figure 7.** Comparison of ethanol yields (relative to microbial growth) as obtained from experiment [1] and derived model

## Graphical Analysis

Comparative graphical analysis of Figure 7-Figure 9 show very close alignment of the curves and shapes from the experimental (ExD) and model-predicted (MoD) ethanol yields. Furthermore, the degree of alignment of these curves is indicative of the proximate agreement between both experimental and model-predicted ethanol yields.

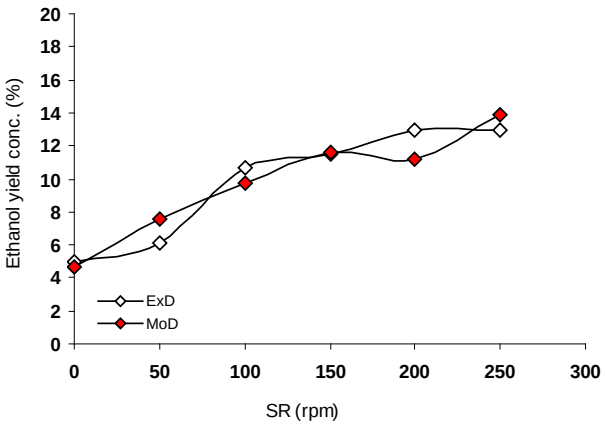


**Figure 8.** Comparison of area covered by ethanol yields (relative to shaking rate) as obtained from experiment [1] and derived model

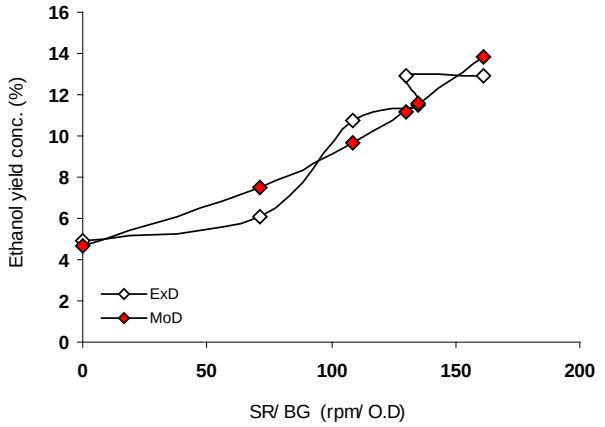


**Figure 9.** Comparison of ethanol yields (relative to shaking rate-microbial growth ratio) as obtained from experiment [1] and derived model

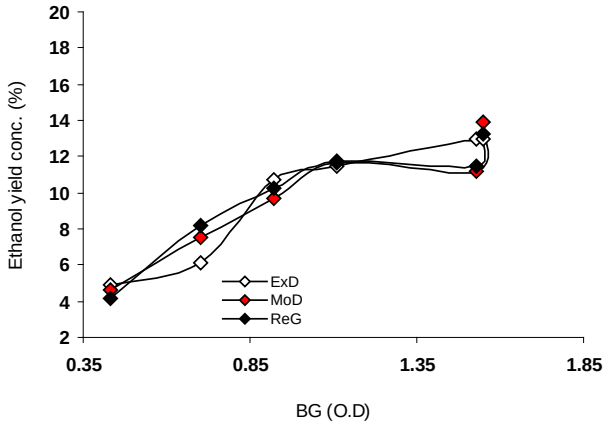


**Figure 10.** Comparison of ethanol yield (relative to microbial growth) as obtained from experiment [1] derived model and regression model

## Comparison of derived model with standard model

The validity of the derived model was also verified through application of the regression model (Reg) (Least

Square Method using Excel version 2003) in predicting the trend of the experimental results. Comparative analysis of Figure 10-Figure 12 shows very close dimensions of aligned areas covered by ethanol yield, which precisely translated into significantly similar trend of data point's distribution for experimental (ExD), derived model (MoD) and regression model-predicted (ReG) results of ethanol yield.

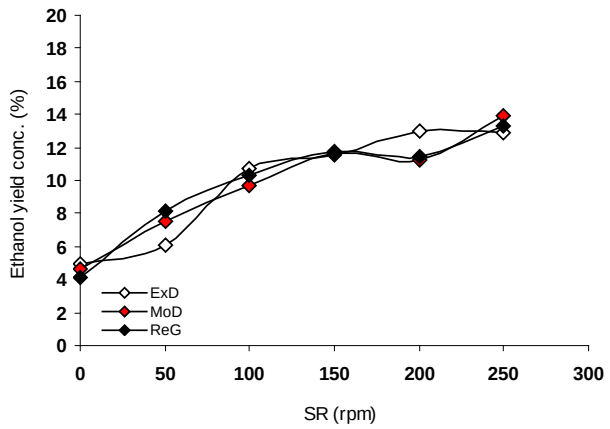


**Figure 11.** Comparison of areas covered by ethanol yield (relative to shaking rate) as obtained from experiment [1] derived model and regression model

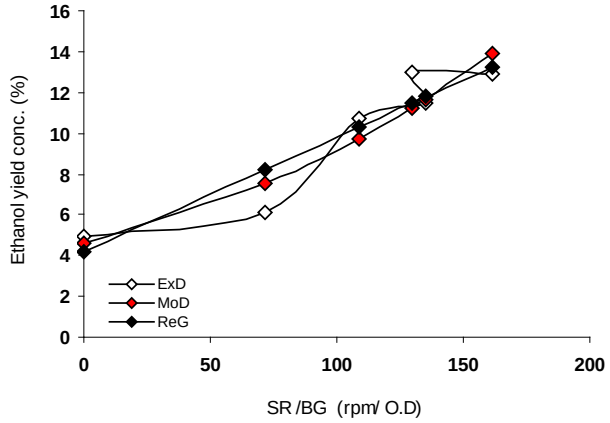


**Figure 12.** Comparison of ethanol yield (relative to shaking rate-microbial growth ratio) as obtained from experiment [1] derived model and regression model

Also, the calculated correlations (from Figure 10-Figure 12) between ethanol yield and SR, BG & SR/BG for results obtained from regression model were 0.8750, 0.8641 & 0.9878 respectively. These values are in proximate agreement with both experimental and derived model-predicted results. The standard errors incurred in predicting ethanol yield for each value of SR, BG & SR/BG considered as obtained from regression model were 1.3380, 1.53 & 3.1459 x $10^{-5}$ % respectively.

***Computational Analysis***

Critical computational analysis of the experimental and model-predicted ethanol yield was carried out to ascertain the degree of validity of the derived model. This was done by comparing results of evaluated ethanol yield per unit value of input ratio SR/ BG as obtained from experimental and derived model within shaking rate and microbial growth range: 0-250 rpm and 0.43 – 1.55 O.D respectively.

Ethanol yield per unit SR /BG ratio $\zeta / (\vartheta / \varkappa)$ (rpm/O.D) was calculated from the equation;

$$\zeta_R = \zeta / (\vartheta / \varkappa) \quad (9)$$

Re-written as

$$\zeta_R = \Delta\zeta / \Delta(\vartheta / \varkappa) \quad (10)$$

Equation (10) is detailed as

$$\zeta_\vartheta = \zeta_2 - \zeta_1 / (\vartheta / \varkappa)_2 - (\vartheta / \varkappa)_1 \quad (11)$$

Where

$\Delta\zeta$ = Change in the ethanol yield $\zeta_2$, $\zeta_1$ at two values of SR/ BG ratios $(\vartheta / \varkappa)_2$, $(\vartheta / \varkappa)_1$.

Considering the points (0, 4.93) & (161.2903, 12.93), (0, 4.6335) & (161.2903, 13.875) and (0, 4.1491) & (161.2903, 13.2548) as shown in Table 1 and Figure 12, then designating them as $(\zeta_1, (\vartheta / \varkappa)_1)$ & $(\zeta_2, (\vartheta / \varkappa)_2)$ for experimental, derived model and regression model predicted results respectively, and then substituting them into equation (11), gives the slopes: 0.0496, 0.0573 and 0.0565 (rpm/O.D) respectively as their corresponding ethanol yield per unit input ratio SR/ BG.

The proximity between these values indicates significantly high validity level for the derived model.

***Deviational Analysis***

Critical analysis of the ethanol yields precisely obtained from experiment [1] and derived model shows deviations on the part of the model-predicted values relative to values obtained from the experiment. This is attributed to the fact that surface properties of the sugar cane molasses and the physico-chemical interactions between the molasses and the infesting microbes which played vital roles during the biofuel production process [1] were not considered during the model formulation. This necessitated the introduction of correction factor, to bring the model-predicted ethanol yield to those of the corresponding experimental values.

The deviation Dv, of model-predicted ethanol yield from the corresponding experimental result was given by

$$Dv = \left( \frac{\zeta_{MoD} - \zeta_{ExD}}{\zeta_{ExD}} \right) x100 \quad (12)$$

Where

$\zeta_{ExD}$ and $\zeta_{MoD}$ are ethanol yield evaluated from experiment and derived model respectively.

The correction factor took care of the negligence of operational contributions of surface properties of the sugar cane molasses and the physico-chemical interactions between the cane molasses and infesting microbes which actually played vital role during the ethanol production process. The model predicted results deviated from those of the experiment because these contributions were not considered during the model formulation. Introduction of the corresponding values of Cf from equation (11) into the model gives exactly the corresponding experimental ethanol yield.

**Table 6. Variation of deviation and correction factor with input ratio SR /BG**

| SR /BG | Dv (%) | Cf (%) |
|---|---|---|
| 0 | - 6.01 | + 6.01 |
| 71.4286 | + 23.66 | - 23.66 |
| 108.6957 | - 9.49 | + 9.49 |
| 135.1351 | + 0.90 | - 0.90 |
| 129.8701 | -13.47 | +13.47 |
| 161.2903 | + 7.31 | - 7.31 |

Deviational analysis of Table 6 relative to input ratio SR/BG indicates that the operationally viable deviation range of model-predicted ethanol yield from the experimental results is 0.9-13.47 %. This invariably translated into 86.53-99.1 % operational confidence and reliability level for the derived models as well as 0.86-0.99 reliability coefficient for the yield response of ethanol to input ratio SR/ BG.

Consequently, in order to obtain high confidence level, the derived model considers input parameter value; 50 rpm (shaking rate) very extraneous. This was as a result of 23.66% deviation associating the use of this input parameter value.

Consideration of equation (12) and critical analysis of Table 6 and Figure 12 indicate that the highlighted deviation range corresponds to ethanol yields: 11.6140 - 11.2058 % and input ratio SR/BG:135.1351-129.8701 rpm/ O.D respectively.

Correction factor, Cf to the model-predicted results was given by

$$Cf = \left( \frac{\zeta_{MoD} - \zeta_{ExD}}{\zeta_{ExD}} \right) x100 \qquad (13)$$

Critical analysis of Table 6 indicates that the evaluated correction factors are negative of the deviation as shown in equations (12) and (13). Table 6 shows that the operationally viable range of correction factors to the model-predicted methane gas yield were – 0.9 to + 13.47 %. Table 6 and Figure 12 indicate that these highlighted correction factors correspond to ethanol yields: 11.6140-11.2058 % and input ratio SR/BG: 135.1351-129.8701 rpm/ O.D respectively.

It is important to state that the deviation of model predicted results from that of the experiment is just the magnitude of the value. The associated sign preceding the value signifies that the deviation is a deficit (negative sign) or surplus (positive sign).

## 5. Conclusion

Ethanol yield response was evaluated based on the operational input ratio of shaking rate (SR) and microbial growth (BG) during bioprocessing of sugar cane molasses with Saccharomyces cerevisiae. Ethanol yield response typified an empirical model which is exponential-linear in nature. The validity of the derived model was rooted on the core model expression $\zeta - 0.00012\,\text{ϑ} = 4.6335e^{0.0068(\text{ϑ}/\text{ϰ})} - 0.00004\varepsilon$ where both sides of the expression are correspondingly approximately equal. Ethanol yield per unit input ratio SR/ BG were evaluated from experimental, derived model & regression model predicted results as 0.0496, 0.0573 & 0.0565 rpm/ O.D respectively. Standard errors incurred in predicting ethanol yield for each value of SR, BG & SR/ BG considered as obtained from experiment, derived model and regression model were 0.13369, 0.9674 and 1.3380%, 1.3096, 1.3615 and 1.5300 % & 1.3701, 0.5969 and 1.1459 x $10^{-5}$ respectively. The operationally viable deviation range of model-predicted ethanol yield from the experimental results was 0.9 -13.47 %. This translated into 86.53-99.1 % operational confidence and reliability level for the derived models, as well as 0.86 - 0.99 yield response coefficient of ethanol to the input ratio SR/ BG. Consequently, in order to obtain high confidence level, the derived model considers input parameter value; 50 rpm (shaking rate) very extraneous. This was as a result of 23.66% deviation associating the use of this input parameter value.

## References


[1] Osman, M. E., Khattab, O. H., Hammad, I. A., El-Hussieny, N. I. (2011).Optimization of Bio-Fuel Production by *Saccharomyces cerevisiae* Isolated from Sugar Cane Bagasse. Journal of American Science. 7(5):485-492.

[2] Shahbazali, E. (2013).Biorefinery: From Biomass to Chemicals and Fuel. Green Processing and Synthesis. 2(1): 87-88.

[3] Gaur, K., (2006). Process Optimization for the Production of Ethanol via Fermentation. MSc. Dissertation, Thapar Institute of Engineering and Technology, Patiala.

[4] Antunes, F. A. F, Chandel, A. K., Milessi, T. S. S., Santos, J. C., Rosa, C. A., and Da Silva, S. S. (2014).Bioethanol Production from SugarCane Bagasse by a Novel Brazillian Pentose Fermenting Yeast, Scheffersomyces shehatae UFMG-HM 52.2: Evaluation of Fermentation Medium. International Journal of Chemical Engineering, 2014:8..

[5] Morimura, S., Ling, Z. Y., and Kida, K. (1997). Ethanol production by repeated batch fermentation at high temperature in a molasses medium containing a high concentration of total sugar by thermotolerant flocculating yeast with improved salt tolerance. J Ferment Bioeng 83: 271-74.

[6] Agrawal, P. K., Kumar, S, and Kumar, S (1998). Studies on alcohol production from sugarcane juice, sugarcane molasses, sugarbeet juice and sugarbeet molasses, Saccharomyces cerevisiae NSI-113. Proceedings of the 60th Annual Convention of the Sugar Technologists Association of India, Shimla, India.

[7] El- Diwany, A I, El-Abyad, M. S. and EL-Rafai, A. H, Sallam, L. A. and Allam, R. P. (1992). Effect of some fermentation parameters on ethanol production from beet molasses by Saccahromyces cerevisiae Y-7. Biores Technol 42: 191.

[8] Bulawayo, B, Brochora, J. M., Munzondo, M. I .and Zvauya, R. (1996). Ethanol production by fermentation of sweet sorghum juice using various yeast strains. World J Microbiol Biotechnol 12: 357-60.

[9] Sree, N. K., Sridhar, M., Suresh, K., Bharat, I. M., and Rao, L. V. (2000). High alcohol production by repeated batch fermentation using immobilized osmotolerant S.cerevisiae. J Indust Microbiol Biotechnol 24: 222-26.

[10] Beall, D. S., Bassat, L. O, Doran, A. B., Fowler, D .E., Hall, R. G., and Wood, B. E. (1992). Conversion of hydrolysate of corn cobs and hulls into ethanol by recombinant E.coli B containing integrated genes for ethanol production. Biotechnol Lett 14: 857.

[11] Arni, S., Molinari., M, Borghi. M., Converti, A. (1999). Improvement of alcohol fermentation of a corn starch hydrolysate by viscosity raising additives. Starch Starke 218-24.

[12] Othman, A. S., Othaman. M. N., Abdulrahim, A. R. and Bapar, S. A. (1992). Cocoa, Pineapples, Sugarcane Waste for ethanol production. Planter 68: 125.

[13] Silva, C. A., Castro-Gomez, R. J. H., Abercio-da-Silva, C., and Gomez, R. J. H. C. (1995). Study of the fermentation process using milk whey and the yeast Kluyveromyces fragilis, Semina londrina 16: 17-21.

[14] Ghalay, A. E. and Ben-Hassan, R. M. (1995). Kinetics of batch production of single cell protein from cheese whey. Appl Biochem Biotechnol - Part A, Enz Engin Biotechnol 50: 79-92. molasses by flocculating yeast for use as a alternative energy source.

[15] Dabas, R., Verma, V. K., and Chauhary, K. (1997). Ethanol production from wheat starch. Indian J Microbiol vol 37: 49-50.

[16] Sharma, S., and Tauro, P. (1986). Control of ethanol production by Saccharomyces cerevisiae. Proceedings of national symposium on yeast biotechnology held at Haryana Agricultural University, Hisar, India.

[17] Yadav, A., Dilbaghi, N., and Sharma, S. (1997). Pretreatment of sugarcane molasses for ethanol production by yeast. Indian j. of Microbiol 37: 37-40.

[18] Ok, T. and Hashinaga, F. (1997). Identification of sugar tolerant yeasts isolated from high sugar fermented vegetables extracts. J Gen Appl Microbiol 43: 39-47.

[19] Skotnicki, M. L., Lee, K. J., Tribe, D. E and Rogers, P. L. (1981). Comparison of ethanol production by different Zymomonas strains. Applied and Environmental. Microbiol 889-893.

[20] Bansal, R, and Singh, R. S. (2003). A comparative study on ethanol production from molasses using Saccharomyces cerevisiae and Zymomonas mobilis. Indian J. Microbiol 43:261-64.

[21] Uma, V. and Polasa, H. (1990). S.cerevisiae of palm wine enhanced ethanol production by using mutagens. J Indust Microbiol Biotechnol 5: 1-4.

[22] Bertolini, M. C., Ernandes, J. R. and Laluce, C. (1991)New yeast strains for alcoholic fermentation at higher sugar concentration. Biotechnol Lett 13: 197-202.

[23] Nwoye, C. I., Odo, J. U., Chukwudi, B. C., and Asuke, F.(2011).Empirical Model for Assessment Evaluation and Optimization of Ethanol Production during Microbial Treatment of Sugar Cane Molasses. Proceedings of the 27th Annual Conference of the Nigerian Metallurgical Engineering, Abuja, Nigeria. Oct., 26-29.

[24] Nwoye, C. I., Odo, J. U., Onyedika, G. O., and Ugwuegbu, C. C. (2011). Model for Predictive Analysis and Optimization of Bio-Fuel Production during Bio-treatment of Sugar Cane Molasses. Proceedings of the 3rd FUTO International Conference on Renewable and Alternative Energy and 2nd Annual Conference of the Renewable Energy and Alternative Energy Society of Nigeria, FUTO Owerri, Nigeria. Aug., 7-11.

[25] Nwoye, C. I., Odo, J. U., Chukwudi, B. C., and Mbah, C. N. (2011). Model for Analysis and Prediction of Ethanol Production Based on Treatment Temperature and Microbial Growth during Biodegradation of Sugar Cane Molasses Combined Proceedings of the Nigerian Materials Congress and Meeting of the Nigerian Materials Research Society, Akure, Nigeria, Nov., 21-24.

[26] Nwoye, C. I., (2008). Data Analytical Memory; C-NIKBRAN.

[27] Nwoye, C. I., and Nwabanne J. T. (2013). Empirical Analysis of Methane Gas Yield Dependence on Organic Loading Rate during Microbial Treatment of Fruit Wastes in Digester. Advances in Applied Science Research 4(1): 308-318.