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Optimization of Production in a Brewery using Artificial Neural Network

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ABSTRACT
The aim of this research was to optimize production in a brewery using Artificial Neural Network (ANN). The Ishikawa diagram was also employed to ascertain the cause of low profit and its effect on the company. Low profit in the brewery was due to production of insufficient quantity of bottled bear, high cost of operation, more resources allocated for other products, frequent damage of products during the packing stage. Here, Feed-forward ANN was trained using set values of solved linear programming problems. In carrying out training for the network, the objective function was set with two (2) variables for canned and bottled beer and four (4) constraints equations for Malted Barley, Sorghum, Hops and Yeast. In the end of the training, the trained neural network was adopted for optimization of production profit for the 2 categories of beer. When the process was optimized, one (1) and fourteen (14) variables of the neutral structure network was formed, an output layer and 1 hidden layer produced 50 neutrons. Also, the feed-forward back propagation algorithm was adopted with a Bayesian regularization error. After producing 115,000 bottles and 137,000 cans of beer for the month of January at a volume 236.55 hectolitres (hl) and production cost of ₦24,673,333, gross profit was observed to be ₦41,653,333 with net profit of ₦16,980,000. In the end of ANN procedure, maximum optimization profit rose from ₦16,980,000 to ₦21,958,263.43 which makes up 29.32% increase. The regression plot for comparison of Simplex method profit and ANN profit gave a reasonable correlation of 0.92735 and goodness of fit/correlation coefficient up to 0.85998. Hence, the neural network correlation results proved to be 92% accurate, when compared with the Simplex method of solving linear programming problems. Thus, this research, if implemented, will lead to an increase in the production rate of beer being recorded, which will eventually bring about an increase in production profit on a monthly basis in International Breweries Plc, Port Harcourt.

KEYWORDS: Optimize, Production, Brewery, Artificial Neural Network, Ishikawa diagram.

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1. INTRODUCTION

This research considers the optimization of production in a brewery using the Artificial Neural Network. These days, companies are more competitive and every detail is important if the business must improve its competitiveness. In this case, it is relevant to keep the customers satisfied and offering them what they are expecting. However, the companies must mobilize an effective approach to be able to compete favourably with their rivals, improve profit, get better performance to do their best for their customers and improve every day. According to Izabo *et al.* (2018), in modern day solving of mathematical problems, Neural Network (NN) algorithms are applied in obtaining the shortest possible way to the most feasible solution. Artificial neural networks (ANNs) can best be likened to the connections and links of neurons in the biological nervous system and the brain in a living organism.

Diana (2018) asserts that ANNs are statistical models designed to adapt and self-program by using learning algorithms in order to understand and sort out concepts, images, and photographs. For processors to do their work, developers arrange them in layers that operates in parallel. The input layer is analogous to the dendrites in the human brain's neural network. The hidden layer is where artificial neurons take in a set of input based on synaptic

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weights, which is the amplitude of strength of a connection between nodes. These weighted outputs generate nodes. These weighted inputs generate an output through a transfer function to the output layer.

According to Haykin (2001) the ANN structure assumes a classical behaviour of system based on interconnected neurons, responsible for the basic processing of information/knowledge acquired by the network. This process occurs mainly due to the learning procedures and the connecting forces between the neurons, called synaptic weights. Lilly *et al.* (2015) opined that end products of production process may suffer from an inherent variability in dimensions, colour, chemical composition or physical properties. According to Isaac and Aziaka (2014) engineering reliability is concerns with the indispensable procedure in managing a particular product. This dependability, specify the peculiarities of a process component to perform well for a particular period of time under some stated conditions.

Kanda *et al.* (2016) in their study used monthly data from 2003 to 2013 comprising of pH, turbidity, temperature and electrical conductivity to predict DO using multi-layer perceptron (MLP), a form of feed forward back propagation ANN. Yashon *et al.* (2020) conducted research on the use of Artificial Neural Network and Multiple Linear Regression Model for the prediction of dissolved oxygen in Rivers. The research presents an approach based on the feed forward neural network (FNN) model for the simulation and prediction of dissolved oxygen (DO) in the river basin in Kenya.

Preety *et al*. (2017) carried out research on the application of ANN in construction activities related to prediction of costs, risk and safety, tender bids, as well as labour and equipment productivity. Elinwa and Okhide (2020) carried out research on the application Artificial Neural Network (ANN) to study the effects of using palm kernel shells (PKS) as aggregates on the compressive strength of concrete. Isaac and Obi (2017) in their study claimed that particle swarm optimization (PSO) is a relatively new method of optimization that has been empirically shown to perform well on many of such problems finding the global optimum solution in a complex search space.

In order to implement an effective optimization programme, an enterprise must first decide which specific standards the product or service must meet. There must be the determination of percentage units' failure which is would be sent to the management personnel for scrutiny. After this, corrective action must be decided upon and taken (for example, defective units must be repaired or rejected and poor service repeated at no charge until the customer is satisfied). If too many unit failures or instances of poor service occur, then a plan must be devised to improve the production or service process and then that plan must be put into action (Latif, 2016). In this research, various applications of ANN were reviewed and recent works on this principle was analyzed to explicitly explain the importance of ANN in order to ensure that every activity in the brewery meets the required standard.

2. MATERIALS AND METHODS

This research was carried out in the Port Harcourt Metropolis of Rivers State of Nigeria. The study involved a brewery with several units and departments which are involved in the production of beer with special emphasis on profit maximization. In this research which is concerned with optimization of production in a brewery using the ANN, a case study was developed to demonstrate a real-life situation. Several vital tools were adopted to carry out this task without the exception of Ishikawa diagram. To this end, several procedures were followed in other to achieve the aim of this research.

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Fig. 1 shows the map of Rivers State and location of International Breweries Plc., with coordinates. It describes the location where this research was carried out.

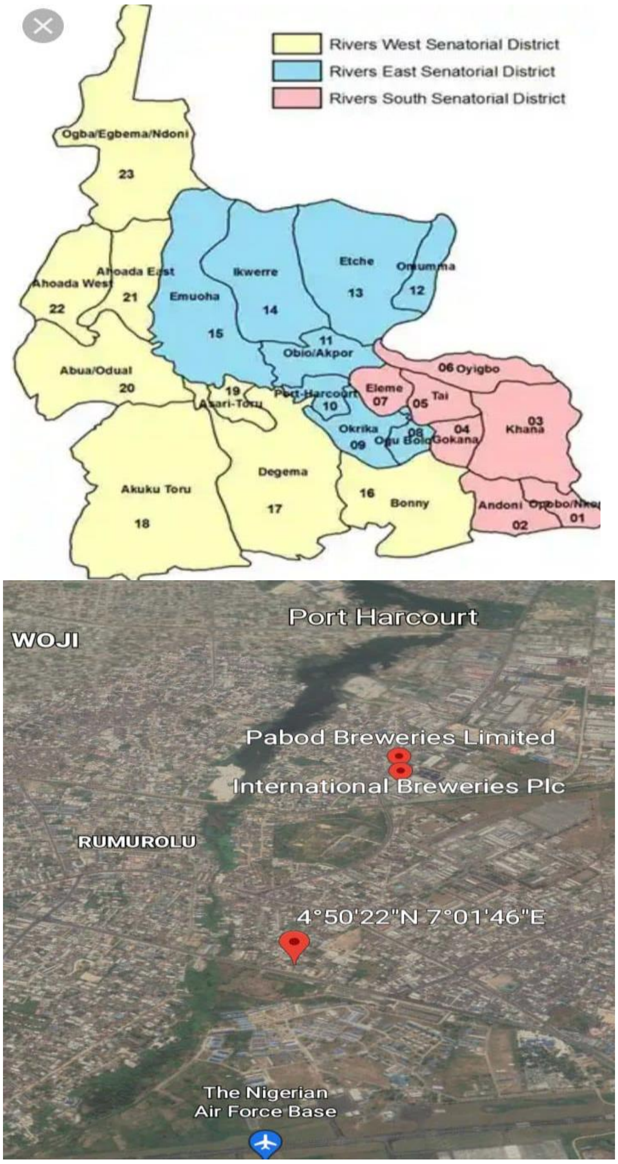

Fig. 1: Map of Rivers State, Showing International Breweries Plc. with Coordinates (Google Earth, 2021)

2.1 General Methodology

i. The various products involved were identified.
ii. The various components and processes required for production of canned and bottled beer were identified.
iii. The quantities in kg of each constituent required for production of beer was obtained.
iv. The quantity of beer brewed for production of canned and bottled beer for the months of January to June, respectively was analysed.
v. The cost of production per canned/per bottled was obtained.
vi. The total cost of production for the months of January to June, respectively was obtained.
vii. The sales cost of each of the products was obtained.
viii. The profit margin per canned/per bottled beer was derived.
ix. The total profit margin for the months of January to June respectively was derived.
x. Artificial Neural Network analysis was carried out using back propagation algorithm.
xi. Linear programming analysis was carried out using simple method.

According to Lilly (2015), linear programming optimization technique is generally used to a large extent by managers to make optimal use of available resources. This assertion can be applied under the following conditions:

i. A situation where there is limited available resources
ii. A situation where the available resources is to be distributed to other activities
iii. A situation where a linear connection exists between the variables.

For the purpose of solving this problem, a model on linear programming was adopted while fulfilling the foregoing conditions.

Let the objective function to be maximized be 'Z'. Optimize (max)

$$Z = f_1x_1 + f_2x_2 + \ldots + f_nx_n + 0s_1 + 0s_2 + \ldots + 0s_m \quad (1)$$

$$a_{11}\, x_1 + a_{12}\, x_2 + \ldots a_{1n}x_n + s_1 = b_1 \quad (2)$$

$$a_{21}\, x_1 + a_{22}\, x_2 + \ldots a_{21}\, x_n + s_2 = b_2 \quad (3)$$

$a_{31}\ x_1 + a_{32}\ x_2 + \ldots a_{3n}\, x_n + s_3 = b_3$ (4)

$a_{41}\ x_1 + a_{42}\ x_2 + \ldots a_{4n} x_n + s_4 = b_4$ (5)

$a_{m1}\ x_1 + a_{m2}\ x_2 + \ldots a_{mn} x_n + s_m = b_m$ (6)

where a_{11} = amount of malted barley required per canned beer in kg, a_{12} = amount of malted barley required per bottled beer in kg, a_{21} = amount of sorghum required per canned beer in kg, a_{22} = amount of sorghum required per bottled beer in kg, a_{31} = amount of hops required per canned beer in kg, a_{32} = amount of hops required per bottled beer in kg, a_{41} = amount of yeast required per canned beer in kg, a_{42} = amount of yeast required per bottled beer in kg; x_1 = amount of product to be optimized for canned beer, x_2 = amount of product to be optimized for bottled beer; b_1, b_2, b_3 and b_4 = constraint of production for malted barley, sorghum, hops and yeast; s_1, s_2, s_3 and s_4 = slack variable for malted barley, sorghum, hops and yeast; $a_{mn}X_n$, s_m and b_m = amount of nth items.

The objective function becomes;
Optimize (max)

$$Z = \sum_{j=1}^{n} fjxj + \sum_{i=1}^{m} (0s1) \quad (7)$$

Subject to;

$$\sum_{j=1}^{n} aijxj + si = bi \quad (8)$$

In matrix form:

$$\text{Optimize (max) } Z = CX^T \quad (9)$$

Subject to;

$$AX + s = b, \quad (10)$$

Where x and s ≥ 0

From the above equations, in relation to production parameters;
A = Materials required for production,
Z = Overall production profit to be optimized,
b = Constraints of production,
X = Optimized products amount,
s = Slack variables.
The objective function for the company will be modelled using the above linear programming equation.

Linear Programming Model for Analyzing the Production Procedure using Simplex Method.

In analysing the production procedure, a Linear programming model was developed using 2 variables and 4 constraint equations as shown below.

For the input data

Let the number of canned beer to be produced each month = x_1 and the number of bottled beer to be produced each month = x_2

$$\text{Max } Z = x_1 f_1 + x f_2 \quad (11)$$

Subject to;

$$a_{11}\ x_1 + a_{12}\ x_2 \leq b_1 \quad (12)$$

$$a_{21}\ x_1 + a_{22}\ x_2 \leq b_2 \quad (13)$$

$$a_{31}\ x_1 + a_{32}\ x_2 \leq b_3 \quad (14)$$

$$a_{41}\ x_1 + a_{42}\ x_2 \leq b_4 \quad (15)$$

After substituting the various values into the equation above, we obtain the following for the month of January, February, March, April, May and June respectively.

For the month of January Optimize (Max) $Z = 40\ x_1 + 100\ x_2$ (16)

Subject to;

$0.0146\ x_1 + 0.0261\ x_2 \leq 15500$ (17)

$0.0073\ x_1 + 0.0140\ x_2 \leq 8100$ (18)

$0.000066\ x_1 + 0.0001830\ x_2 \leq 30$ (19)

$0.000058\ x_1 + 0.0001480\ x_2 \leq 25$ (20)

For the month of February

Optimize (Max) $Z = 42\ x_1 + 121\ x_2$ (21)

Subject to;

$0.0096\ x_1 + 0.0232\ x_2 \leq 13300$ (22)

$0.0072\ x_1 + 0.0116\ x_2 \leq 7000$ (23)

$0.000064\ x_1 + 0.0001340\ x_2 \leq 23$ (24)

$0.000024\ x_1 + 0.0000804\ x_2 \leq 12$ (25)

For the month of March

Optimize (Max) $Z = 42\ x_1 + 121\ x_2$ (26)

Subject to;

$0.0098\ x_1 + 0.0188\ x_2 \leq 14300$ (27)

$0.0049\ x_1 + 0.0120\ x_2 \leq 7400$ (28)

$0.000041\ x_1 + 0.0001200\ x_2 \leq 19$ (29)

$0.000024\ x_1 + 0.0000900\ x_2 \leq 20$ (30)

For the month of April

Optimize (Max) $Z = 35\ x_1 + 114\ x_2$ (31)

Subject to;

$0.0104\ x_1 + 0.0183\ x_2 \leq 12000$ (32)

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$$0.0057\ x_1 + 0.0087\ x_2 \leq 6000 \quad (33)$$
$$0.000085\ x_1 + 0.0001060\ x_2 \leq 20 \quad (34)$$
$$0.000019\ x_1 + 0.0000870\ x_2 \leq 12 \quad (35)$$

For the month of May

$$\text{Optimize (Max) } Z = 44\ x_1 + 123\ x_2 \quad (36)$$

Subject to;

$$0.0141\ x_1 + 0.0248\ x_2 \leq 14500 \quad (37)$$
$$0.0082\ x_1 + 0.0086\ x_2 \leq 7000 \quad (38)$$
$$0.000059\ x_1 + 0.0001100\ x_2 \leq 20 \quad (39)$$
$$0.000044\ x_1 + 0.0000860\ x_2 \leq 15 \quad (40)$$

For the month of June

$$\text{Optimize (Max) } Z = 47\ x_1 + 123\ x_2 \quad (41)$$

Subject to;

$$0.0215\ x_1 + 0.0328\ x_2 \leq 18000 \quad (42)$$
$$0.0096\ x_1 + 0.0176\ x_2 \leq 9500 \quad (43)$$
$$0.000089\ x_1 + 0.0001800\ x_2 \leq 35 \quad (44)$$
$$0.000067\ x_1 + 0.0001680\ x_2 \leq 30 \quad (45)$$

The data given was studied, and calculations were carried out based on the monthly production procedures. The equations are translated into linear programming model. This is to enable the Artificial Neural Network to actually understand the various inputs in a tabular form in the same way in which the data was trained.

2.2 Performance Evaluation of the Neural Network

The optimum performance of the network architecture was calculated using the formula below.

$$R^2 = 1 - \frac{\sum j\ (tj - 0j)^2}{\sum j (0j)^2} \quad (46)$$

where

tj = Targeted value
$0j$= Output value
R^2 = Coefficient of determination
j = processing elements

The Neural Network can be used for linear programming optimization problems by using the structure above to relate with the LP equation. A back propagation algorithm will be used to teach the neural network on solving the optimization problems.
Mathematically,

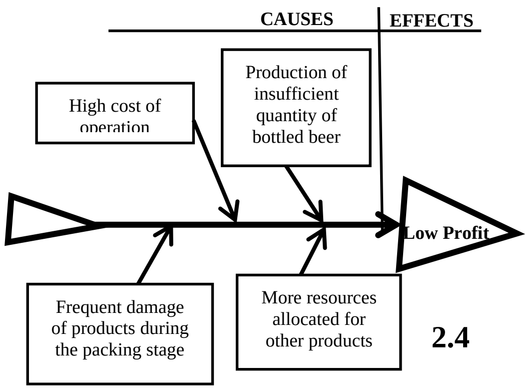
$$F\ (X) = Yi = \sum_{i=1}^{n} ((Xij)(Wij) - (Hij)) \quad (47)$$

where

Y_i = Output variable
X_{ij} = Input variable
W_{ij} = Weights between layers
H_{ij} = Hidden layer containing activation/ Transfer function

2.3 Causes and Effect of Low Output in the Brewery Using Ishikawa Diagram

Fig. 2 shows the Ishikawa diagram which helps to ascertain the causes and effect of low output in the brewery. In this research, the Ishikawa diagram has helped to determine the causes of poor profit output in the brewery which are; frequent damage of products during the packing stage, including manufacturing of some reduced volume of beer bottles.



2.4

Fig. 2: The Ishikawa Diagram showing the Causes of Low Profit in A brewery and their Effect

Neural Network Training State

Fig 3 shows the neural network structure. Every input given has an assigned weighted connection to generate the output values. In the NN structure, each input is weighted with an appropriate value of W, the sum of weighted inputs and the bias 'b' for the input of a transfer function, whose neurons can use any differentiable transfer function to generate their output. The network structure consists of 1 input layer with 14 variables, 1 hidden layer with 50 neurons and 1 output layer.

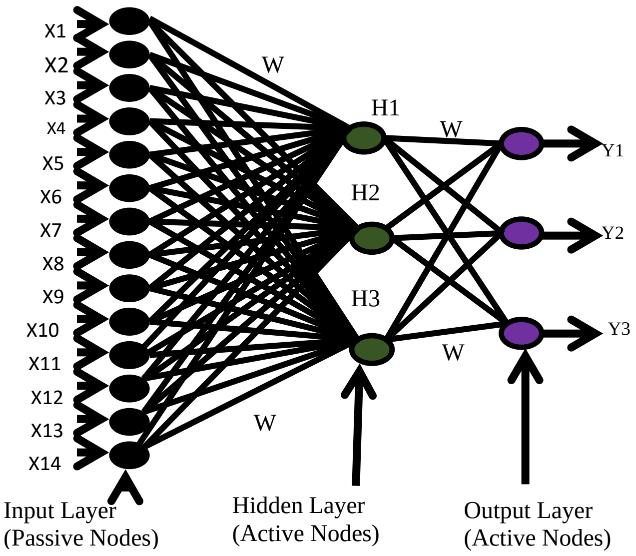


Fig. 3: Schematic Representation of the Neural Network Architecture

As seen in Fig. 4, the structure used in this research is a 3-layer feed-forward back propagation neural network which is made up of sigmoid hidden neurons and linear output neurons. The sigmoid function is a mathematical function with an S-shaped curve which is used to carry out logistic tasks. On the other hand, the linear transfer function is a mathematical tool which consists of a unit relation between its output and input.

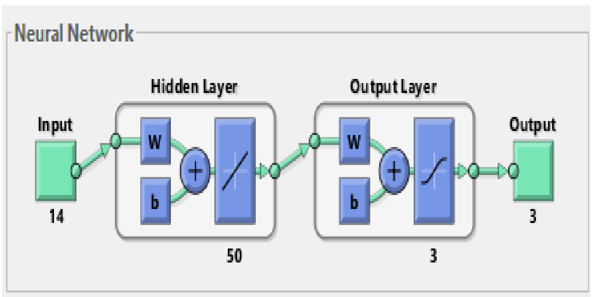


Fig. 4: Structure of the Neural Network with Input and Target Variables

3. RESULTS AND DISCUSSION

3.1: Profit Optimization Performance of Neural Network

Fig. 5 shows the process of profit maximization using the neural network for 1000 iterations, it was noticed that the best performance occurred at 2nd epoch (iteration), with a performance value of 41353492.9422. This is the point where the best result was recorded for maximum profit. Furthermore, from the optimization procedure, the error had 20 bins. The results when compared to previous works conducted on the performance of CI engines, it was observed that a better training performance was achieved (Dey *et al.*, 2021).

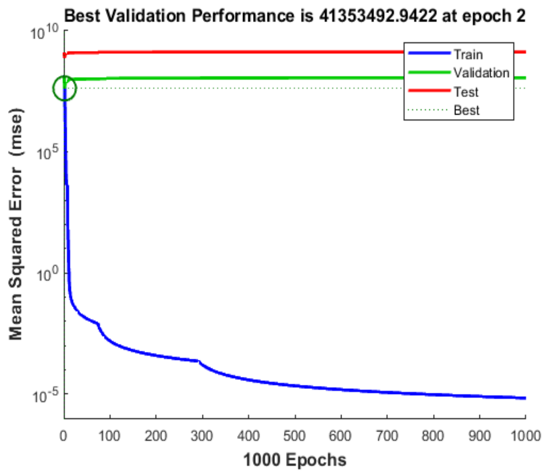


Fig. 5: Maximum Profit Optimization Performance

As seen in Fig. 6, the error histogram shows that there are 400 instances with zero (0) error. It is observed that there is no error for all the instances.

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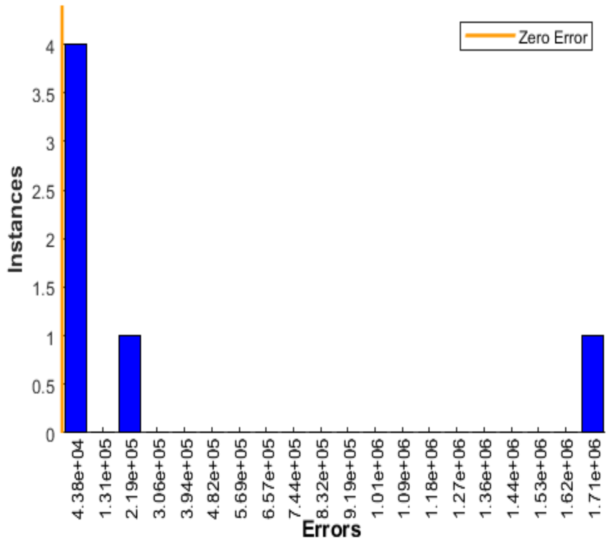

Fig. 6: Error Histogram (20 Bins)

It is also observed that there was a significant increase in profit from the initial brewery profit of ₦16,980,000.00 to ₦21,958,263.43 in the first month (January) which constitutes about 29% increase. The results showed that greater the number of bins, the better the prediction which is in line with the study of Heinrich (2021), that if too few bins are chosen, the rank histogram is likely to miss calibrations, if too many are chosen, even perfectly calibrated forecast systems can yield rank histograms that do not appear uniform, thereby improving on the performance of the model.

As seen in Fig. 7, Neural Network training state is a group of plots from a trained set of gradient, mu, and validation fail results versus Epochs. The gradient represents the direction and magnitude obtained during the training phase of the neural network that improves the network weights, while the mu plot versus Epochs shows a small value of mu. The plot of validation shows that validation fail starts to rise from zero (0) to 998 Epochs (iterations), which corresponds to the sphere that depicts a very good validation performance. The output obtained on the database shows that the result obtained is in line with the work of Plumb *et al.* (2005), that an efficiency training of a dataset helps to prepare the dataset for effective prediction.

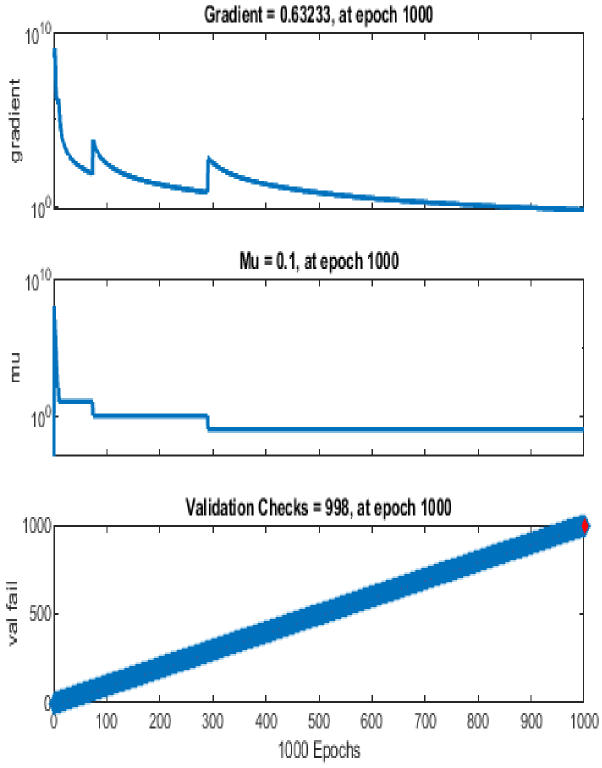

Fig. 7: Neural Network Training State

correlation of 0.876923 and a goodness of fit/correlation coefficient up to 0.768994 were obtained from the comparison of the actual company's profit with the simplex method profit.

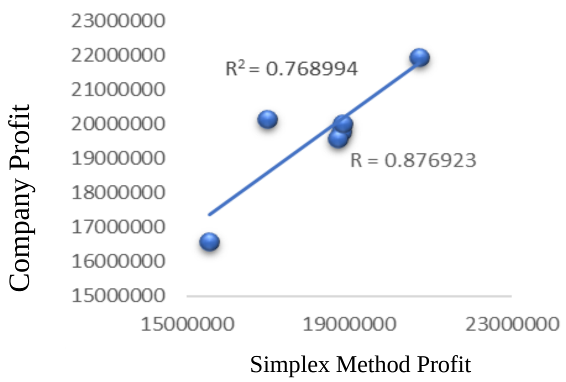

Fig. 8: Regression Plot of Company's Profit and Simplex Method Profit (ANOVA)

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The Fig. 9 shows that a slightly weak correlation of 0.634575 and goodness of fit/correlation coefficient up to 0.402685 were obtained from the comparison of the company's profit with the ANN profit.

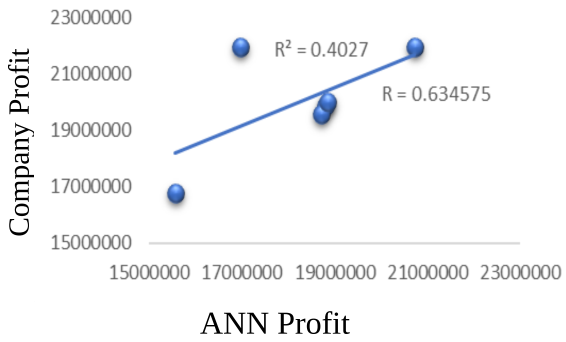

Fig. 9: Regression Plot of Company's Profit and ANN Profit (ANOVA)

The Fig. 10 shows that a good correlation of 0.92735 and goodness of fit/correlation coefficient up to 0.85998 were obtained from the comparison of the Simplex method profit with the ANN profit.

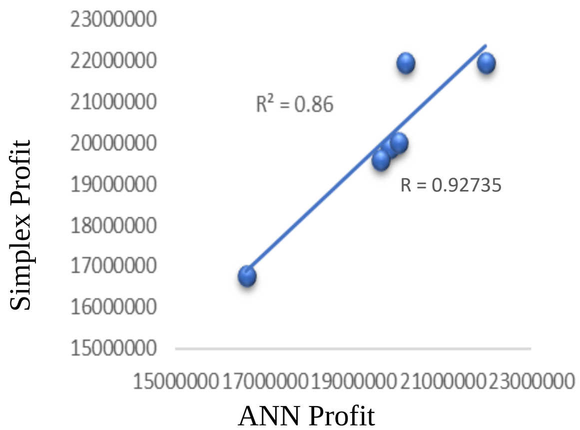

Fig. 10: Regression Plot of Simplex Method Profit and ANN Profit (ANOVA)

As seen in Fig. 11, when the process was optimized applying ANN, it is observed that was an increase in profit of the following months when compared with the company's profit January, February, March, April, May and June.

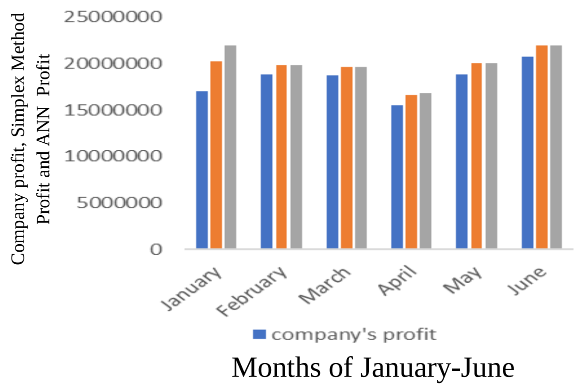

Fig. 11: Overall Comparison of Results from Company's Data, Simplex Method and Artificial Neural Network results for Maximum Profit from Production of both Bottled and Canned Beer.

The Fig. 12 shows the comparison of the actual company's profit, the optimal solution using Simplex method and ANN.

Actual Profit = [January: ₦16980000, February: ₦18802000, March: ₦18,718,000, April: ₦15,566,000, May: ₦18,855,000, June: ₦20,720,000];

Simplex Method Profit = [January: ₦20,207,000, February: ₦19,891,000, March: ₦19,607,000, April: ₦16,603,000, May: ₦20,023,000, June: ₦21,964,000];

ANN Profit = [January: ₦21,958,263.43, February: ₦19,891,000, March: ₦19,607,000, April: ₦16,784,165.55, May: ₦20023000, June: ₦21,963,999.34];

After optimization procedure was carried out, it became noticeable that the maximum profit from the artificial neural network was more than the brewery's recorded profit.

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However, the initial maximum profit from the brewery stood at ₦20,720,000 in the month of June. Hence, after the optimization procedure was done, profit rose to ₦21,963,999.34 which constitutes about 6% increase in maximum profit from the previous data.

When the process was optimized applying ANN, it is observed that there was an increase in profit of the following months when compared with the company's profit January, February, March, April, May and June as shown in Fig. 11. The profit optimization are as follows; **For January:** Company's Profit = ₦16,980,000, Simplex method profit = ₦20,207,000, ANN Profit = ₦21,958,263.43, **For February:** Company's Profit = ₦18,802,000, Simplex method profit ₦19,891,000, ANN Profit = ₦19,891,000, **For March:** Company's Profit = ₦18,718,000, Simplex method Profit = ₦19,607,000, ANN Profit = ₦19,607,000, **For April:** Company's Profit = ₦15,566,000, Simplex method profit = ₦16,603,000, ANN Profit = ₦16,784,165.55, **For May:** Company's Profit = N18,866,000, Simplex method Profit = ₦20,023,000, ANN Profit = ₦20,203,000, **For June:** Company's Profit = ₦20,720,000, Simplex method Profit = ₦21,964,000, ANN Profit = ₦21,963,999.34. This shows that the ANN is a powerful tool for optimization of any production system.

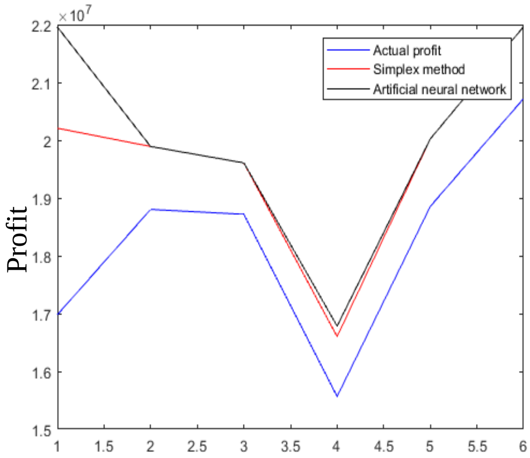

Fig. 12: Comparison of the Company's Profit, the Maximum Optimization Profit using Simplex method and Artificial Neural Network.

4. CONCLUSION

In this research, the production processes and various essential ingredients required for beer production were analyzed with emphasis on the profit output for the months of January to June, 2019. The Ishikawa diagram was also employed to ascertain the cause of low profit margin and its possible effect on the company.
From this research, artificial neural network was modeled and used to optimize the production of beer for International Breweries Plc, Port Harcourt. A back propagation algorithm where the network is able to learn any given parameter or target was adopted to carry out the optimization task.
After comparing the results, it was noticed that both the Simplex method of solving linear programming problems and the artificial

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neural network were identical by a correlation of 92%.

After computing, the maximum projected profit was observed to have increased from ₦16,980,000 to ₦21,958,263.42.34 which constitutes about 29.32% increase.

Thus, in order to bridge the gap from previous works, this research has proven that the combination of ANN, Ishikawa diagram and Simplex method of solving linear programming problems is effective for production optimization in a brewery by reducing waste and downtime in the facility.

However, this can be achieved with the following recommendations.

i. The results obtained be compared with that of other tools such as pinch, particle swarm optimization and random forest.
ii. Incorporate a larger data set as it will improve the accuracy of the model.

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