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**Research Article**

# Determination of Agro-Oil Seeds Processing Machinery Effectiveness for Product Quality Enhancement and Waste Control

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**Abstract:** Agro-oils are oils extracted from agro –seeds with oil potentials. These oils from Groundnuts, Melons, Maringa, Cocoa beans , Palm fruits and the likes are consumed by people due to their, medicinal and minerals content for human health. Their extractions requires quality approach and are costly therefore waste of these materials cannot be compromised. Hence the needs for machines that are of high effectiveness which is the products of efficiency, quality rate and availability. Cocoa beans processing machine was used as case study .By determining its efficiency, quality rate and availability and compared the results with the acceptable standards of these strategic decisions. The machine effectiveness acceptable standard was set at 0.85 (85%), but this case study shows 0.77 (77%). This is low compared with the acceptable standard of $\geq$ 0.85 with negative deviation of 0.08. This is caused by the low values of machine availability and Quality rate which should not be $\leq$ 0.90 and $\leq$ 0.99 respectively. The availability of the machine was improved to 0.94 and its quality rate to 0.97. This gave a new acceptable machine effectiveness of 0.875328 (87.5%) which led to better achievement on the cocoa oil yiled thus: Cocoa Liquor (chocolate colored paste from milled nibs), based on pure Cocoa Beans available (after foreign material removal) which is 14.2589% . The percentage of liquor available for pressing to get the oil called cocoa butter was 85.7411%. Cocoa Butter yield (based on total Cocoa Liquor was 35.25% while the Cake yield ( residue after oil extraction) was 43.95% Cocoa Butter waste (based on total Cocoa Liquor ) 2.435% and Coca cake wasted was 4.076%. This model will find its application in small, medium and large scale agro oil extraction industries.

**Keywords:** Model development, agro-oil seeds, machine effectiveness, oil yield and strategic decisions.



## INTRODUCTION

Oil agro seeds as groundnuts, cocoa, melon, palm fruits are important food; feed and principal oil seeds crops which are cultivated on a large scale throughout the world. They are annual crops principally for their edible oil and protein rich kernel seeds, borne in pods which develop and mature below the soil surface (Ayoola and Adeyeye, 2010; Odoemelam, 2005).

Vegetable oils has made an important contribution to the diet in many countries, serving as a good source of protein, lipid and fatty acids for human nutrition including the repair of worn-out tissues, new cells formation as well as a useful source of energy (Grosso *et al.*, 1997). and can also serve as a source of oleochem icals (Morrison *et al.*, 1995). Oleochemicals are completely biodegradable and so could replace a number of petrochemicals (Ayoola and Adeyeye, 2010).

The vast food preparations incorporating edible oils to improve the protein level have helped in no small way in reducing malnutrition in the developing countries (Asibuo *et al.*, 2008; Adeyeye and Ajewole, 1992; Penny and Kris-Etherton, 1999 ). The regular consumption of some of these edible oils lower the blood cholesterol level (Lokko *et al.*, 2007; Bello and Fatimehin, 2015). Penny and Kris-Etherton (1999) reviewed the scientific data concerning groundnut consumption and coronary heart disease and concluded regular consumptions of groundnuts significantly reduce risk. Edible oil extraction in most developing nations such as those of Africa is usually done manually by hand, and like all other manual operations it is drudgery and time consuming (Olaomi, 2008 ; Akerele and Ejiko, 2015; Mwanzab, 2017).

The most common method of extracting edible oil from oilseeds is mechanical pressing of oilseeds after cleaning and milling before the press (ICCO , 2011 and Prinz; 2017). This method ensures extraction of a non-contaminated, protein-rich low fat cake at a relatively low cost (Bamgboye and Adejumo, 2007 ; Ajao, *et al.*, 2010; Muchiri and Pintelon2014) . The commonly used machines are winnower for cleaning, milling machine for grinding to paste and pressing machine for the oil extraction and optimum performance of these machines by reasons of their effectiveness enhance the yield level expected from pressing (Adzimah *et al*.,2010 ; Akinnuli *et al*., 2016 and Akinnuli *et al.,* 2018).

Some areas of the nation's foreign earning is the edible oil extraction (Dasilva *et al*., 2010; Ntiamoah and Afrane, 2008 and Afoakwa,*et al*.,2011b).

And so if an empirical model can be developed to forecast yield expected of any quantity of oil seeds input for processing it will be of immense benefit and advantage for both existing and prospective oil seed processing industries to predict the likely losses and profits that can result from the foreknowledge of their production output and their processing machines used needs to perform effectively this is the the grand purpose of this research work.

A mathematical model of a real physical system is an evolution equation suitable to define the evolution of the state variable in charge to describe the physical state of the system itself (Bellomo et al., 2007 and Gitau, *et al.*, 2013 ) The process of mathematical modelling involves : formulating the real world data obtained to get the mathematical model; this is then analysed to draw the mathematical conclusion which is interpreted and then used for prediction; the data are now used to test the model (Gerda, 2001).

## METHODOLOGY

Methodology to this research involved machine effectiveness strategic decisions identification, model development, determination the performance of the models developed its and application using a case study cocoa oil extraction to determine the yield level base on the machine effectiveness**.**

**Overall Machine Effectiveness** $\left[\ddot{A}\right]$

This is the capability of producing a desired result. When something is deemed effective, it meansit has an intended or expected outcome, or produce a deep, vivid impression. The three major attribute for its determination are machine availability $\left[\tilde{A}\right]$, performance efficiency $\left[\dot{\eta}\right]$ and rate of quality product $\left[\phi_r\right]$.

Therefore,

**Determination of machine availability** $\left[\tilde{A}\right]$

Machine availability is the running time per day $(R_t)$ divided by the operating time of the machine $\left[OP_t\right]$

$$\tilde{A} = Rt/\left[OP_t\right] \qquad (1)$$

**Performance Efficiency of Machine** $\left[\dot{\eta}\right]$

This is the machines operating speed rate $\left[\dot{\varepsilon}\right]$multiply by net operating rate $\left[\tilde{N}\right]$

$$\dot{\eta} = \left[\dot{\varepsilon}\right] \times \tilde{N} \qquad (2)$$

To determine the net operating rate, this is actual processing time divided by operating time as:

$$\tilde{N} = A_p / OP_c$$

While operating time $OP_t$ is loading time $L_t$ less set up time t.

$$OP_t = L_t - S_t \qquad (3)$$

The operating speed rate $\left[\dot{\varepsilon}\right]$ is the actual cycle time $\left[Act\right]$divided by the ideal cycle time [Ict]

$$\left[\ddot{\Sigma}\right] = \left[Act\right]/Ict \qquad (4)$$

**Determination of rate of quality product** $\left[\phi_r\right]$

This is obtained by deducting the defective per day '$Q_d$' from throughput for day $T_p$ and divide the running time per day ($R_t$) as:

$$\left[\phi_r\right] = \left(T_p - Q_d\right)/R_t \qquad (5)$$

**Determination of Overall Machine Effectiveness** $\left[\ddot{A}\right]$

This is the product of the three major decision attributes. The mathematical model required as:

$$\left[\ddot{A}\right] = \tilde{A} \times \ddot{\eta} \times \phi_r \qquad (6)$$

## APPLICATION OF OVER ALL MACHINE EFFECTIVENESS MODELS.

**Determination of Machine Availability** $\left[\tilde{A}\right]$

This is achieved by application of equation 1.

$\left[\tilde{A}\right] = R_t / \left[OP_t\right]$

The machines runs 10 hour per day $(R_t)$ while the operation time of the company is 16 Hrs per day $\left[OP_t\right]$

$$\left[\tilde{A}\right] = \frac{15}{18} = 0.833$$

= 83%

The remaining 17% of the operating time is for machine set up, shift for labor and recess time.

**Determination of Performance Efficiency** $\left[\dot{\eta}\right]$

Equation 2. was used for this computation performance efficiency is machine operating speed divided by machine net operating speed.

$$\left[\ddot{\eta}\right] = \left[\ddot{\varepsilon}\right] / \tilde{N}$$

This machine design (not) operating speed is 1500 rpm but when loaded and operating the speed is 1420 rpm is measured by Tardiometer.

$$\therefore \left[\ddot{\eta}\right] = \frac{1420}{1500} = 0.9466 \approx 0.95$$

**Determination of Rate of Quality Produced**

The computation required is output per day minus quantity defected divided by quantity produced per day. Equation 3.

$$\left[\phi_r\right] = \left[\phi_{pd} - \phi_d\right] / \phi_{pd} \qquad \phi_{pd} = 20{,}000$$

$$= 20{,}000 - 400 \qquad \phi_d = 0.02\,(\phi_{pd})$$

$$= \frac{19{,}600}{20{,}000} = 0.98 \qquad O_{pt} = 18 \text{ Hrs}$$

**Determination of the machine overall effectiveness** $\left[\ddot{A}\right]$

This is the products of availability, machine efficiency and the quality production rate as shown in equation 4.

$$\left[\ddot{A}\right] = \tilde{A} \times \ddot{\eta} \times \phi_r \qquad \tilde{A} > 90\% \quad 0.90$$

$$= 0.83 \times 0.95 \times 0.98 \qquad \left[\ddot{\eta}\right] > 95\% \quad 0.95$$

$$= 0.77273 \qquad \left[\phi_r\right] > 99\% \quad 0.99$$

$$= 0.773 \qquad \left[\ddot{A}\right] > 85\% \quad 0.85$$

The machine effectiveness (0.773) is low compared with the acceptable standard of 0.85 with negative deviation of 0.08. This is caused by the low values of availability and Quality rate $\phi_r$ which should not be less than 0.90 and 0.99 respectively. But in this case they were 0.83 and 0.98 respectively. Hence there are needs for these two criteria optimization for better results of yield.

**Description of Processing Layout**

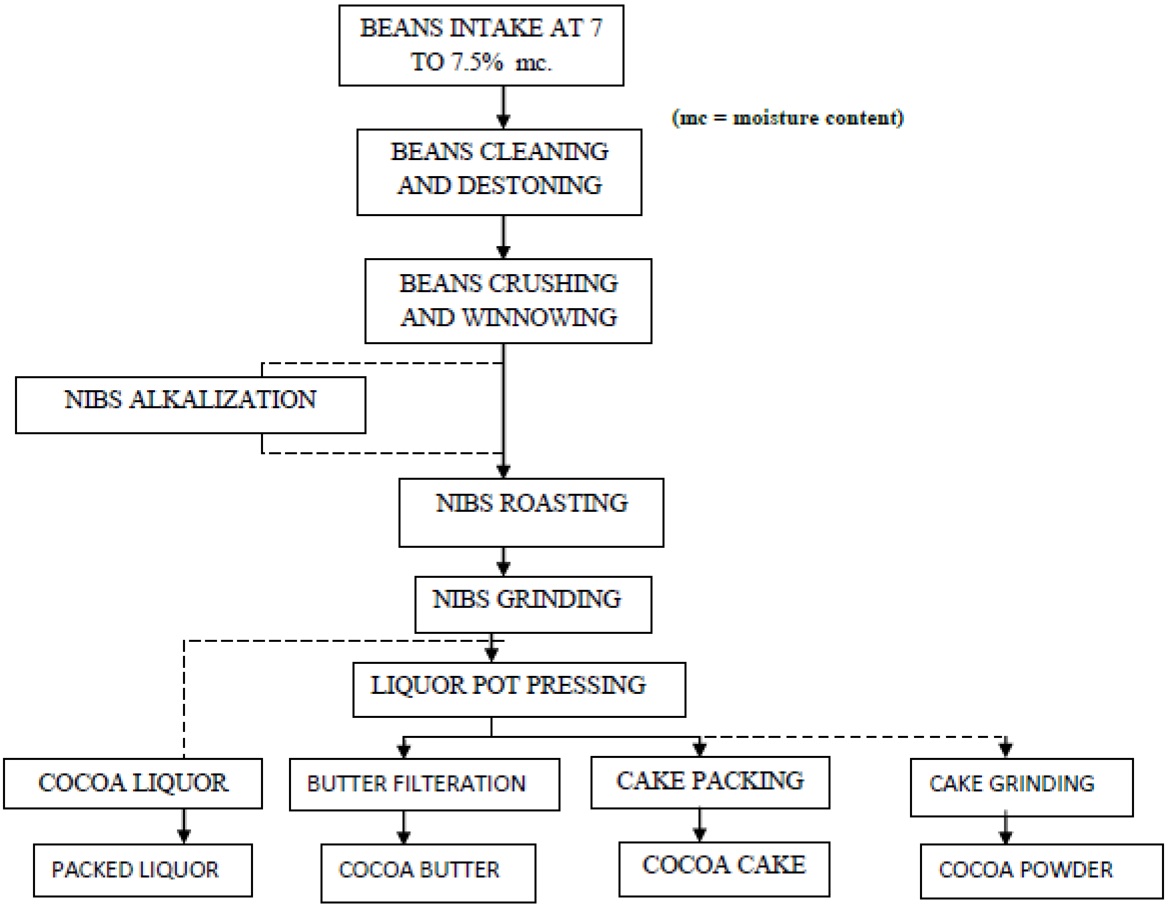


**Figure 1:** Cocoa Beans Process Flow Chart Source: (Adenuoye, 2001 and Akinnuli *et al*., 2011).

Figure 1 shows the processing layout diagram of cocoa beans passes through some stages before final products.

**Model Development.**

The aim of the project is to empirically determine the yields of cocoa beans (butter and cake), expected before actual processing starts. The models required for computations are hereby stated:

**Determination of Net Cocoa Beans Processed.**

**(a) Actual Mass of Cocoa Beans to be process**($B_a$)**:**

This is the actual quantity of cocoa beans available for processing after the foreign material ($FM_m$) in cocoa beans and the loss involved during the cleaning process ($BN_w$), were subtracted from Mass of Beans available for milling ($Bm_a$)

$$B_a = Bm_a - (FM_m + BN_w) \qquad 1$$

(b) .**Determination of cocoa nibs available:**

This is the quantity of broken beans available when the shell ($Sh_{mr}$) and loss of nibs ($NB_w$)during the cracking and winnowing processes, are removed

**(c) Mass of Nibs produced-** $NB_p$

$$NB_p = B_a - Sh_{mr} \qquad 2$$

**(d). Actual Nibs Ground -**$NB_g$

$$NB_g = NB_p - NB_w \qquad 3$$

## DETERMINATION OF COCOA LIQUOR AVAILABLE:

This is the quantity of cocoa nibs ground minus Liquor waste ($Lq_w$) during the grinding process from which Butter Yield and Cake Yield when Butter waste ($BT_w$ ) and Cake waste ($CK_w$) are deducted respectively.

**2.5.1. Actual mass of Liquor produced-$Lq_p$**

$$Lq_p = NB_g - Lq_w \quad 4$$

**2.5.2. Determination of Butter and Cake Yields**

These are the targeted output expected from the model, which are the quantities of Butter and Cake respectively. Adding these two quantities gives the total output yields (expression 7)

**2.5.3.Butter yield from the liquor mass $BT_y$**

$$BT_y = Lq_p\ (\%BT_p) - BT_w \quad 5$$

$\%BT_p$, $BT_w$ (are percentage of butter produced and butter wasted respectively)

**2.5.4. Cake yield from liquor $CK_y$**

$$CK_y = Lq_p\ (\%CK_p) - CK_w \quad 6$$

$\%CK_p$, $CK_w$ (are percentage of Cake produced and Cake wasted respectively)

**2.5.4=3. Total output Yields $BT_yCK_y$**

This is addition of Butter yield and Cake yield.

$$BT_yCK_y = BT_y + CK_y \quad 7$$

## RESULTS

Other years of machine effectiveness were computed for the Liquor Press the results were shown thus: 2008(0.94), 2009(0.90), 2010(0.95), 2011(0.82), 2012(0.77)., 2013(0.85), 2014( 0.96), 2015 (0.71), 2016(0.84) and 2017(0.87).

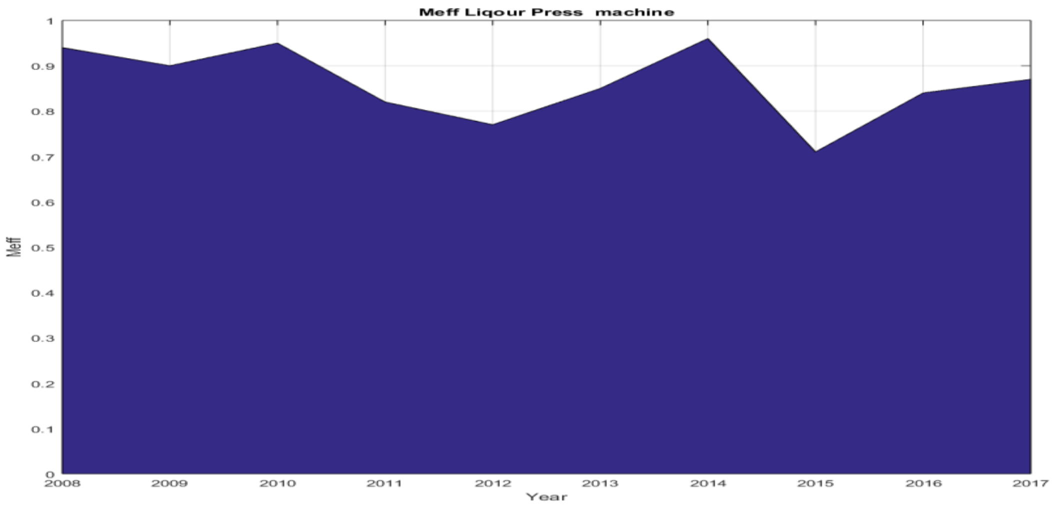


**Figure 2.** Shows the effectiveness of the machine from 2008 till 2017

From the above chart the liquor press machine has an average effectiveness of 86.1% (0.86) with a variance of 0.0065. the effectiveness of the machine was very low in 2015. This can be as a result of increase in down time of the liquor press machine.

**Table 1:** The results from the model application

| Parameter Number | Parameter | Results of computations (kg). |
|---|---|---|
| 1 | Mass of Cocoa Beans Available | 21500 |
| 2 | Mass of Foreign Material | 143.33 |
| 3 | Mass of Cocoa Beans Wasted | 317.574 |
| 4 | Mass of Shell Removed | 1512.266 |
| 5 | Mass of Nibs Wasted | 1430.470 |
| 6 | Mass of Liquor Wasted | 1181.451 |
| 7 | Mass of Butter Wasted | 925.598 |
| 8 | Mass of Cake Wasted | 546.304 |
| 9 | Actual Cocoa Beans Processed | 21039.096 |
| 10 | Cocoa Nibs Produced: $NM_p = B_a - Sh_{mr}$ | 19526.83 |
| 11 | Liquor Produced from Milled Nibs | 16914.91 |
| 12 | Mass of Butter Produced | 6873.359 |
| 13 | Mass of Cake Produced | 8569.649 |
| 14 | Total Produced: 12+13 | 15443.008 |

Table 1: shows the results from the manual computations of the model with the inputs of: mass of Cocoa Beans available (21500 kg) and mass of foreign material (143.33 kg) while percentage of losses as it affects: Cocoa Beans waste ($BN_w$) was 1.487%, Cocoa Nibs waste ($NB_)$ 6.698%, Cocoa Liquor waste ($Lq_w$) 5.532%, Cocoa Butter waste ($BT_w$) 4.334 %, Cocoa Cake waste ($CK_w$) 2.558% .

Total Loss ($T_1$) was 20.609 %

Percentage of yields as it affects Cocoa Liquor, based on pure Cocoa Beans ($BN_p$) available (after foreign material removal) was 79.20% (100% Liquor) , Cocoa Butter yield-$Bt_y$ (based on total Cocoa Liquor - $Lq_p$) 40.635%, Cocoa Cake yield-$Ck_y$ (based on total Cocoa Liquor - $Lq_p$)50.663%, Cocoa Butter waste-$BT_w$ (based on total Cocoa Liquor - $Lq_p$)5.472%, and Cocoa Cake waste-$CK_w$ (based on total Cocoa Liquor - $Lq_p$)3.230% The above Model relative yields and wastes are represented in the following graphs for the purpose of clarity.

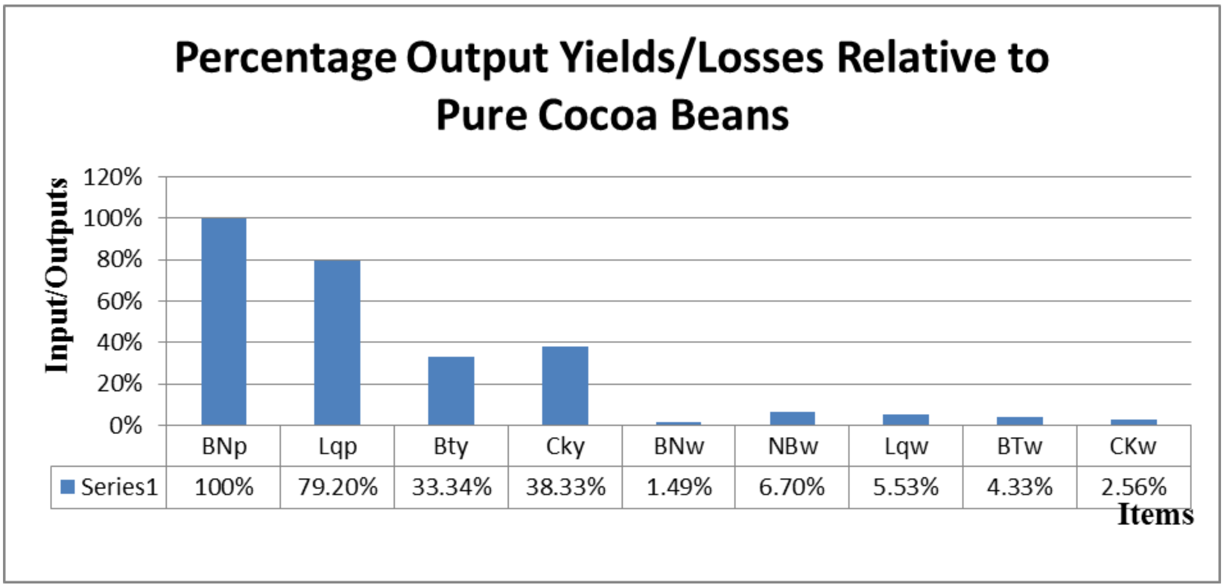


**Fig. 3:** Chart Showing Relative Percentage Yields/Losses of production Outputs (of $BN_p$)

This is the graphical chart showing the relationships of yields (Liquor produced, butter yield and cake yield) and output wastes (butter waste and cake waste) to the input (pure Cocoa Beans).

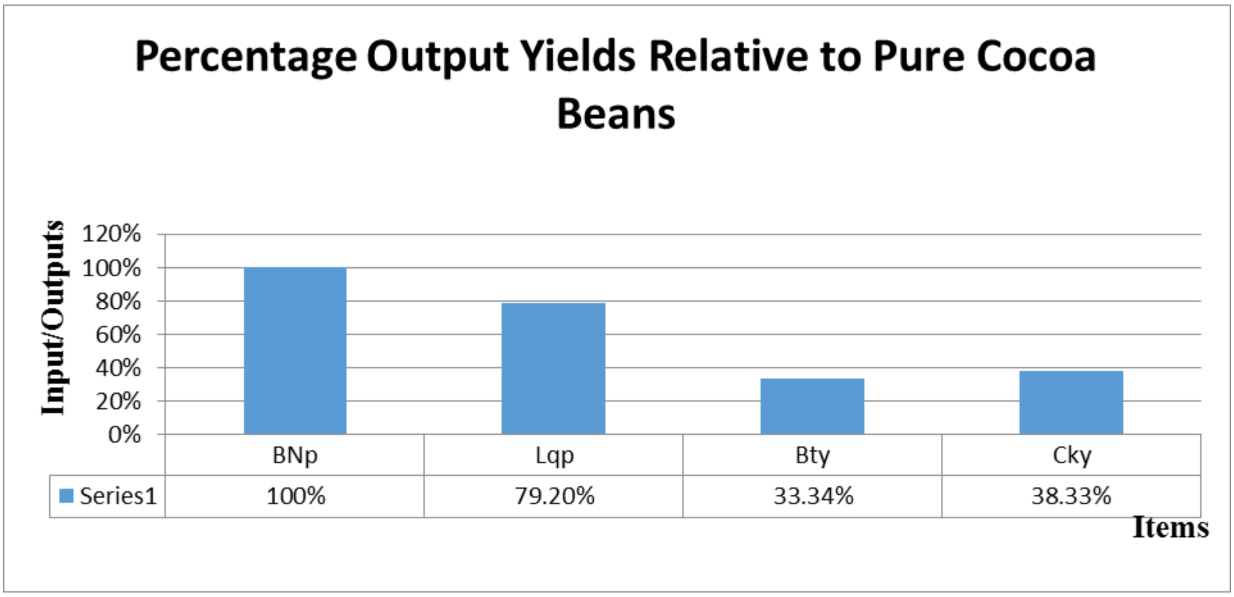


**Fig.4:** Chart Showing Relative Percentage Yields of production Outputs ($of\ BN_p$)

This chart shows the percentage yields of Butter and Cake based on the output liquor when losses were analysed together.

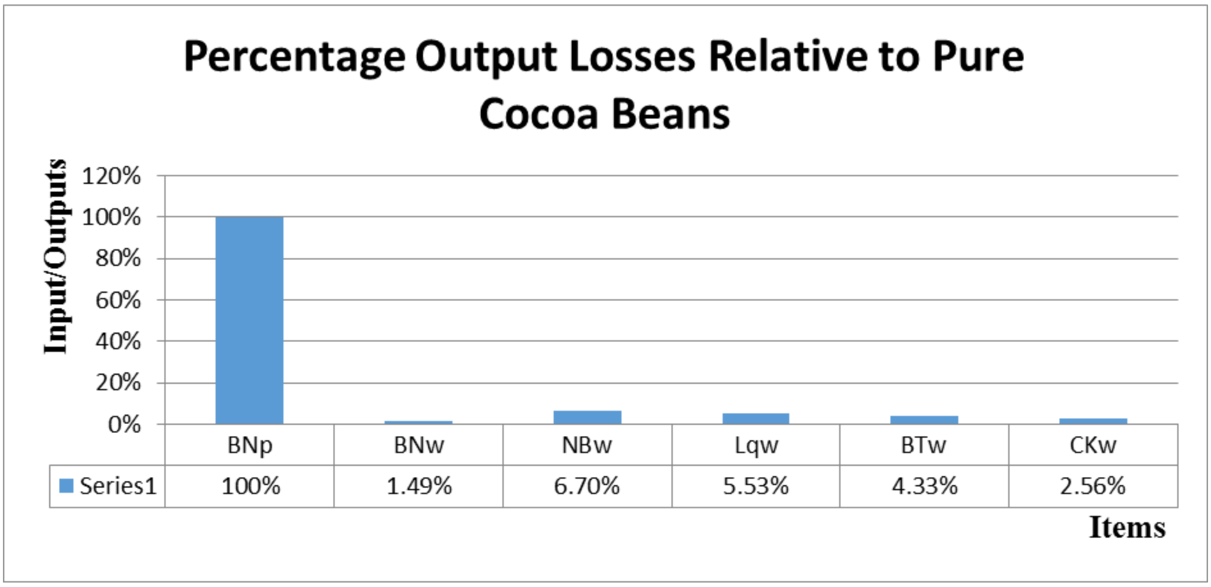


**Fig.5:** Chart Showing Relative Percentage Losses of production Outputs (of $BN_p$)

This chart shows the percentage wastes of parameters based on the input Cocoa Beans when only losses were analysed.

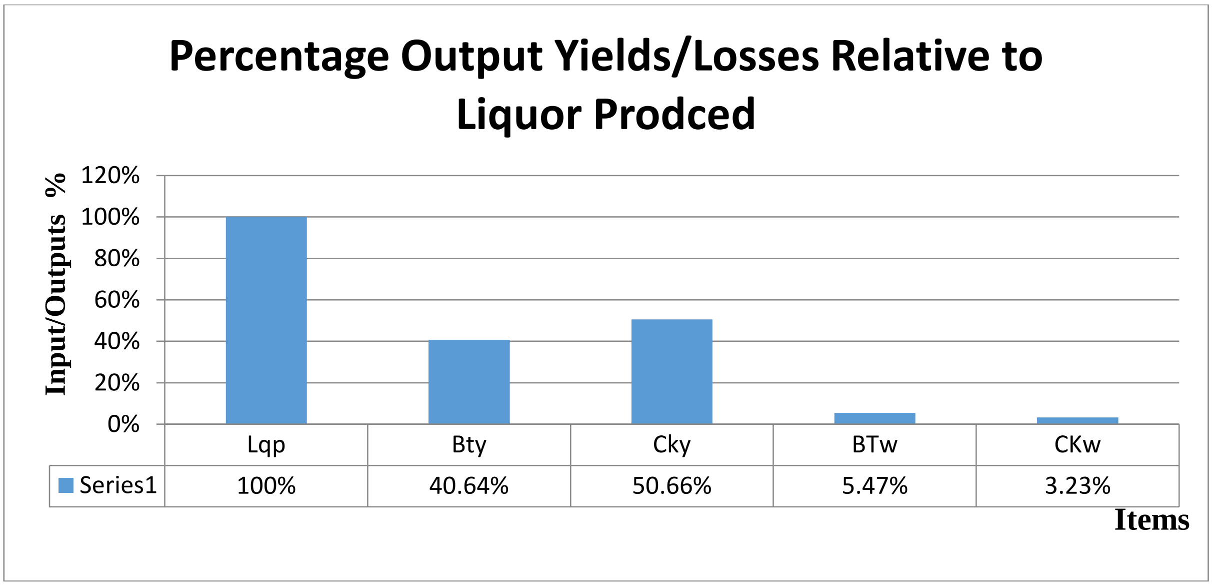


**Fig 6:**Chart Showing Relative Percentage Yields/Losses of production Outputs ( $of\, Lq_p$)

This chart shows the percentage yields and wastes of Butter and Cake based on the output liquor when losses were analysed together.

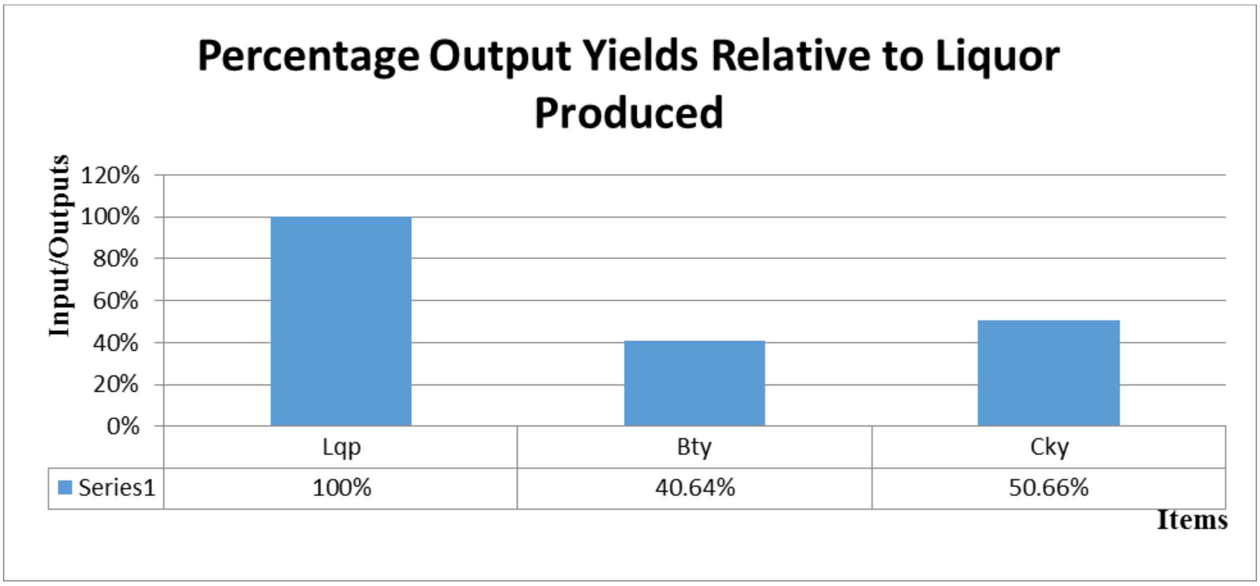


**Fig.7:** Chart Showing Relative Percentage Yields of Production Outputs ( $of\, Lq_p$)

This chart shows the percentage wastes of Butter and Cake based on the output liquor when yields Butter and Cake were treated separately.

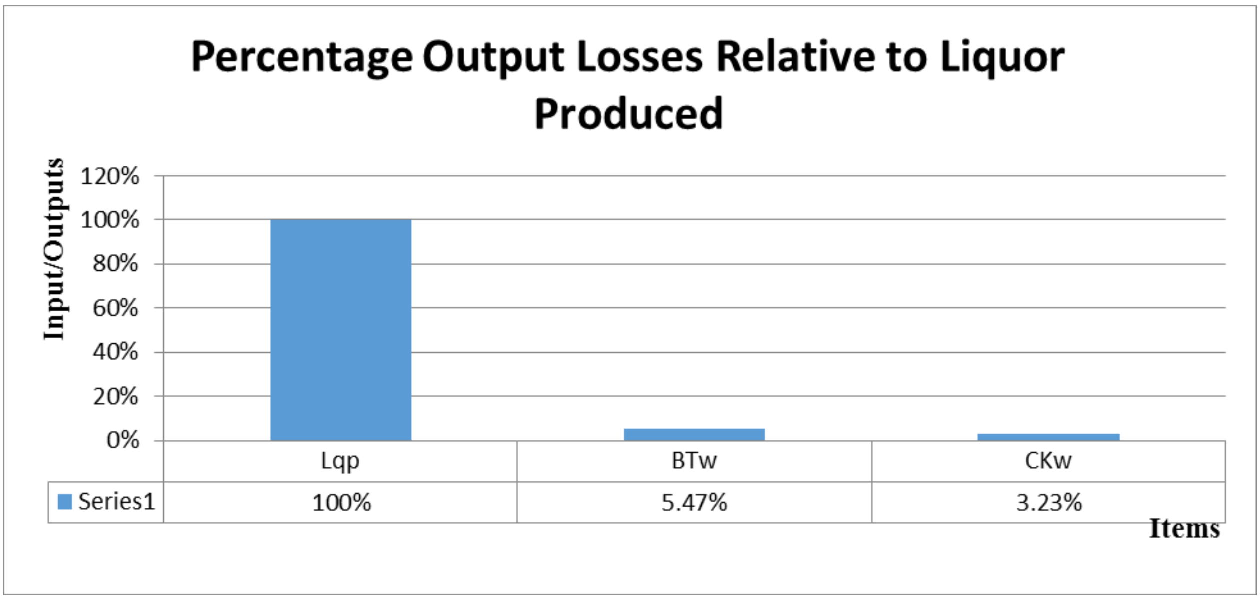


**Fig.8:** Chart Showing Relative Percentage Losses of production Outputs ( $of\, Lq_p$)

This chart shows the percentage wastes of Butter and Cake based on the output liquor when losses were treated separately.

## DISCUSSION

The amount of butter and that of cake can be forecast, knowing just the input 'Cocoa Beans' and its corresponding 'foreign material'; or, only the input 'Cocoa Beans' as may be applicable from the foregoing .Constant percentage yields of 72.31% were observed when the output yields were based on pure Cocoa Beans (after the foreign materials were removed).

From this research, the secondary Cocoa Beans Processing industrialists (those who only process cocoa beans from liquor stage) can also have the foreknowledge of their expected output yields, that is, Butter and Cake, as well as their inherent losses before processing; especially if their processing machines are of the same status to those of the case study factory. This fact is also graphically illustrated in figures 6, 7 and 8. This, therefore, also means that, if the effectiveness of these equipment can be improved to reduce the percentage wastes of Butter and Cake, the output yields of cake and butter will increase.

From this research, it can be easily deduced that between seventy (70) and seventy-three (73) per cent output products-butter and cake can always be obtained from any quantity of Cocoa beans processed.

## CONCLUSION

This study was able to identified the strategic decision required for machine effectiveness determination, developed the mathematical models required for decision making after intrigating the models to from the logic. The developed model was applied to solving the problem of a cocoa processing industry for its performance evaluation determination.

When the effectiveness of the machine was 77% Which is low to the standard set (85%) the oil yield was 63.48% . When the causes of this low effectiveness was identified as low value of machine availability and quality rates ,these were improved to get a new machine effectiveness of 87.7% the oil yield from the cocoa beans increases from initial yield of 63,48% to 72.31%.

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