

Computer Aided Design for Cocoa Beans Processing Yield Prediction

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Abstract

Ability of Cocoa Beans Processing Industries to predict the yield of Cocoa Beans before processing will be a great advantage. This knowledge will aid: proper planning as per resources allocation, predicting profit margin and decision making on acceptability of contract (by considering cost of production and profit margin). The approach taken in this research was to identify the parameters needed for processing Cocoa Beans yield such as: actual mass of Cocoa Beans to process; mass of foreign material; mass of shell removed; quantity of Cocoa nibs to be processed; mass of butter and mass of Cake from Cocoa Liquor obtained from ground nibs; consideration was also given to material wastes at each processing stage. These identified parameters were used to develop mathematical models, from which computer algorithm and software were also developed. The developed software was tested and validated for performance evaluation using Visual Basic programming language because of its friendliness and versatility. The software, when used in OLAM Cocoa Processing Industry in Akure, Ondo State, Nigeria, 21.5 tonnes mass of Cocoa Beans was processed. The model predicted yield for Butter to be 6873.359 kg and that of Cake to be 8569.649 kg. In actual sense from the factory floor when the same mass of Cocoa Beans (21.5 tonnes) was processed a yield of 7005.25 kg and 9130.261 kg of Butter and Cake were realized respectively. This result proved this model to be 95.71 % efficient. Hence, this can now serve as a useful tool for both prospecting and existing Cocoa Processing Industries in their visibility study and production planning respectively.

Keywords: Cocoa Beans, Processing Yield, Waste Control, Software Development

Introduction

Cocoa has been an essential commodity and important cash crop in Nigeria agricultural sector. Indeed Nigeria had once been the world second largest Cocoa producing country before its decline due to neglect caused by the oil boom in the 70s which made the government to relegate this area of the nation's foreign earning to the background (Dasilva et al, 2010). But in recent years, efforts have been geared towards reviving this sector of Nigeria economy and in fact, because of many other benefits derivable from it, there has been many cocoa processing industries established in the country and abroad and many more are still fast springing up due to the increasing market force for cocoa products (Ntiamoah and Afrane, 2008). However, many are rushing into this aspect of business without adequate knowledge of how viable or feasible it is to obtain good yields and hence are falling short of their expectations. Therefore, it would be very encouraging and enterprising if such disappointed and prospective industrialists can obtain a foresight of the picture of their intended business output before they venture into it. Even the existing cocoa processing industries should be able to empirically forecast their output yields for a determined quantity of their input. Development and establishment of an empirical model will be of immense benefit and advantage for both existing and prospective Cocoa Beans Processing Industries to forestall the likely losses that can result from inadequate knowledge of their production output; hence the grand purpose of this research. The research developed an empirical model that can be used by Cocoa Beans Processing Industries in Nigeria to determine cocoa beans output yields before processing, through identification of the parameters required for processing Cocoa Beans yield development of mathematical models and software for the identified parameters; identifying and controlling areas with material wastes for optimal yield; as well as testing and validating the developed software for performance evaluation.

Literature Review

Ajayi et. al. (2012) worked on “Modelling Temperature as a Constraining Factor for Cocoa Yield in Ondo State”. The study focused on the contribution of temperature on the yield of cocoa in Ondo state and concluded that months with high cocoa yield are relatively hot with temperature above 30⁰C; abrupt monthly mean temperature below 30⁰C during the fruiting period (November to January) correspond to low sunshine, thereby impeding ripening and quick drying of cocoa beans, hence low cocoa production.

Mathematical modelling of the cocoa drying process has been reported in literatures mostly in hot air drying under continuous operation carried out by Nganhou, et al. (1992), Wan Daud, et al. (1996), Fotso, et al. (1994) and Cornell University (2007) and also on modelling of the thin layer drying kinetics of cocoa beans using natural and artificial drying processes that simulates the real farm operation (Bozaan, 2012). Another study was carried out to model the thin layer drying kinetics of cocoa beans in natural and artificial drying and select the best model for these processes where Regression analyses were carried out to select the thin layer model that best described the drying kinetics of the artificial and natural drying of cocoa beans (Verma et al. 1985). Akmel et al. (2012) researched on “Mathematical Modelling of Sun Drying Kinetics of Thin Layer Cocoa (*Theobroma Cacao*) Beans” in which the sun drying behaviour of cocoa beans was investigated and found that, the logarithmic model, amongst other mathematical models investigated satisfactorily described the drying behaviour of cocoa beans. Green and Peter (1996) worked on the usability analysis of visual programming environments.

Jinap et al. (1995) also worked on ‘Mathematical Modeling of Cocoa Bean-Nibs Roasting Conditions’ to determine suitable roasting conditions. The study revealed that roasting was carried out as suggested by Central Composite Design (CCD) using Design-Expert software version 6.0 (Stat Ease Software) and two independent variables were used, temperature (110- 160⁰C) and time (15 - 40 min), with six dependent variables (responses) determined.

Super Pro Designer Version 7.5 is a software developed for the simulation of Cocoa Beans manufacturing process: The major processing steps include cleaning, roasting, winnowing and breaking, alkalisation, drying, grinding, crushing and pulverizing and the four products produced from this simulated process are cocoa powder, butter, cakes and liquor (Omar et al., 2010).

The use of CAD/CAM (Computer Aided Design/Computer Aided Manufacture) software has been well documented in food research centers, large food production organizations and culinary institutions, though, the average food designer/medium scale food production companies have not yet incorporated its use in their day-to-day business partly due to the expenses involved. But with the advent of outsourcing computer-aided design procedures to professional designers, these expenses have been drastically reduced (Adzimah and Asien, 2010).

A typical application of CAD to material processing is “3D printing, or additive manufacturing”. This is the process of using a computer-programmed machine to create three-dimensional objects. This is used in a broad range of industries such as automotive, aerospace, medical, jewelry, footwear, and food. With the recent transition of 3D printers from industry use to home use, the idea of using this process to make food has become more prevalent as busy people are looking for a quick and easy meal. The first 3D printer that can fabricate food was built by a group of professors and students at (Cornell University, 2007) and has since been in use for printing edible cupcakes. Every software needs algorithm, a deterministic automation for accomplishing a goal which gives an initial state and terminates in a defined end state as claimed by (Yuri, 2000).

This research is intended to address the existing plaguing challenge: the inability to forecast output yields of cocoa beans right from the input stage by Cocoa Beans Processing Industries.

The work, therefore, is expected to provide a model for predicting the quantity of cocoa butter and cocoa cake that can be derived from any quantity of cocoa beans to be processed right from the input stage before processing. This will help in budgeting for material storage; inventory required and project revenue that can be generated before processing takes place.

Methodology

In carrying out this research, survey of previous work was done, strategic decisions required were identified, processing layout were studied, concerned various workstations were identified and data cards for collection of necessary data from a Cocoa processing plant was developed.

Such data include: quantity of ‘cocoa beans’ input per month, the effect of various stages in the processing line and net ‘cocoa beans’ processed after all the foreign material have been removed through the stage of cleaning process.

The output analysis of ‘cocoa beans’ processed, which includes percentage reduction by: shell removal; Nibs Waste; Liquor Waste; Butter waste; and Cake Waste was carried out. This led to percentage yield prediction of the targeted products: ‘butter’ and ‘cake’ yields.

This was followed by mathematical modelling taking cognizance of the above mentioned parameters. Flow chart as well as computer algorithm was developed to prepare the expected software in two versions.

Model Development

The model was developed based on various parameters input and consequent output. Such parameters as: the quantity (mass) of cocoa beans available for milling; the sum of the quantity (in Kg) of foreign material in the available cocoa beans and the mass of cocoa beans wasted during the cleaning process stage were taken and subtracted from the total available beans for milling, to obtain the actual quantity of cocoa beans to be processed equation 1 was used. The next parameter that was determined is the actual amount of cocoa bean nibs produced which is the subtraction of the mass of shell removed from the broken cocoa beans-nibs during winnowing process i.e. equation 2. Following the same format, the quantity of cocoa nibs ground to liquor is obtained by subtracting the quantity of mass loss during the grinding process, from the mass of cocoa nibs, after the broken cocoa beans were winnowed (the shell removed) (equation 3). Then the quantity of cocoa mass (liquor) is further reduced through sub-grinding process before it is converted to targeted output products: butter and cake (see equation 4). Further losses were still experienced through the final finishing processes that butter and cake are subjected to for obtaining the final output yields: “Butter Yield” and “Cake Yield” express respectively, mathematically in equations 5 and 6.

Model Formulation

The model is to empirically determine the yields of cocoa beans (butter and cake), expected before actual processing starts.

Determination of Net cocoa Beans Processed

The actual mass of cocoa beans to process (B_a) is determined using equation (1) is the actual quantity of cocoa beans available to process after the foreign material in cocoa beans and the loss involved during the cleaning process, are subtracted.

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

(where; Bm_a , FM_m , and BN_w are total mass of unprocessed Cocoa Beans available, mass of foreign material and mass of Cocoa Beans wasted respectively).

Determination of Cocoa Nibs Available

This is the quantity of broken beans available when the shell and loss of nibs during the cracking and winnowing processes, are removed.

Mass of Nibs produced (NB_p) is determined using equation (2)

$$NB_p = B_a - Sh_{mr} \quad (2)$$

Where; Sh_{mr} = Mass of shell removed

Actual Nibs Ground is determined using equation (3)

$$NB_g = NB_p - NB_w \quad (3)$$

Where; NB_w = Cocoa nibs wasted

Determination of Cocoa Liquor Available

Cocoa liquor available is the quantity of cocoa nibs ground minus the waste during the grinding process. The actual mass of liquor produced (L_{qp}) is determined using equation (4)

$$L_{q_p} = NB_g - L_{q_w} \quad (4)$$

Where; L_{q_w} = Cocoa liquor wasted

Determination of Butter and Cake Yields

These are the targeted output expected from the model, which are the quantities of Butter and Cake. The addition of the two quantities gives the total output yields (equation 7)

The butter yield from the liquor mass BT_w is determined using equation (5)

$$BT_y = L_{q_p}(\% BT_p) - BT_w \quad (5)$$

Where; % BT_p and BT_w are percentages of butter produced and butter wasted respectively.

Cake yield from liquor CK_y is determined using equation (6)

$$CK_y = L_{q_p}(\% CK_p) - CK_w \quad (6)$$

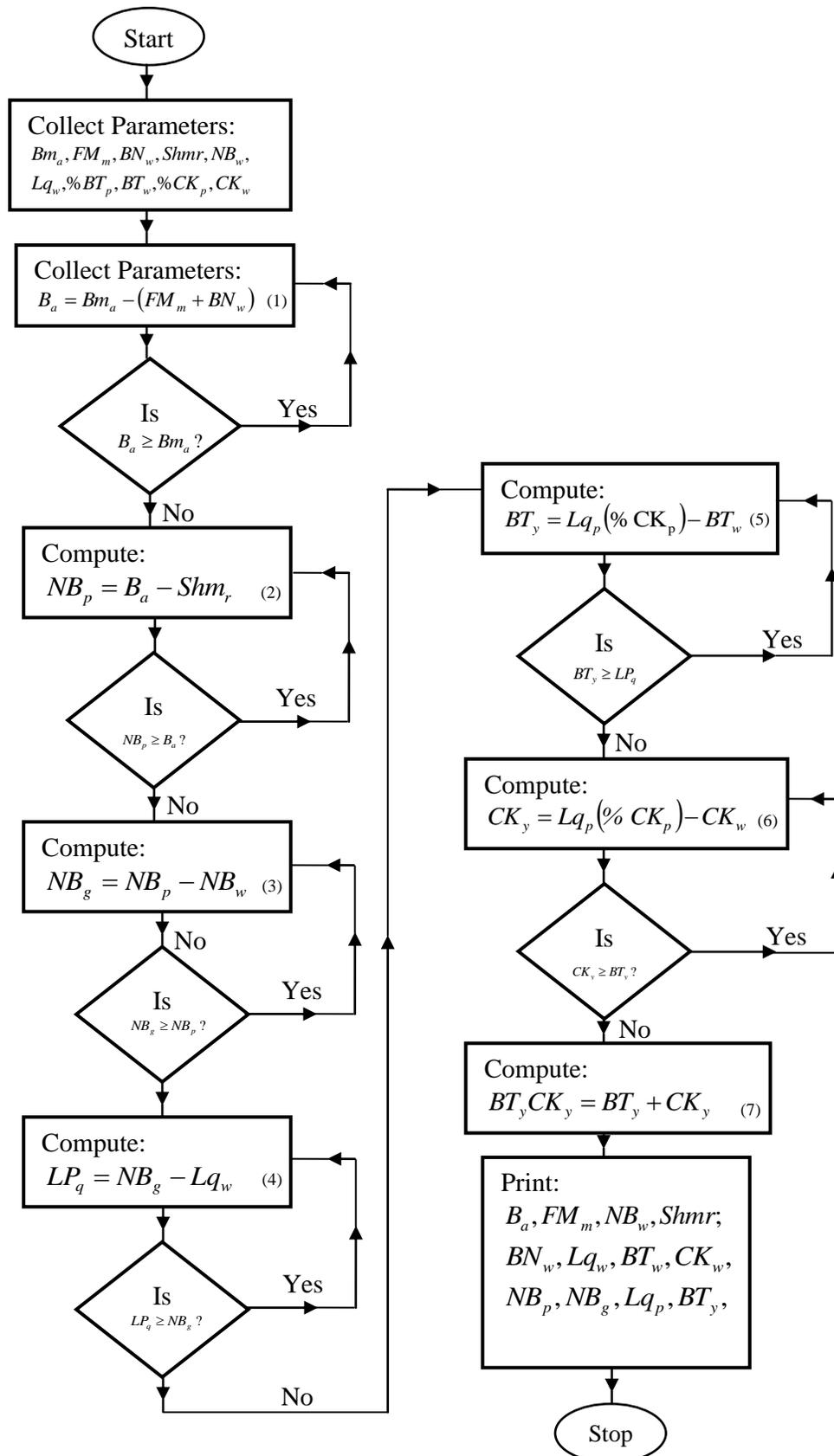
Where; % CK_p and CK_w are percentages of cake produced and cake wasted respectively

Total Output Yields BT_y, CK_y is determined using equation (7)

This is addition of Butter yield and Cake yield.

$$BT_y, CK_y = BT_y + CK_y \quad (7)$$

The flow to these models for software development is as shown in figure 1.



Computer User Interface for the Software

Interface is a portion of a computer program which the user interacts in order to make the program easier to use, i.e., the interface between a user and a computer program, with the goal of effective operation and control of the model and the feedback from the model which aids the user in making decisions (Green and Petre, 1996). The Graphical User Interface (GUIs) were constructed by computing the quantities of input parameters to obtain the quantities of required output parameters. These are presented in figs. 2 – 3.

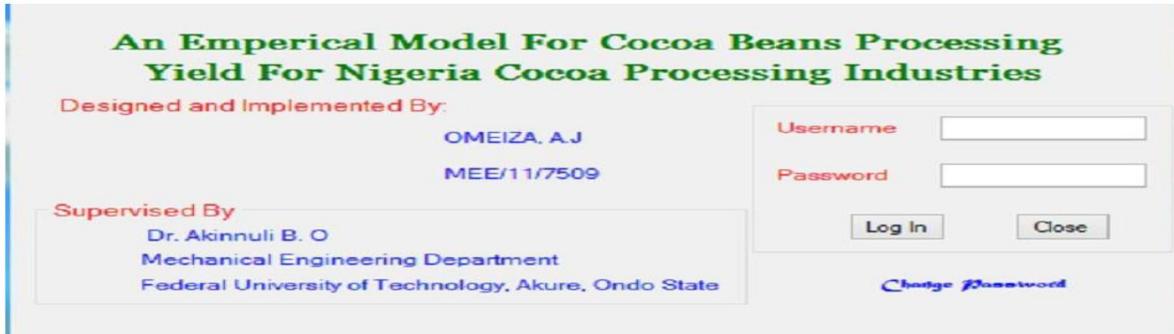


Fig. 2: Graphical User Interface for the Welcome Page

The graphical user interface gives the introduction of the software showing the particulars of the project Author and the Supervisor. At this welcome interface, the Username and Password are inputted in the boxes as shown at left-hand side of the interface and directly under these are the ‘Log In’ and ‘Close’ buttons. The ‘Log In’ button is clicked to continue or the ‘Close’ button is clicked to close if needs be. Clicking the “Log In” button to continue takes us to the main interface where input data (mass of Cocoa Beans available for milling and mass of foreign material in Cocoa Beans) can be supplied (Fig. 2). As seen above, the provision is also made to change the password and/or the Username when desired.



Fig. 3: Shows the Graphical User Interface for Processed Cocoa Beans Input and Output analysis all in one window

At this interface, the two required input data: the mass of Cocoa Beans available for milling and the mass of foreign material in the Cocoa Beans for milling are supplied in the input boxes at the top left hand side; and when the “estimate” button, just immediately below these input boxes is clicked, the resulting outputs as itemized in the lower part of the user interface are displayed automatically.

Results and Discussion

The required parameters for the study have been identified as: mass of Cocoa Beans available to be processed, the amount of foreign material in the beans, the shell to be removed and all the various wastes that constitute the percentage mass losses along the processing stages: Cocoa Beans waste, nibs waste, Liquor waste, Butter waste and Cake waste. These identified parameters were well integrated into the development of mathematical models and the software was successfully developed as proposed, using Visual Basic language because of its friendliness and versatility.

Also, areas of material wastes to be controlled for optimal yield were identified thus: percentage wastes of Nibs, Liquor and Butter were observed to be relatively high as compared to other waste parameters and can be reduced through targeted concerted effort for the purpose of increased or maximum yield.

The developed software was run as designed and the following graphical user interface displays the outputs generated by the software when the model was tested with data collected from a Cocoa Processing industry. The results obtained when compared with the manual computation of the developed model revealed that both are equal, confirming the validation of the model. The graphical user interface in Figure 3 shows the output results. When a mass of 21500 kg were brought for processing in OLAM Cocoa Industry, Akure, Ondo State, Nigeria, with the foreign material of 143.33 kg; Cocoa Beans waste of 317.574 kg; mass of shell removed being 1512.266 kg; mass of Cocoa nibs waste proved to be 1430.470kg. Waste on Cocoa liquor was 1181.451kg; that of Butter and Cocoa Cake were 925.598kg and 546.304kg respectively. The output yields from the 21500kg of available Cocoa Beans were 6873.359kg for Butter and 8569.649 kg for Cake. After processing the Cocoa Beans, the yields were 7005.25kg for Butter and 9130.261kg for Cake. The developed software efficiency was determined to be 95.71%.

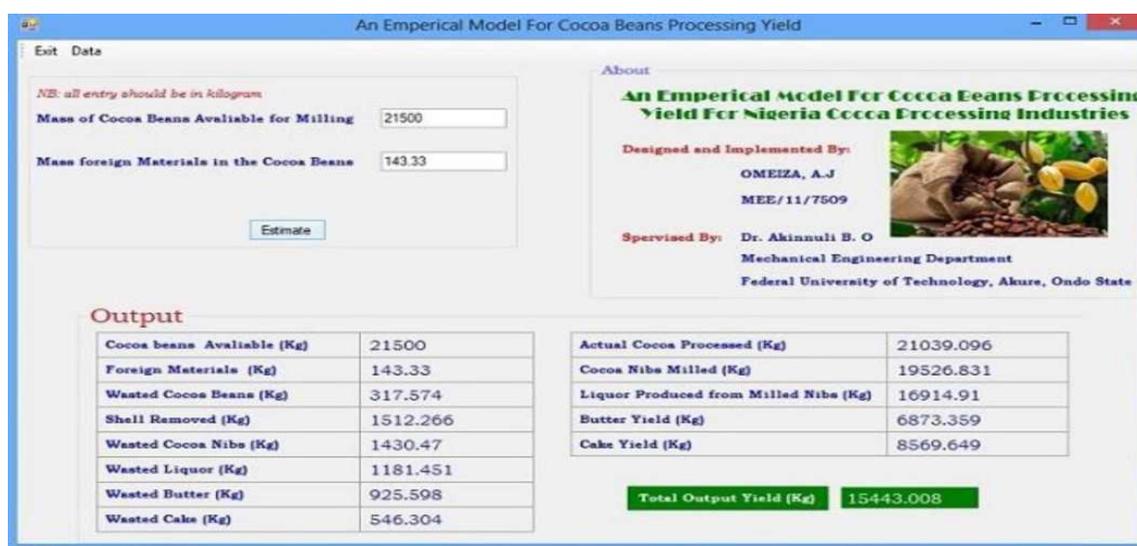


Fig. 4: Graphical User Interface showing the input-output data Results of the Software

Fig. 3 shows the resulting output details and the input data-mass of Cocoa Beans for milling and the foreign material to be: 21500Kg and 143.33Kg respectively; and the resulting output details as can be seen above in figure 4.

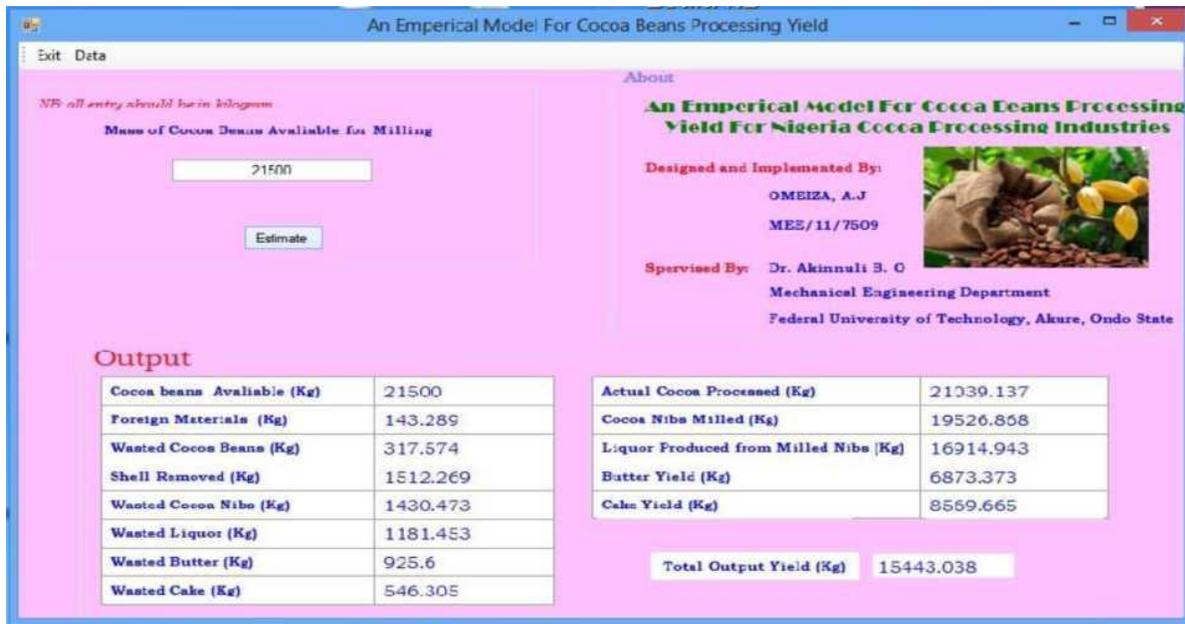


Fig. 5: Graphical User Interface showing the input-output data Results of the Software (Second Version)

The second version of the model software is a simplified version: only the quantity of Cocoa Beans to process is the required input, which is not involving. Just inputting any figure gives you the corresponding results at any instant, anywhere. The observed variations between the two versions (Fig. 4 and Fig. 5) are due to approximation made in the second input of the first version to two decimal places (143.33). When the same output result of foreign material obtained in second version (143.289) was inputted in the first version, the output results were the same with the outputs of the second version all through (Figure 6).



Fig. 6: Graphical User Interface Showing the Input-Output Data Results of the Software

Table 1: Result Summary of the Developed Software Application

Parameter Number	Parameter	Manual Computation (Kg)	Software Application Computation (Kg)	Remark
1	Mass of Cocoa Beans Available	21500	21500	0.000
2	Mass of Fallen Material	143.33	143.33	0.000
3	Mass of Cocoa Beans Wasted	317.574	317.574	0.000
4	Mass of Shell Removed	1512.266	1512.266	0.000
5	Mass of Nibs Wasted	1430.470	1430.470	
6	Mass of Liquor Wasted	1181.451	1181.451	0.000
7	Mass of Butter Wasted	925.598	925.598	0.000
8	Mass of Cake Wasted	546.304	546.304	0.000
9	Actual Cocoa Beans Processed	21039.096	21039.096	0.000
10	Cocoa Nibs Produced	19526.83	19526.831	0.001
11	Liquor Produced from Milled Nibs	16914.91	16914.91	0.000
12	Mass of Butter Yield	6873.359	6873.359	0.000
13	Mass of Cake Yield	8569.649	8569.649	0.000
14	Total Yields: 12+13	15443.008	15443.008	0.000

The Table 1 shows the results of both manual computation of the model and the output results of software developed using the same input data. Both results show no differences in all the computed parameters.

Conclusion

From this study, the objectives have been successfully achieved and established. The focus of the study to produce a CAD for cocoa beans processing yield prediction through identification of the parameters required for processing Cocoa Beans yield (actual mass of Cocoa Beans to process, mass of foreign material, mass of shell removed, quantity of Cocoa nibs to be processed, mass of Butter and mass of Cake from Cocoa Liquor-obtained from ground nibs, as well as material wastes at each processing stage); development of mathematical models and software for the identified parameters; identifying and controlling areas with material wastes for optimal yield; and testing and validating the developed software for performance evaluation.

Visual Basic programming language was used in the software development because of its friendliness and versatility. When the software was tested and validated it was discovered that when so run gave successful and promising results.

The software developed was used in OLAM Cocoa Processing Industry in Akure, Ondo State, Nigeria in kilogram Twenty – one thousand five hundred, cocoa beans (21,500 kg) mass was processed. The predicted yield for Butter was 6873.359 kg and that of Cake was 8569.649 kg. In actual sense from the factory floor when the same mass of Cocoa Beans (21.5 tonnes) was processed, a yield of 7005.25 kg and 9130.261 kg of Butter and Cake were realized respectively. This result proved this model to be 95.71 % efficient. Hence, this can now serve as a useful tool for both prospecting and existing Cocoa Processing industries in their visibility study and production planning respectively.

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