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Establishment of a Cereal Processing Plant to Obtain Flour in Cameroon

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Abstract: ***The work presented in this paper is to set up a cereal processing plant to obtain flour, using cereals like maize, corn, sorghum and soya bean in Cameroon. The study aims to determine the steps to design a plant that can operate in a sustainable way from its commissioning with the objective of a maximum production capacity of 6 t/h. The procedure to achieve this objective is through the use of the V. CAUDILL method which gives the steps for the development of a new processing plant. The functional analysis for the design and sizing of the equipment for the processing chain, the Pareto diagram in order to make the best choice of equipment suppliers. The determination of the characteristics of the machines from suppliers allowed us to calculate the supply power of 315 kVA and then to choose the appropriate transformer of 630 kVA, followed by the calculation of the minimum surface area of approximately 3259 m² of implantation of the processing plant. An application has also been set to help economic developers make decisions on the different combinations of cereals, to produce according to the desired profitability. The software gives sorghum as the most profitable cereal in the case of milling each grain in isolation. On the other hand, the comparative study of the different possible combinations of cereals by the software shows that the most profitable is the combination of the four cereals and that in making the combination of three cereals the most profitable is the sorghum, maize and soya combination.***

Keywords: Cereal, Sizing, Flour, Plant, Processing

1. Introduction

To produce sufficient quantities in all economic sectors remains an objective for Cameroon, but nutrition emerges among all the need of the households as the most important and compelling. Given that its satisfaction falls not only within and proven utility, but rather more of an essential and vital necessity. To do this, Cameroon therefore, intends to strengthen its agricultural and agro-industrial sector which until now has huge failures. Statistics shows that the index of maize consumption in Cameroon is approximately 51 kg per capita per year according to [1], which creates a deficit of more than 120,000 tons of maize per year in relation to the supply and annual demand. This maize serves an unequal importance in human nutrition, animal feed (feed manufacturing), manufacturing of drinks (beer companies), and other agro-industries. It should also be noted that two out of three Cameroonians consume maize in all its forms. If there is deficit at the level of maize, there will necessarily be at the level of maize flour.In Cameroon, there is less than fifteen producers operating more than 100 hectares of maize. This is the reason why potential economic developers intend to establish wide plantations of maize of more than 500 hectares and a processing plant, the plant will also be used for the transformation of corn, sorghum and soya. It will be the prescribed objective to participate in the sustainability of the future company. To achieve these objectives, the work will be articulated in several steps.First, the production process of cereal flours will be presented, then follow the description of the appropriate methodology used for sizingand selecting the technological part (main equipment and accessories). Furthermore, the method to determine the characteristics of the electrical part and the minimum area of the plant. Finally, the analysis and discussion of the results.

2. Material and Method

2.1 Processing of Cereal to Obtain Flour

According to the study done by [2], the model of the industrial unit for processing cereals (such as maize, corn, sorghum and soya) to obtain flour is described on Fig.1 below. The transformation goes through several stages such as the cleaning of dry grain, operation that is to remove impurities of all kinds, the shelling or husking according to the cereal, milling and sieving to obtain the flour and finally packaging. Depending on the cereals, other additional operations are necessary such as anchor or hydration which is to add some grain water content, the roasting that for the case of soya especially is an operation to toast the product by a roaster to make it digestible. The breakdown and converting to turn corn into flour cornmeal.

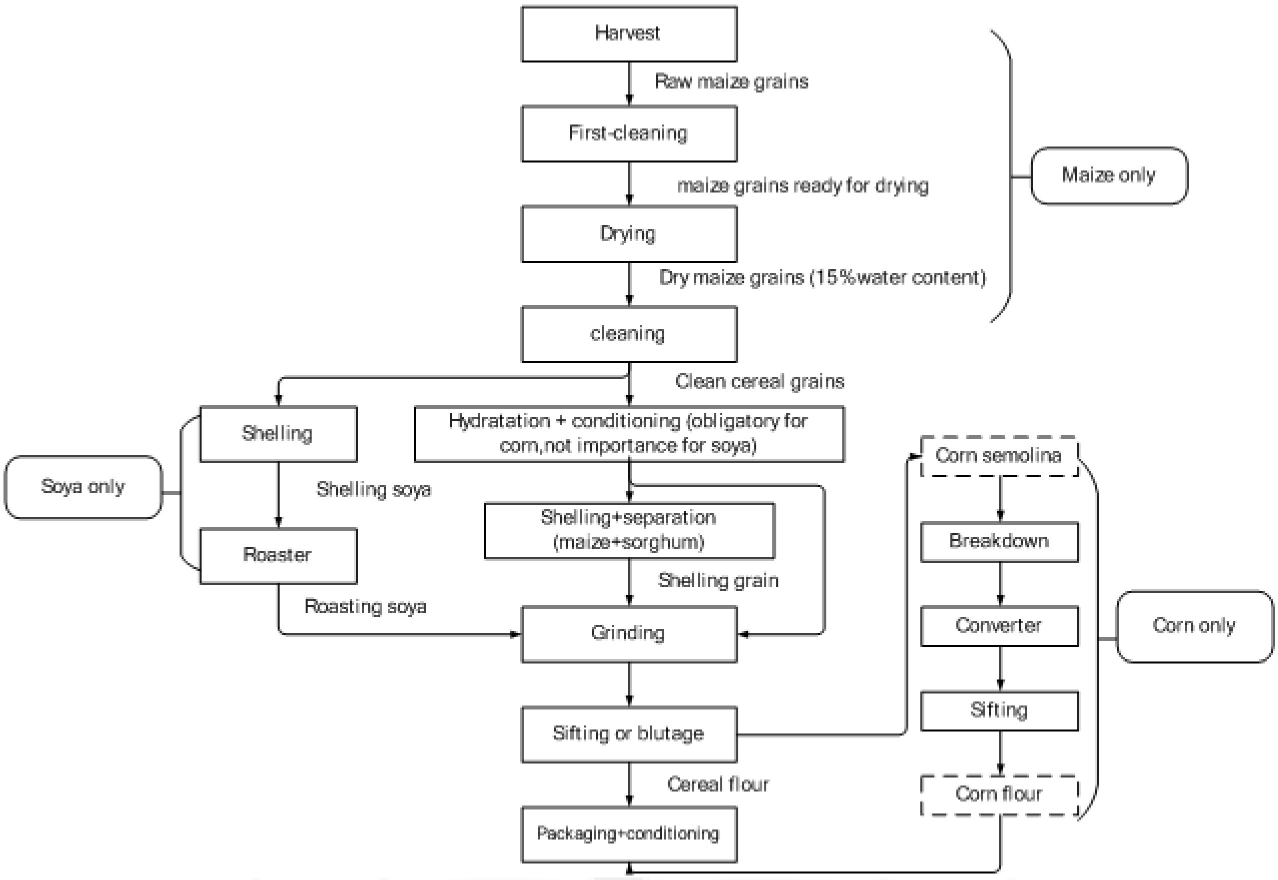

Figure 1: Processing of cereal to obtain flour

2.2Description of the Processing Line

According to the model on Fig. 2 below, the maize arrives at the plant in wet grain. These grains are first introduced into the drying area where they are dried effectively and then into a cleaning unit for a complete cleaning. Then they are directed in the decorticator or directly in the crusher depending on the type of flour to be processed, (complete flour or degerm). They can also be headed in a storage silo, after grinding, the flour is conveyed using a screw conveyor to a bolter where it is sieved. The products obtained is packed using the packing machine and conditioned.

Meanwhile other products arrive at the factory as alreadydry grain, and they are introduced into their respective silo. Sorghum follows the same process as maize and Soya is first roasted to be digestible before being crushed and then it follows the same process as the maize too. Corn, after cleaning is hydrated using the hydrator. Then, it is conditioned and put at rest in a silo already laid out. After the rest period, it is directed to the mill to be ground. Then the obtained flour is transported using the conveyor to the bolt machine where it will be bolted. The fine flour is directed to the packing machine for packaging. As for less fine flour, it will be directed to the breakdown and converting area where it will again be ground. It is then returned to the bolt machine to be sifted then ready for packaging.

3. Method

In the design part, the functional analysis was used to identify the needs to be met and find technical solutions to achieve these functions. The functional analysis and its associated tools have been used on the basis of the implementing the approach according to the studies done by [3], [4].

3.1 Method Choice of Machines from Suppliers

The choice of machines from the suppliers was made according to the procedure described by [5] and using the ABC method. The approach involves establishing a list of data by decreasing value. Quantifying each of these data, performing the sum of values, calculating the percentage of each value and performing the cumulative percentages obtained and finally representing them on graph. This approach allows us to consider the opportunities in the market, the evolution of the environment and possible techniques. It is characterized by the identification of the criteria for selection and been ranked as the determination of the weight of each criterion based on the weighted sum established in the matrix of preference, determination of the grade of each criterion, the determination of the overall rating of each supplier using Eq. (1) and finally the choice of the machine from the suppliers.

$$N = \sum P_d \times n_i \qquad (1)$$

Whereas P_d is the weight of the criterion, n_i is the mark of the criterion, and N is the final mark.

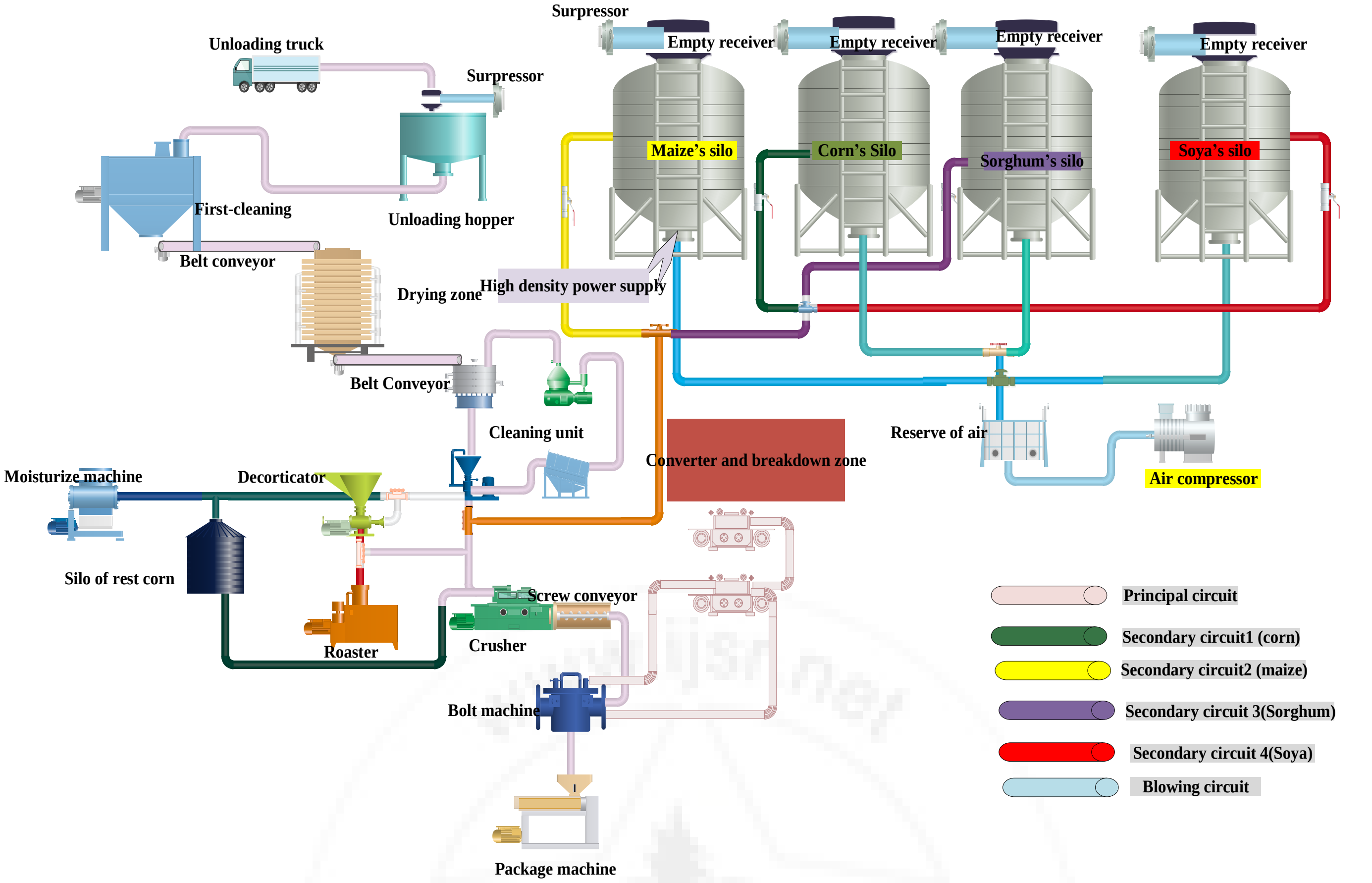

Figure 2: Overview of the processing chain

3.2 The electric Part Sizing Method

According to the methodology of [6], emphasis was made on the choice of the transformer. It is necessary to use the installed powers of the machines chosen from the suppliers to calculate the power of the necessary transformer and the choice is made using the catalogs. The calculation is shown below as:

The Installed PowerP_i

It is given in the Eq. (2) below:

$$P_i = 1.2 \times \sum P_a \quad (2)$$

Whereas, P_a is the apparent power,P_i is the installed power.

Note: take a safety factor of 20%.

The Used PowerP_u

The installed power is greater than the power actually used, to know the latter, it must be applied to the power of receivers or group of receiverstwo coefficients considering their operation. It is the maximum operating factor ($ku \leq 1$) which corresponds to the fraction of the total power of the receiver used. Then the simultaneity factor ($ks \leq 1$) that considers the fact that the groups of receivers do not necessarily work simultaneously. The sum of the various affected powers of the previous coefficients gives the power used as *Pu* (kW), which is part of the installed power as seen in Eq. (3) below.

$$P_u(kW) = \sum P_i \times K_u \times K_s \quad (3)$$

The Supply PowerS_a

An arithmetic summation gives enough order of magnitude given approximations already made (statistical values and use factors) and neighboring lower values of angles corresponding to the $cos\emptyset$. The Eq. (4) shows the relationship of the supply power.

$$S_a\,(kVA) = \sum \frac{P_i(kW) \times K_u \times K_s}{\eta\,.Cos(\emptyset)} \quad (4)$$

Whereas *Pi* is the installed power, *Ku* and *Ks* are the factors of simultaneity and the use factors respectively. Considering losses in the order of 30%, [7] recommends to take the standard value of a power transformer *X* as Eq. (5) below:

$$0.7X = S_a \quad (5)$$

The Maximum Operating Current I_E

At the level of the circuits, the maximum operating current is the one that fits the apparent power of the receivers. At the level of distribution channels, this is the current corresponding to the power usage, which considers simultaneity and use coefficients. It is determined using the Eqs. (6) and (7) below.

$$S_a = UI_E\sqrt{3} \quad (6)$$

Whereas

$$I_E = \frac{S_a}{U\sqrt{3}} \quad (7)$$

3.3 Method of Sizing for the Minimum surface area of the Plant

According to [8], the determination of the minimum area of the factory goes through the calculation of several basic area.

The Equipment Ground AreaS_s

The equipment ground area represents an area exclusively occupied on the ground by the equipment. It's the clean area in terms of the ground of the equipment installed. The expression of this area is given by the Eq. (8) below:

$$S_s = L_i \times l_i \quad (8)$$

Whereas $L_i \times l_i$ is the size of the equipment, $L_i and l_i$ are the maximum length and width respectively.

The Area of Gravitation S_g

The area of gravitation represents the area used around the workstation by the worker and the raw materials supplied, it is mathematical represented as in Eq. (9) below:

$$S_g = S_s \times N \quad (9)$$

Whereas S_s is the equipment ground area, N is the number of sides to access the machine.

The Area of Evolution S_e

The area of evolution represents an area necessary to reserve between workstations for travelling and handling, it is given by Eq. (10) below.

$$S_e = \left(S_g + S_s\right) \times K \quad (10)$$

whereas K is a factor

The total minimum area of S_t for the plant according to [9] and Eq. (11) is achieved by an arithmetic sum of the calculated areas.

$$S_t = S_s + S_g + S_e \quad (11)$$

3.4 Method of Assessment of the Profitability of the Project

To assess the profitability of the project, [10] stated that it must proceed through the calculation as in Eq. (12).

The Investment Cost of the Project I_0

It is determined using the Eq. (12) below

$$I_0 = C_{equip\ pro} + I_1 + I_2 + I_3 + I_4 \quad (12)$$

Whereas $C_{equip\ pro}$ is the cost of production equipment, I_1 is the cost of overhead and storage services, I_2 is the studies and engineering costs, I_3 is the contractor fees, and I_4 is the contingencies.

The Annual Forecast Charges

These are the charges that the factory must bear each year, namely electric charges, the cost of buying cereals, social charges, the cost of purchasing fuels and other expenses.

The Annual Sales

This is the sales of the products obtained (flour, semolina and others).

The Net Present Values

The net present value (NPV) is the difference between the cash flows discounted on date 0 and the capital invested. It is given by Eq. (13) below:

$$NPV = -I_0 + \sum_1^n \frac{F_i}{(1+r)^n} \quad (13)$$

Whereas r is the investment rates, I_0 is the capital invested, F_i is the cash flow, and n is the life of the project

The Software Package

The software package allows us to obtain data used to carry out tests of combination between different cereals by varying the flow of annual production. The profitable combinations found are presented in the results section.

4. Results and Discussion

4.1 Results of the Sizing and Selection of Machines

Based on the sizing method described in the methodology, it allowed us to make the choice of machines from supplier using the Pareto chart. After identifying the criteria, they were ranked in order of preference to achieve the Pareto chart as shown in Fig. 4 below.

Illustration: Case of the Combine Harvester

We find out the indicators on which one must base to make the choice of the CombineHarvester. To know among other things, the power, the weight, the cost, the consumption, the productivity, the lines and the width of work, the obstruction, the height of change, and the nominal speed.

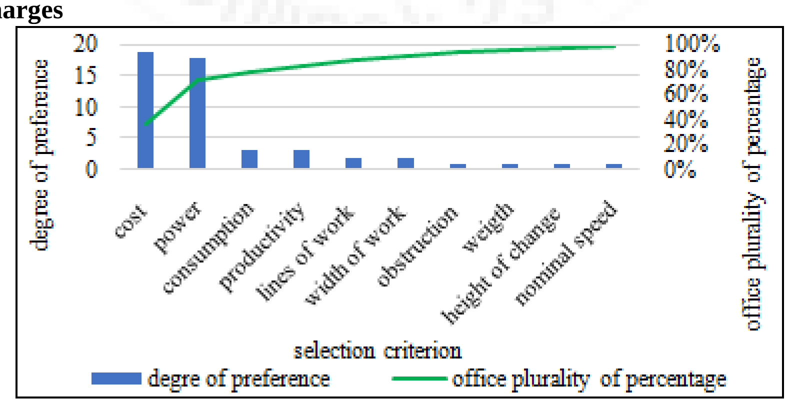

Figure 3: Pareto of Combine Harvester

Having classified the criteria of choice, they are weight in the following way, the first criterion gets the largest weight and so on as shown in the table 1.

Table 1: Weighting of the selection criterion

Characteristics	C	P_T	Con	P_r	R	L	E	P	H	V	Weight P_d)
Cost (C)	1	1	1	1	1	1	1	1	1	1	10

Power (P_T)		1	1	1	1	1	1	1	1	1	9
Consumption (Con)			1	1	1	1	1	1	1	1	8
Productivity (P_r)				1	1	1	1	1	1	1	7
Lines of work (R)					1	1	1	1	1	1	6
Width of work (L)						1	1	1	1	1	5
Obstruction (E)							1	1	1	1	4
Weight (P)								1	1	1	3
Height of change (H)									1	1	2
Nominal speed (V)										1	1

Subsequently the mark of each criterion on a scale of 3 must be rated as indicated in table 2.

Table 2: Criterion notation of the Combine Harvester

Criterions/ Mark	3	2	1
Cost (FCFA)	≤ 10000000	10000000 - 30000000	≥ 30000000
Power (KW)	75 - 100	100 - 120	≥ 120
Consumption (l/ha)	12 - 30	30 - 40	≥ 40
Productivity (ha/h)	≥ 0.7	0.5 - 0.7	0.3 - 0.5
Lines of work	6 - 7	4 - 5	< 4
Width of work (mm)	≤ 1000	1000 - 2000	2000 – 3500
Obstruction (m^3)	4×3×3 - 6×4×3	6×4×3 - 8×5×4	≥ 9 × 7 × 5
Weight (kg)	3 000-5 000	5000 - 6000	> 6000
Height of change (mm)	400 - 800	300 - 400	< 300
Nominal speed (tr/min)	2000 - 3000	1000 - 2000	< 1000

To choose a supplier, a list of suppliers will be sifted through the notation. The table 3 below gives the rating obtained by suppliers and the supplier F3, was selected from the suppliers screened. It was the supplier who obtained the highest rating in accordance with the Eq. (1) and tables 1 and 2, therefore, it has the best quality/price ratio and characteristics as shown in table 4 below.

Table 3: Harvesters proposed by the suppliers rating

Provider/ Criterion	F1	F2	F3	F4
Cost	1	1	3	3
Power	1	1	3	3
Consumption	1	1	3	2
Productivity	2	3	2	3
Lines of work	2	3	1	1
Width of work	1	1	1	1
Obstruction	1	1	3	3
Weight	1	1	3	1
Height of change	1	3	1	3
Nominal speed	2	3	2	3
Final mark	69	87	131	129

Table 4: Characteristic of Combine Harvester

	C(FCFA)	P_T(KW)	Con (l/ha)	Productivity (ha/h)	R	L(mm)	E(m^3)	P(kg)	H(mm)	V(tr/min)
F3	6 000 000	83	20	0.5	3	1860	5.9×2×3.1	3600	2000	2 400

This methodology was done for all the equipment of the processing chain and the results are presented in table 5 below.

Table 5: Equipment and principal characteristics

Equipment	Reference	Number	Installed Power (kW)	Obstruction(m^3)	Productivity	Cost(FCFA)
Combine Harvester	4YZB-3A	1	83	5.9×2×3.1	0.5 ha/h	6 000 000
Pre - cleaner	KF12	1	0.75	0.88×1.095	3 t/h	2 000 000
Washer-separator	-	2	4.1	2.3×1.1×2.4	3 t/h	2 000 000
Alveolar sorter	TR-620	2	1.1	0.6×1.9	4 t/h	2 000 000
Gravity table	KA-1900	2	8.5	0.53×0.53	3.6 t/h	2 000 000
Crusher	-	1	82	12×8×10	6 t/h	30 000 000
Huller	-	1	4	1.2×0.85×0.9	-	2 500 000
Roaster	-	3	1.1	2.3×1.3×1.4	0.2 t/h	1 057 565
Blutoir	SYM-1500	1	1.5	Standard	-	1 500 000
Packing machine	KD-450	1	2.7	4.1×1.05×1.56	40-180 sac/min	5 600 250
Conveyor belt	-	4	2	16×0.8	2 t/h	2 500 000
Fan	7.1d	1	80	-	$13000m^3/h$	1 499 500
Compressor	-	4	5	-	$17m^3/min$	220 350
Booster	-	4	1.1	-	-	500 000
Screw conveyor	GX-A	2	3	4,5×1,5×0,5	3 t/h	1000 000
Storage silos	GSW	4	-	Diameter:7.334 m height: 21,42 m	Capacity: 500 t	3 000 000
Transformer and accessories	-	-	630KVA	-	-	25 000 000

4.2 Results on the Choice of Transformer

After determining all the features of the processing chain, the supplied power of the plant was calculated using Eq. (4) through the calculation of the power installed using Eq. (2) and the output power on the basis of Eq. (3). The summary of results is presented in table 6 below.

Table 6: Electric Characteristics of equipment

Devices	Number	P_a(KW)	$P_i = 1.2P_a$	K_u	K_s	P_u	$S_a(KVA)$
First-cleaning	1	0.75	0.9	0.85	0.9	0.69	1.01
Alveolar sorter	2	1.1	2.64	0.85	0.9	2.02	2.97
Densiometric table	2	8.5	20.4	0.85	0.9	15.61	22.95
Wrapping machine	1	2.7	3.24	0.85	0.9	2.48	3.65
Crusher	1	82	98.4	0.85	0.9	75.28	110.70
Huller	1	4	4.8	0.85	0.9	3.67	5.40
Producer	1	1.5	1.8	0.85	0.9	1.38	2.03
Bagger	1	2.7	3.24	0.85	0.9	2.48	3.65
Roaster	1	1.1	1.32	0.85	0.9	1.01	1.49
Compressor	4	5	24	0.85	0.9	18.36	27.00
booster	4	1.1	5.28	0.85	0.9	4.04	5.94
Belt conveyor	4	2	9.6	0.85	0.9	7.34	10.80
Fan	1	80	96	0.85	0.9	73.44	108.00
Screw conveyor	1	3	3.6	0.85	0.9	2.75	4.05
Cleaner-separator	1	4.1	4.92	0.85	0.9	3.76	5.54
Total							315.16

In table 6, *Pi* is the installed power; *Ks* and *Ku* are the factors of simultaneity and the use factors respectively. Considering losses of 30%, it is wise to choose the standard value of a power transformer X using the Eq. (5) such as:

$$0.7X = 315.16$$

Whereas X is 450.23, the directly higher standardized value is then a power transformer of 630 kVA. Transformers of suchcharacteristics are summarized in table 7 below.

Table 7: Characteristic of transformer

Active Power (KVA)	Maximal Intensity (A)	Distribution		Frequency	Cos Ø
		Primary	Secondary		
630	479.4	15KV	380V/220V	50HZ	0.8

4.3 Minimal Area of the Factory

After determining the supply power of the plant, it was imperative to calculate the minimum area of the factory using the Eq. (8) to (11). The calculation of the equipment' surfaces is summarized in table 8 below:

Table 8: Equipment obstruction of the processing chain

Device	Number	length	Width	*N*	*K*	*Ss*	*Sg*	*Se*
Alveolar sorter	2	1.9	0.6	4	0.5	2.28	9.12	5.70
Densiometric table	2	0.53	0.53	4	0.5	0.562	2.2472	1.40
First cleaning	1	1.095	0.88	4	0.5	0.964	3.8544	2.41
Separator-cleaning	2	2.3	1.1	4	0.5	5.06	20.24	12.65
Crusher	1	12	8	4	0.7	96	384	336.00
Decorticator	1	1.2	0.85	4	0.7	1.02	4.08	3.57
Roaster	1	2.3	1.3	4	0.6	2.99	11.96	8.97
Screw conveyor	1	4.5	1.5	4	0.4	6.75	27	13.50
Package machine	1	4.1	1.05	4	0.5	4.305	17.22	10.76
Belt conveyor	4	16	0.8	4	0.4	51.2	204.8	102.40
Drying enclosure	1	14	10	4	0.6	140	560	420.00
Suppressor	4	6.3	2.4	4	0.3	60.48	241.92	90.72
Compressor	4	6.3	2.4	4	0.3	60.48	241.92	90.72
Total						432.1	1728.36	1098.81

The total surface area is given by the sum of the above areasas$S_t = 3259.27m^2$.

4.4 Decision Guide of the Combination of Cereals to Make

To help economic developers make decisions on the different combinations of cereals to produce according to the desired profitability, it is necessary to vary the flows by entering the data in the main interface of the software package and this provides several results. In this case, the financial analysis of the project was made using Eq. (12) and the Eq. (13).For example, by milling each grain in isolation as shown in Fig. 4, sorghum is the most profitable cereal because the green curve in relation to the net present value (NPV) is much higher than that of other cereals.

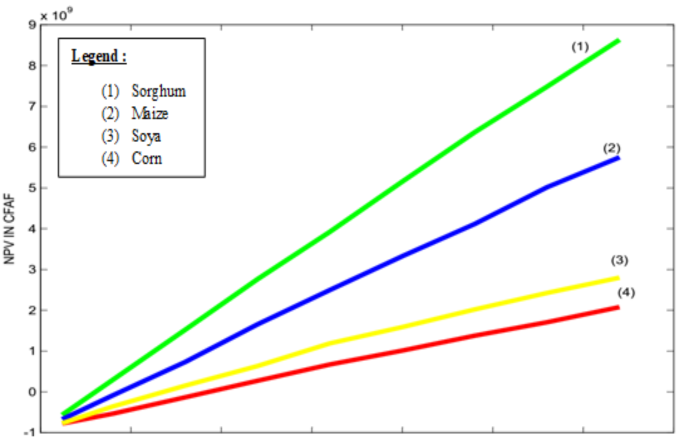

Figure 4: Cereal taken in isolation

Moreover, the comparative study of the different possible combinations of cereals shows that the most profitable is the combination of the four cereals and that, the combination ofthe three most profitable cereals is the combination ofsorghum, maize and soya as shown in Fig. 5 below.

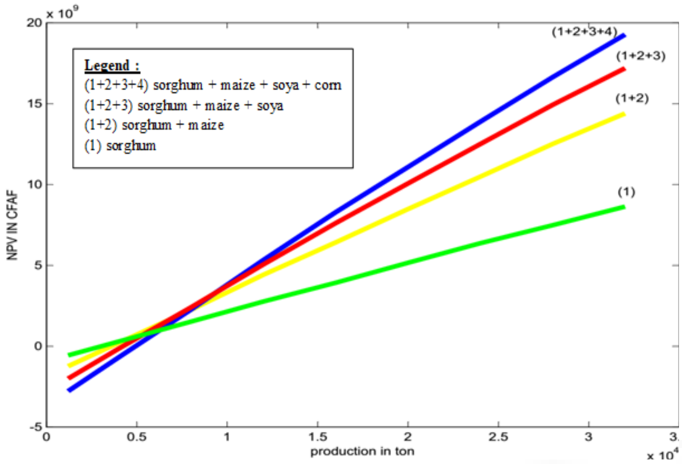

Figure 5: Different combination

5. Conclusion

This work consisted of setting up an industrial cereal processing plant for flour production. The approach throughout this work focused on the study of flour production techniques and technologies based on corn, maize, sorghum and soya.The methodology of V. CAUDILL was chosen among the methods of setting up industrial plant. Regarding the design and sizing of the processing chain, the functional analysis was made, as well as the sizing of the main accessories and equipment of the production lines.The choice of machines from the suppliers was also made, which allowed us to size the electrical part and the minimal surface of the factory. A profitability study was also conducted, based on operating expenses (consumption of electricity, remuneration of operators, purchase of cereals, purchase of fuels for drying), and sales over the evaluation period.

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