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Design and Development of Soya Bean to Flour Processing Plant of Capacity, Two Metric Tonnes Per Eight (8) Hours Work Per Day.

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ABSTRACT

Soya bean (Glycerinmaxl) is a leguminous plant that is most frequently grown in the world and it is an important source of protein and fat in food and animal feed industries. Soya bean seeds contain from 38 to 42% of protein, from 19 to 22% of fat in dry matter. Soya bean also contain many other compounds, including minerals which are beneficial for health and reduce the risk of, manydiseases.It is a cheap source ofprotein eaten to alleviate nutritional problems.

Nigerians feed more on starchy staples with resultant malnutrition and high incidence of chronic illness such as diabetes heart associated problem due to high intake of vegetable oils rich in omega -6- fat.Also, soya bean oil is known to lower chances of heart problems because it reduces cholesterolabsorption in the digestive system.Soya bean is widely cultivated in Nigeria, in about seventeen (17) states of the country. Improvement of African soya bean lines through the crossing of tropical glycerin cross (TGX) lines with other Asian origins by the international institute of tropical agriculture (IITA) has boosted Nigerians soya bean production since around 1974 to about 758,033 tons (1.0 ton/ hectare) in 2018. Nigeria is currently the second largest African producer of soya bean after south-Africa. There is every need to process raw soya seeds to different types of soya meal e.g. milk, flour, etc.

In Nigeria, the mechanized technology for the processing of soya bean to different food varieties is lacking, most of the processing is carried out manually. The manual process cannot yield high quality product, loss of production time, loss of materials, high labour input etc. are serious disadvantages.In view of all mentioned above, design and development of mechanized soya bean to flour processing plant of capacity two (2) metric tones per eight (8) hours work per day was conceptualized, developed, and tested.

Material balance was carried out. based on the material balance, the capacity of each unit operation machinesare stated below.

Distoning machine = 0.5tons/hr.

Rotary toasting machine = 0.33 tons/hr.

De-husking/separation machine =

Micro-milling machine = 0.297 tons

Cyclone dust collector = 0.2829 tons

The plant layout of the installation of the developed machines in the factory was also developed. Cost estimate of each unit operation machine were stated, and installation were developed.

Key Words: Soya Bean, Processing, Flour, Machines, Plant.

I. INTRODUCTION

Soya bean (Glycerin maxl) is a leguminous plant that is most frequently grown in the world and it is an important source of protein and fat in food and animal feed industries (SHARMA et al 2014). Soya bean seeds contain from 38 to 42% of protein, from 19 to 22% of fat in dry matter (BELLALOUI, GILLEN 2010). Soya bean also contain many other compounds, including minerals which are beneficial for health and reduce the risk of many diseases (KUMAR et al 2014). Humans require at least 22 minerals element for their well-being (WELCH, GRAHAM 2002, WHITE, BROADLEY 2005, GRAHAM et al 2007). Food and water are primarily a source of minerals for humans and animals, and content of essential elements in both soil and plant.

The level of minerals in plants raw materials is dependent on environmental and varietal factors, but it is also possible to influence mineral content through agronomic practices (WANG et al 2008, DEVI et al 2013). Soya bean is also widely cultivated in Nigeria for food, oil and feed purposes. It is grown due to its inherent ability to improve soil fertility thereby boosting crop production. Soya bean is a cheap source of protein eaten to alleviate nutritional problem in Nigeria (IDRISA et al, 2010).Nigerians feed more on starchy staples with resultant malnutrition and high incidence of chronic illness such as diabetes, hence a need to ameliorate the trend with incorporation of soya bean in our meals (Akah et al, 2021).

Nigerians suffer from health issues such as heart problem due to consumption of vegetable oils high in omega -6- fat (Falada et al 2017). However, soya bean oil is known to lower chances of heart problems because it reduces cholesterol level in the digestive system through the reduction of cholesterol absorption (Messina et al 2021).

In the early 20^{th} century, imported soya bean seed was only thriving in the guinea savanna region of Nigeria after several failed attempts to cultivate in the rain-forest region of southern Nigeria (Shurtleff and Ayogi, 2021). Soya bean was introduced in Nigeria in 1908 (fennel, 1966) but extensive production only began in 1937 using the Malayan variety found suitable in Benue state (Root et al. 1987). The great potential of the Malayan variety which showed apromising yield potential led to its mass multiplication and supply to farmers in 1946. A total 9tons of soya bean were initially exported from Nigeria in 1947 from cultivation in Benue, Zaria and Kastina (Shurtleff and Ayogi, 2021). The Tiv division of Benue province was the main production area with about 10.5 tons and 700tons of soya in 1946 and 1948respectively. Subsequently, Nigerians soya bean exportation rose from 9 tons in 1947 to 15,86o tons in 1963 (Shurtleff and Ayogi, 2021). To date, Benue province remains the most important location of soya bean production in Nigeria.

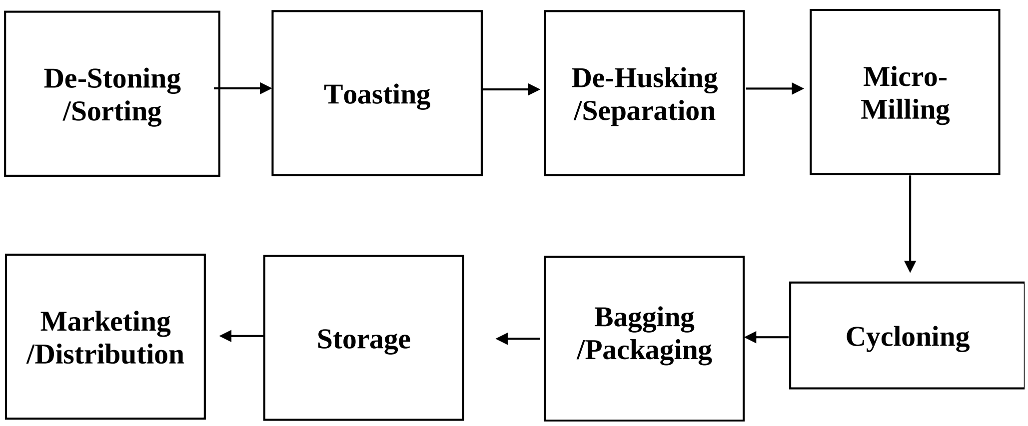
After the introduction ofthe Malayan variety for commercial cultivation of soya bean in Nigeria, the variety was found to be late maturing, low yielding, susceptible to bacterial diseases and pod-shattering (Smith et al 1995). Therefore, studies were conducted to develop earlier maturing varieties that are high yielding with good agronomic traits and capable of modulating in association with the local rhizobia (IITA, 1994). Improvement of African soya bean lines through the crossing of tropical glycerin cross (TGX) lines with other Asian origins by the international institute of tropical agriculture (IITA) has boosted Nigerians soya bean production since around 1974 to about 758,033 tons (1.0 ton/ hectare) from 780,679 hectares in 2018 (Nzossie and Bring, 2020).

The expansion of soya bean production in other states were accredited to its nutritional composition and economic importance (Nater et al, 2021). Nigeria is currently the second largest African producer of soya bean after south-Africa (Khojey et al, 2018). It is well known in the northern region of Nigeria with sub humid and semiarid savanna agroecology due to its peculiar soils with low nitrogen and phosphorous (Dugje et al, 2009). The guinea savanna belt of Nigeriaisconsidered the major production region (Hanina et al, 2015). Of the seventeen (17) producing states. The low amount and duration of rainfall within the Sudan and Sahel savanna suggest the use of the early maturing soya bean varieties. However, late- maturing soya bean varieties are known to produce higher grain with more biomass yield when compared to early maturing varieties.

II. Material and Method

The process flow line for conversionis soya bean to flour.

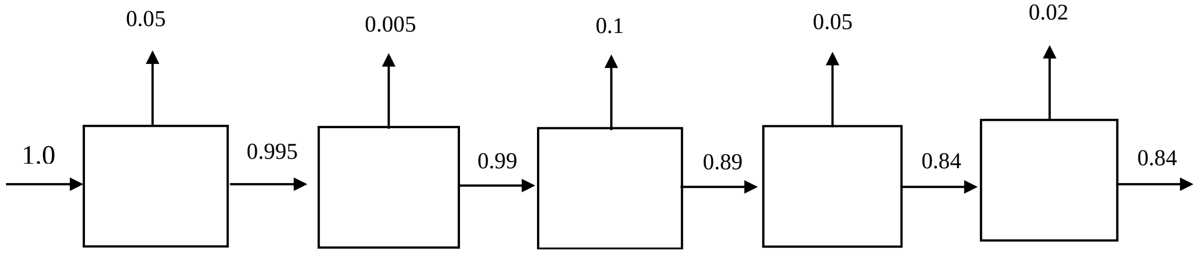
The processing flow line for conversion of dried soya bean to flower is outlined below. In the squares are the unit operations that are carried out.



(ii) material balance for the two tons per eight hours works per day processing plant.

III. MATERIAL BALANCE FOR THE SOYA BEAN FLOUR PRODUCTION PILOT PLANT

Our desire is to obtain two tons of soya bean flour per 8 working hour per day on the basis of tones per hour of production. We have two tones per 8 hours = 0.25tons per hour. Considering percentage conversion in each stage of the unit operation production we have:



Where: DS = De-stoner

R = Rotary toasting machine unit

D = De-husking/Separation unit

M = Micro-milling unit

C = Cyclone bagging unit

Applying back word integration method starting from C (Cyclone bagging unit). Assuming we have 2tons per 8hrs at a conversion of 82% which results to 2tons/8hrs = 0.25tons per hours.

0.82 = 0.25

0.01 =?

= <u>0.02 x 0.25</u>

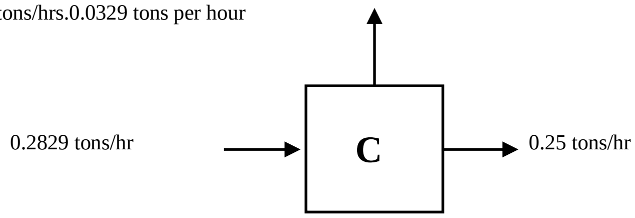
0.82

= 0.0329tons/hrs.

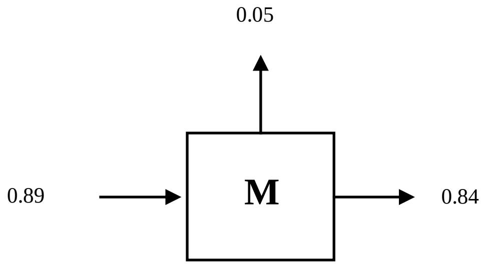
Material Balance on the Cyclone Banging Unit (C)

Material Input = Material Output + Material Loss

=0.25 + 0.0329 = 0.2829tons/hrs.0.0329 tons per hour



Material balance on the micro-milling machine (M)



0.84 = 0.2829 tons/hr

0.05 =?

= <u>0.05 x 0.2829 tons/hr</u> = 0.015 tons/hr

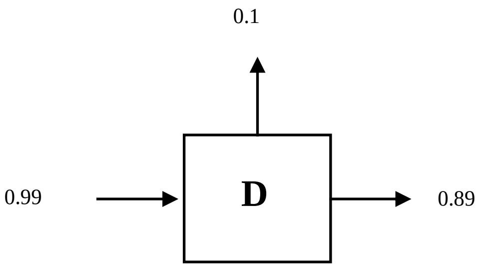
0.89

Material input = material output + material loss

= 0.2829 + 0.015

= 0.297tons/hrs.

Material Balance on the De-husking/Separation Unit (D)



0.89 = 0.297tons/hr

0.1 =?

$= \frac{0.1 \times 0.297 \text{ tons/hr}}{0.89} = 0.033$ tons/hr

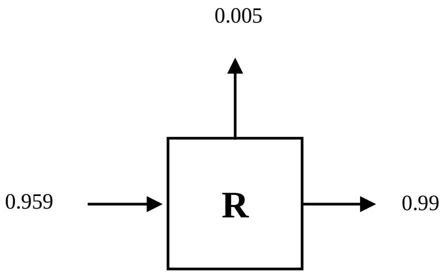
Material input = material output + material loss

= 0.297 tons/hr + 0.033 tons/hr

= 0.33 tons/hr

Material balance on the rotary toasting machine (R)

R =



0.98 = 0.33 tons/hr

0.005 =?

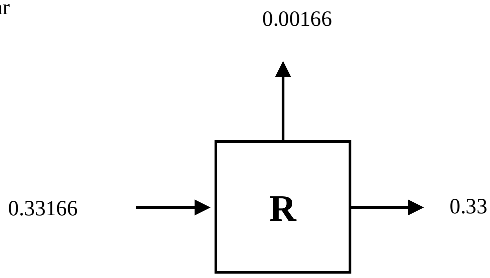
$= \frac{0.005 \times 0.33\text{tons/hr}}{0.99}$

= 0.00166 tons/hr

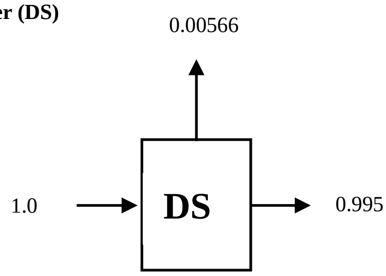
Material input = material output + material loss

= 0.33 tons/hr + 0.00166 tons/hr

= 0.33166 tons/hr



Taking material balance on the de-stoner (DS)



Material inputs = Material output + Material loss

0.995 = 0.33166 tons/hr

0.005 =?

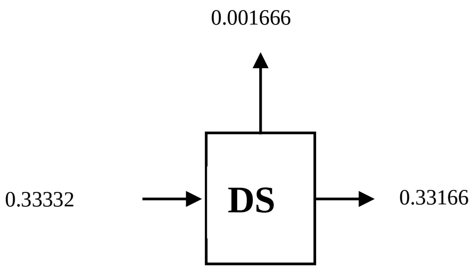
$$= \frac{0.005 \times 0.33166 \text{ tons/hr}}{0.995}$$

= 0.00166 tons/hr

Material input = Material output + Material loss

= 0.33166 tons/hr + 0.00166 tons/hr

= 0.33332 tons/hr



The overall material balance of the soya bean processing pilot plant is given as:

Material input to the soya bean = material output from the system + material loss from the system

Material loss from the system

= 0.0165 + 0.0165 + 0.033 + 0.015 + 0.03 = 0.08 tons/hr

The overall material balance

0.333 tons.hr = 0.25 + 0.08

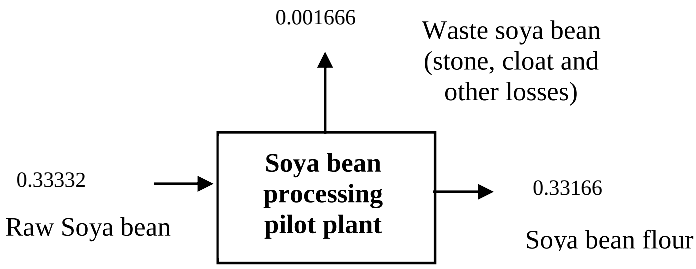
0.333 tons/hr = 0.333 tons/hr

Total input to the system = Total output to the system.

For 8 hours running operations we need a total of 8 x 0.333 = 2.64 tons of feed.

If we need to run 2 shifts of 16 hours per day, we need 2 x 2.64 tons = 5.28 tons of soya beans to produce 4 tons of processed soya bean flour.

Summary of Metal Balance



IV. Design specifications of the unit operation machines

I. Destoning Machine:

The destoning machine is designed to remove unwanted stones form the bulk soya bean that is to be processed. Considering the industrial process, the destoner makes available ready destoned soya bean all the time for processing operation. In this manner the destoner is built of higher capacity so that no weighting or loss of time is incurred. The destoner has the following capacity: 0.5 tons (5ookg) per hour. The machine has an inclined vibrating screen with maximum vertical displacement (amplitude)of 0.1mm. the unwanted stones pass through the eye of the screen while the soya bean which is larger in size rows down the incline. Both the stones and the clean soya bean are collected at different outlets.

The pictorial vie of the destoner is shown in figure 2 below:

II. Rotary Toasting Machine:

The double barrel rotary toaster has electrical heating devices lined at the outside of the barrels and is thermostatically controlled. The inside of the barrel has baffles, which are encased in another enclosure that is heavily insulated. The barrels rotate at 5-8rpm and driven with a geared motor coupled to another external gear arrangement. The double barrel toaster has a capacity of 0.33 tons (330kg per hour).

The pictorial view of the designed machine in figure 3 is shown below:

III. De-husking/Separation Machine:

De-husking/de-coating is the removal of the hard-shell cover of the soya bean seed in order to free the inside white seed. Soya bean can be de-husked or de-coated wet or dry. Wet de-coating requires soaking in water for a very long time, usually a whole day before attrition is applied for the removal of the coats. Large quantity if water is required for washing and for the separation of the coast from the inners seed. After washing the soya-bean is dried again before processing continues. This method of de-husking is very expensive, time consuming and highly labour intensive. This method of de-husking is not adopted for this plant design.

Dry de-husking which is cheaper, faster, with increased productivity and de-husking separation is adopted for the design of this plant. One of the essences of toasting is to increase the temperature of the soya bean coating, thereby making it to be very fragile which is suitable for light impact operation. The toastedsoya beans are given a radial force at high angular velocity and restricted to heat an anvil, thereby causing the breakage of the coatings and isolating the inner seeds from broken coatings. The volumetric air generated by the arrangements of fan blades inside the system separate the light broken coatings from the inner seeds. Both the broken coatings and the inner seed are collected at different points. The double chamber de-husking and separation machine has a capacity of 0.33tons (330kg) per/hr.

The pictorial view pf the dry de-husking machine in figure 3 is shown below:

IV. **Micro-Milling Machine:**

The micro-milling, is a crushing operation, in which the toasted de-husked and separated soya beans dropping by gravity from the large hopper of the micro-mill is crushed to powdery formation by a systematically arranged rotary hammers at a very high angular velocity. The beans are continuously crushed until; the particle size is so small about 10-50 microns, which now pass through the eye of the mesh (sieve) of the micro mill.

The micro-mill has two distinct chambers namely: The milling chamber, suction chamber/delivery section. While the milling section has an arrangement of crushing hammers, the suction section has an arrangements of air blades which generates high velocity air required to effect suction of the powdery particles through the eye of the sieve and transport them through the transparent host to the cyclone. The design micro-mill has the capacity of 0.2907 tons (297kg) per/hr.

Power rating of the electric motor = 10kw, Revolution per minute =3000rpm

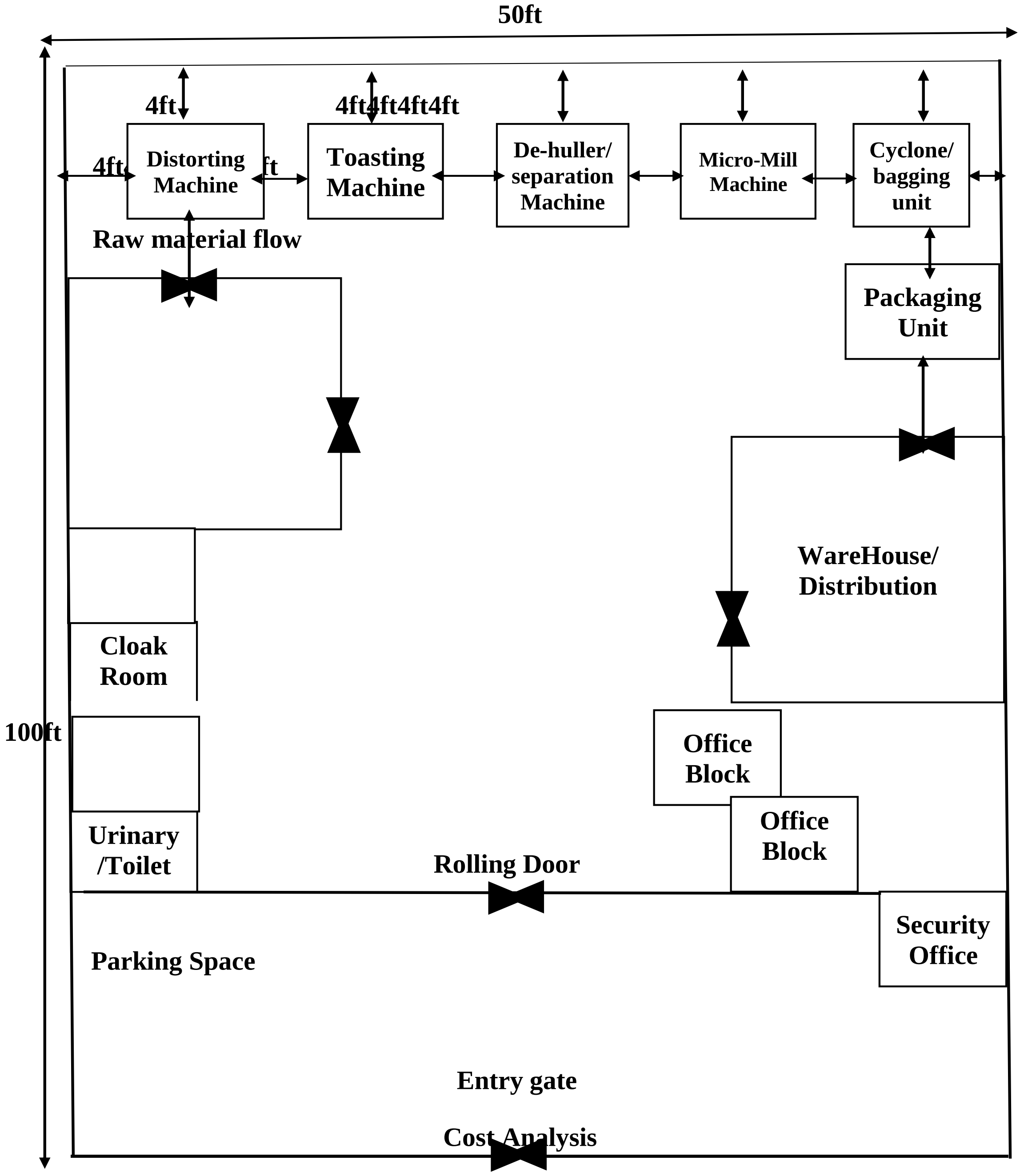
The pictorial view of the micro-mill in figure 4 is shown below:

V. **Cyclone Bagging Unit:**

Cycloning is a particle collection process. The high velocity air laden with particles sucked from the micro-mill and is directed to enter tangentially to the cylindrical section of the high through put cyclone, the air swirls round the cyclone wall with the help of the centrifugal force. In this process, the particle dropsthrough the cyclone collection hopper. While most of the particles are tapped and collected, some finer particles escape with the air centrally. The escaping air is directed to enter tangentially to the second stirmand high efficiency cyclone where the finer particles are collected. The cyclone id]se designed to collect 0.2829 tons (282. 9kg) of dust (flour) per/hr.

The pictorial view of the double Cycloning system in figure 5 is shown below:

Machine/Plant Layout of the 2 Tons Per Eight (8) Hours Work Per Day Plant.



Cost Analysis

The cost of the designed Unit Operation Machines as at 25/08/2024 is shown in the table below:

Table 1:

S/N	**Name of Machine**	**Capacity**	**Material of Construction**	**Unit Cost (N)**	**Total Cost (N)**
1	Distoning Machine	0.5tons/hr	Mild Steel/Stainless Steel	1,200,000	---
2	Double Barrel Toasting Machine	0.33tons/hr	Mild Steel/Stainless Steel	2,500	---
3	Double Chamber De-husking and Separation Machine	0.33tons/hr	Mild Steel/Stainless Steel	3,200,000	---
4	Micro-Mill	0.297tons/hr	Mild Steel/Stainless Steel	2,200,000	---
5	Twin Cyclone with Structural Stand	282.9tons/hr	Mild Steel/Stainless Steel	1,800,000	---
6	Sub-Total				10,900,000
7	Installation = 20% of Machine Cost				2,180,000
8	**Total Cost**				**13,080,000**

Please Note that this cost of N 13,080,000 is exclusive of cost of building.

VI. Conclusion

The conceptualized 2 tons per 8hours work per day soya bean to flour pilot processing plant was developed, installed and test runned. The problems encountered during the development of the pilot plant including the following:

(i) Inadequate funding

(ii) Epileptic power supply

(iii) Bureaucratic administrative bottle necks

(iv) Lack of state-of-the-art fabrication equipment and

These problems though over-comed affected the completion and the commissioning time of the plant. The test-run of the pilot plant was successful. Various arms of government, the private and industrial sector in Nigeria are herebychallenged to key into the establishment of both the micro,small and medium enterprises of this soya-bean to flour processing in order to mass produce this large protein content food product. The mass production of this product will contribute to the food security of Nigeria and equally generate revenue for the nation through export market. Proposal on the level of production on this plant can be raised and collaboration be made with local and international fund-raising organizations like bank industry, ministry of agriculture, world food programme (WFP), food and agricultural organization (FAO), the international fund for agricultural development (IFAD) and other organizations towards raising fund for establishment of micro, small and medium scale industries.

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