



DEVELOPMENT OF AN IMPROVED KNEADING MACHINE FOR SHEA BUTTER PRODUCTION PROCESS

BY

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Abstract

The research focused on the optimization and development of an improve kneading machine for Shea butter production process by designing an improve Shea butter kneading machine using stainless steel materials in the construction. The study also evaluates the local methods of traditional Shea butter production and quality in some selected Local Government Areas of Niger State based on the prevalence of their Shea processing activities as most active LGAs. These includes: Katcha/Lapai in Zone “A”, Bosso/Shiroro in Zone “B” Kontagora/Wushishi LGAs in Zone “C” which were purposively selected.

The data for this study was obtained from primary source from a cross sectional survey of identified Shea nut and Shea butter processors through the use of oral interview schedule and questionnaires with the assistance of trained enumerators from Niger State Agricultural Mechanization Development Authority (NAMDA) equipped with communication skills in both lingua franca and natives of the study area, One Hundred and Thirty Two (132) questionnaires were administered to respondents and the results were collected, coded using Microsoft Excel based on the selected LGAs and their coordinates taken. The statistical analysis were carried out using SPSS 23 version.

The results from the study were classified using it cumulative percentages and it frequency. Zone “A” comprising of Katcha/Lapai has 60%, 60 closely followed by zone “B” comprising of Bosso/Shiroro with 35%, 35, and Zone “C” comprising of Kontagora/Wushishi with 30%, 32 respectively. The application of the response system methodology (RSM).

The experimental results were analyze to understand the effect of the input process factors to the response, the variation of the variables, the reduction of wastes, and the optimization of the production process to reduce and save time wastes of different batch sizes for 20kg, 40kg and 60kg. The result for 20kg batch size shows that the optimal solutions of the input factors, that is the weight of the curd is 12.023kg; the weight of the wet cake is 2.076kg, the weight of oil is 4.308kg and finally, the weight of waste is 1.903kg, while the optimal solution for the response parameter shows a reduced time of 23.72minutes for processing the system. The 40kg batch size result shows that the optimal solutions of the input factors, that is the weight of the curd is 21.000kg; the weight of the wet cake is 7.000kg, the weight of oil is 8.977kg and finally, the weight of waste is 1.500kg, while the optimal solution for the response parameter shows a reduced time of 40.446minutes for processing the system. The 60kg batch size result shows that the optimal solution of the response parameter is 48.784 minutes, while the optimal solutions of the input factors, that is the weight of curds is 25 kg; the weight of wet cake is 11.0kg; the weight of oil is 11.003kg, and the optimal weight of waste is reduced to 8.011kg. The desirability of achieving the optimal solution for the input factors and the 20kg response parameter is one hundred percent (100%), while the desirability of achieving the optimal solutions for 40kg and 60kg batch production in the system is ninety point fifty nine percent (90.59%0) and seventy one point ninety three percent (71.93%) respectively.

The results show that the Shea paste kneading processing increase the quality standard and enhance the production capacity thereby reduce and save time, reduce the work rate and increase the marginal profits of

the local processors. This optimal solution correspond with the aim of the research and its objective by achieving the optimal solution that reduce production time, which maintain quality and enhance production capacity of the Shea kernel kneading process for traditional butter production system. The developed machine shows a significant improvement and superiority over the traditional method of producing the Shea butter with the machine, than when compared with the manual open market Shea butter produced for the market consumption. The research therefore recommends the use and application of the developed machine for the traditional method of producing and processing Shea butter products.

Keywords: Shea Butter; Production Process; Machine; Kernel; Kneading; Traditional Method

1.1 Introduction to the Study

Shea butter is a fat (triglyceride; mainly oleic acid and stearic acid) extracted from the nut of the African Shea tree (*Vitellaria paradoxa*) (Manding, 2022). It is ivory in color when raw and commonly dyed yellow with borututu root or palm oil. It is widely used in cosmetics production as a moisturizer, salve or lotion. Shea butter is edible and is used in food preparation in some African countries (National Research Council, 2006). Occasionally, Shea butter is mixed with other oils as a substitute for cocoa butter, although the taste is noticeably different (Masters, Yidana and Lovett, 2004; Fold, 2013).

The Shea tree *Vitellaria paradoxa* produces fruits whose kernels contain about 40–50 lipids usually referred to as Shea butter (Bunde *et al.*, 2019). Although the tree is indigenous to Sub Saharan Africa, its oil is highly cherished and used in chocolate formulations as cocoa butter replacer and cosmetics in Europe, America and some parts of Asia such as Japan, *etc.* The market for Shea nuts and butter has been on a constant rise with cosmetics utilizing 10% of the total production. Traditionally, the main actors in the production sector are women and children who get up early in the production season and work kilometres to collect the nuts. This collection, processing and sale either as dried nuts or as butter represent significant income earning opportunities for these local women (Bunde *et al.*, 2019). The number of productive Shea trees in the Shea belt is estimated at about 500 million. Castol oil and this oilseed are considered to be the second in terms of foreign exchange earnings after palm oil amongst the oil crops of Africa. Given the fast rate of growth witnessed in the Shea industry over the past decade, it is suggested that Shea nut volumes multiplied by recent tonnage prices, even prior to butter extraction, can earn West African Sahel-Savannah rural communities in the region (Lovett, 2010). Though the zones of production are known, the level of activity in the sector varies from one zone to the other. The production and marketing of Shea nuts and butter are not synchronized so that far reaching decisions that can impact the activities in all producing countries can be undertaken. This paper seeks to highlight the importance of the Shea tree as an important crop and which processing should be given attention similar to that accorded to the conventional ones such as palm oil, groundnuts, cocoa, coffee, *etc.*

The Shea tree is a wild indigenous tree exclusive to Africa and is increasingly being managed in farmlands while it's found also in the Savanna parklands. It usually grows to an average height of about 15 m with profuse branches and a thick waxy and deeply fissured bark that makes it fire resistant (Fobil, 2007; SNV Netherland Development Organization, 2011). The Shea tree grows wild in the dry Savannah belt of West Africa from Senegal in the west to Sudan in the east, and onto the foothills of the Ethiopian highlands. It occurs in 19 countries across the African continent, namely Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Cote d'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra

Leone, Sudan, Togo, Uganda, Zaire and Guinea (Bondé *et al.*, 2019). In Ghana, it occurs extensively in the Guinea savannah and less abundantly in the Sudan Savannah (SNV, 2011).

Two varieties of Shea have been identified as the *Vitellaria paradoxa* and *Vitellaria nilotica*. The former is found in West Africa whereas the latter is indigenous to East Africa, particularly Northern Uganda and Southern Sudan (Ferris *et al.*, 2001; Nasare *et al.*, 2019; Abdul-Mumeen *et al.*, 2019). In Ghana, the Shea tree occurs almost in the entire area of Northern Ghana (about 77,670 km²) and supports the livelihood of approximately 900,000 rural women involved in the sector of Northern Ghana (SNV, 2011). Selected patches of dense parklands of Shea trees can be found in areas around Western Dagomba lands, Southern Mamprusi, Gonjaland, Eastern parts of Nadowli, Sissala lands and Western parts of the Upper West Region especially around the sanctuary areas of Wechiau (Graphic Showbiz, 2021; Fobil, 2007). There is also sparse Shea tree cover found in the Brong-Ahafo, Ashanti, Eastern and Volta regions in southern Ghana (Fobil, 2007, Hatskevich *et al.*, 2011, SNV Netherland Development Organization, 2011). Estimates of tree population vary and there are no available statistics on exact numbers. However, according to Adams *et al.* (2016) the Shea sector employs about 85 % of rural women and this contributes about 70 % of the income of rural households in Wa Municipality and its environs. Shea butter production is made up of local, semi-mechanized and automated processes in Nigeria and Ghana (Adams *et al.*, 2016; Akraasi *et al.*, 2021).

The Shea industry generates employment and income for about a million rural women in North central of Nigeria and northern Ghana involved in picking nuts and marketing processed Shea kernel and Shea butter. Major Shea activities involve picking or gathering fruits and nuts, processing nuts into butter, and distributing and marketing Shea commodities. Shea butter entrepreneurs, mostly women, sell to both domestic and international markets. Processing Shea commodities has attracted different kinds of support from export companies, NGOs, development partners and the government. Shea commodities (Shea kernel and butter) have become tradable and have entered the international market because of their export potential. According to the American Shea Butter Institute, there are about twenty-one (21) uses of Shea butter. Major uses include local consumption of Shea butter as food, use for cosmetics, soaps and detergents, medicines, and for cultural/religious purposes. The major industrial and commercial uses are cosmetics and pharmaceuticals. In many countries such as Japan, the United Kingdom, Germany, and the Netherlands Shea butter is considered a valuable product for natural/luxury cosmetics such as skin creams, soaps and shampoos because of its moistening/hydrating, protecting and softening properties (Schreckenber, 2004; Basit, 2010; Jasaw *et al.*, 2015; Abdul-Mumeen *et al.*, 2019). Shea butter is a major source of economic sustenance for women because Shea butter processing (handcraft butter) remains in the hands of rural women especially those in North central Nigeria and Northern Ghana (Saba, 2018; Sualihu, 2019). It is argued that the profit margins of those engaged in handcraft butter processing are very marginal. Despite the numerous benefits derived from Shea butter, many have questioned the profit generated by rural women into Shea butter production business (Issahaku, Bruce, & Al-Hassan, 2012, Laube, 2016). The profitability is affected by many factors, some of which may be outside the control of the women, while others are due to

inefficiencies. Many studies have only concentrated on the contribution of Shea to food security (Quaye, 2008; Owusu *et al.*, 2011; Tsiboe *et al.*, 2016).

The Shea tree grows naturally in the southern regions of the Sahel and the northern regions of the Guinea zone. Global production thrives in the West African countries of Mali, Burkina Faso, Benin, Senegal, Cote D'Ivoire, Ghana, Namibia, and Nigeria. In Nigeria, the Hausas call it 'mankade', the Ibos Okwuma and the Yorubas Igi-emi Orio-oyo (Adesiji, *et al.*, 2015). Issahaku, Sarpong, & Al-hassan (2011), stated that the Shea tree is valued for its nutritional value of cooking oil and fruit pulp. Bark, roots, and leaves are used in traditional medicines. The tree is naturally endowed with vitamins such as A, E, and F (Okullo *et al.*, 2012) and is widely used for domestic uses such as cooking and skin moisturizers and commercially as an active ingredient in cosmetic, pharmaceutical, and edible products (Alexander, 2004). From time immemorial women have traditionally played a significant role in the extraction of Shea butter, right from the stage of collection of Shea nuts to final processing into Shea butter. Indigenous food processing and preservation techniques enable people, particularly women in rural areas, to survive under stressful conditions. This collective knowledge is imperative to the survival and future safety of local communities and of the indigenous population as they try to maintain their livelihoods under difficult environmental conditions. All over the globe, rural women have elegant indigenous food processing and preservation techniques that are recognized to be more sustainable. Rural women are known to possess indigenous cultural practices which support maintaining household food security, notably in terms of drought and famine as well as offering a reserve for expanded periods of financial hardship (Issahaku, Sarpong, & Al-hassan, 2012). Adesiji, *et al.* (2015), noted that many practices disappear only because of the interruption of foreign technologies or advancement concepts that promise short-term gains or outcomes to problems without being capable of sustaining them.

It is against this background that the researcher seeks to find out the most effective and improved means of the kneading stage of the Shea kernels/ pastes as it is critical in the Shea butter production. This could ultimately improve incomes and promote socioeconomic development in northern Nigeria.

1.2 The aim and Objectives of the Study

The aim of the study is to develop an improved kneading machine for Shea butter production

To achieve the stated aim, the following objectives were pursued:

1. Design and fabricate a kneading machine for Shea butter production;
2. Characterize the quality of Shea butter produced from the kneading machine and compare with the Shea butter already in the open market (Physical and Chemical properties);
3. Optimize the Shea butter production parameters.

2.0 Development of a Kneading Machine Prototype

Design and fabrication of a kneading machine

Materials and methods

The materials use for the construction includes stainless steel materials as the Shea pastes will be in contact with the kneader components and because of its resistance to high corrosion as reported by Shehu *et al.*,

2017. The following materials and machines were used in carrying out the test: Dried Shea kernels, Roaster\Toaster, Crusher, Miller, Weighing balance, Filter cloths, Aluminum pots, Plastic rubber and buckets.

The methodology is to sort out black nuts, sprouted nuts and diseased nuts before weighing 20kg and 50kg of dried Shea nuts respectively and crushed to reduce the particle size, this is spread out on mat or platform to allowed it to cool for about 30 Min, this is an important stage or link aiming at obtaining more oil yields. The crushed kernels are then milled by a milling machine to a pasty form which is allowed to cool overnight before kneading. Several batches can be kept overnight for kneading the previous day.

Kneading is done by adding small quantity of water to the mixtures to make it fluidly before pouring it unto the kneading machine for about 15Min to at most 25Min. Soon as the mixtures turns from brownish to milky colour large quantity of water is then introduced into the mixtures which forces the curds to raised on top of the mixtures and wastes/water is first of all discharged from the outlet before collecting the curds which is boiled to collect the Shea butter and packaged in to our customized containers as soon it solidifies. No additives is added and that is why it is tagged “NIFOR Prime Natural”.

This test is carried out twenty times for each category of weight taken as shown in fig 3.9 and 4.0 respectively.

Table 4.1: Experimental Results of testing the machine at 20kg per batch

Date	Weight of kernels (kg)	Weight of Milled kernels (kg)	Weight of curds (kg)	Weight of wet cake (kg)	Weight of oil (kg)	Weight of waste (kg)	Time (Min)
4/01/2023	20 (kg)	20 (kg)	12 kg	2 kg	5 kg	1kg	28
11/01/2023	20 (kg)	20 (kg)	11 kg	1kg	5 kg	3kg	29
18/01/2023	20 (kg)	20 (kg)	12 kg	2 kg	4 kg	2kg	27
25/01/2023	20 (kg)	20 (kg)	11 kg	2 kg	4 kg	3 kg	28
1/02/2023	20 (kg)	20 (kg)	12 kg	2 kg	5 kg	3 kg	27
8/02/2023	20 (kg)	20 (kg)	12 kg	2 kg	5kg	3 kg	29
15/02/2023	20 (kg)	20 (kg)	12 kg	2 kg	6 kg	2 kg	30
22/02/2023	20 (kg)	20 (kg)	12 kg	2 kg	5 kg	3 kg	26
1/03/2023	20 (kg)	20 (kg)	12 kg	2 kg	4 kg	2 kg	28
8/03/2023	20 (kg)	20 (kg)	12 kg	2 kg	5 kg	1 kg	27
15/03/2023	20 (kg)	20 (kg)	11 kg	3 kg	5 kg	1 kg	26

22/03/2023	20 (kg)	20 (kg)	12 kg	2 kg	4 kg	2 kg	25
29/03/2023	20 (kg)	20 (kg)	12 kg	2 kg	4 kg	2 kg	27
5/04/2023	20 (kg)	20 (kg)	12 kg	2 kg	4 kg	2 kg	26
12/04/2023	20 (kg)	20 (kg)	13 kg	2 kg	3.5 kg	2.5 kg	25
19/04/2023	20 (kg)	20 (kg)	11 kg	1.5 kg	4 kg	1 kg	27
26/04/2023	20 (kg)	20 (kg)	12 kg	2 kg	4 kg	2 kg	12

Table 4.1 shows the experimental results for the 20kg Shea kernel kneading process for butter production system.

Table 4.2 Experimental Results of testing the machine at 40kg per batch Weight of Kernel

Date	Weight of kernels (kg)	Weight of Milled kernels (kg)	Weight of curds (kg)	Weight of wet cake (kg)	Weight of oil (kg)	Weight of waste (kg)	Time (Min)
4/05/2023	40 (kg)	40 (kg)	21 (kg)	10 (kg)	7 kg	2 kg	43
11/05/2023	40 (kg)	40 (kg)	20 (kg)	9 (kg)	8 kg	2 kg	45
18/05/2023	40 (kg)	40 (kg)	19 (kg)	7 (kg)	9 kg	5 kg	45
25/05/2023	40 (kg)	40 (kg)	21 (kg)	10 (kg)	7.5 kg	1.5 kg	43
1/06/2023	40 (kg)	40 (kg)	20 (kg)	9 (kg)	8 kg	3 kg	41
8/06/2023	40 (kg)	40 (kg)	19 (kg)	9 (kg)	8.5 kg	3.5 kg	43
15/06/2023	40 (kg)	40 (kg)	21 (kg)	10 (kg)	6.5 kg	2.5 kg	45
22/06/2023	40 (kg)	40 (kg)	21 (kg)	9 (kg)	6.6 kg	3.4 kg	45
1/06/2023	40 (kg)	40 (kg)	20 (kg)	10 (kg)	8 kg	2 kg	43
8/07/2023	40 (kg)	40 (kg)	21 (kg)	9 (kg)	7 kg	3 kg	41
15/07/2023	40 (kg)	40 (kg)	21 (kg)	8 (kg)	7kg	4 kg	42
22/07/2023	40 (kg)	40 (kg)	20 (kg)	8 (kg)	9 kg	3 kg	43
29/08/2023	40 (kg)	40 (kg)	20 (kg)	10 (kg)	8 kg	2 kg	44
5/08/2023	40 (kg)	40 (kg)	19 (kg)	11 (kg)	8 kg	2 kg	44

12/08/2023	40 (kg)	40 (kg)	19(kg)	12 (kg)	7 kg	2 kg	42
19/08/2023	40 (kg)	40 (kg)	20(kg)	10 (kg)	8 kg	2 kg	41
26/08/2023	40 (kg)	40 (kg)	21(kg)	9 (kg)	8 kg	2 kg	40

Table 4.2 shows the experimental results for the traditional Shea kernel butter production process in the system.

Table 4.3 Experimental Results of testing the machine at 60kg per batch

Date	Weight of kernels (kg)	Weight of Milled kernels (kg)	Weight of curds (kg)	Weight of wet cake (kg)	Weight of oil (kg)	Weight of waste (kg)	Time (Min)
5/09/2023	60	60	25	12	15	8	55
12/09/2023	60	60	25	11	14	10	56
18/09/2023	60	60	25	11	14	10	55
24/09/2023	60	60	24	12	15	9	53
1/09/2023	60	60	22	13	16	9	51
7/09/2023	60	60	22	14	15.5	8.5	53
16/09/2023	60	60	21	12	16.5	10.5	55
21/09/2023	60	60	21	13	14	12	57
2/09/2023	60	60	25	12	13	12	53
9/09/2023	60	60	25	12	12	11	52
15/09/2023	60	60	23	13	12	12	53
21/09/2023	60	40	22	14	11	13	54
28/09/2023	60	60	21	12	13	14	54
6/10/2023	60	60	22	13	13	12	56
11/10/2023	60	60	23	12	14	11	52
20/10/2023	60	60	23	12	12	11	51
27/10/2023	60	60	22	12	13	13	54

Table 4.3 shows the experimental; results of the 60kg Shea kernel kneading processing of the Shea butter production system using the traditional processing method.

Description of machine parts

Body Tank

The Body is a cylindrical shape with a diameter of 650mm by 650mm long and it can conveniently handles 50Kg or more of milled Shea kernels per batch. It is the mixing chamber that accommodates the blades and the central shafts.

Hopper

The hopper is a frustums measuring 370mm diameter by 300mm long. It has a capacity of 50 litres of milled Shea kernels or water. It is used as feeding inlet of milled Shea kennels and water.

Discharge trough.

The discharge trough is measuring 200mm by 170mm long and it is the point of collecting Shea curds and discharge of sludge after the kneading operations.

The pulley is made up of machined mild steel of 15mm groove and 150mm diameter. It uses 57mm single v-belt

Engine Seat

The engine seat stand is made up of 40mm Mild steel angle iron measuring 370mm by 470mm. It is firmly attached to the engine during operations.

Engine

The engine is 6.5 Hp petrol engine that is durable, sturdy and easily operated by the local processors. It is found to be cost effective in the rural settings where majority of the processors reside.

Gear Box

The gear box is of tree ratio one (3:1) slow speed gears. It used is to reduce the speed of the impeller to increased output of the kneading process.

Fig 1 shows the schematic view of the kneading machine



Plate 1.3 D Design of the Machine



Plate 2. Rear view of the machine



Plate 3. Front view of the machine

3.0 Design Considerations

The design consideration in term of the strength, stress, torque and speed is to be determine to avoid failure of the components part during operations

3.1 Design Analysis

The following design analyses were carried out to select the main machine component in terms of strength torque and speed etc.

3.2 Design of hopper

Where:

Let L = Length

B = Breath

H = Height

V = Volume

$$\pi = \frac{22}{7}$$

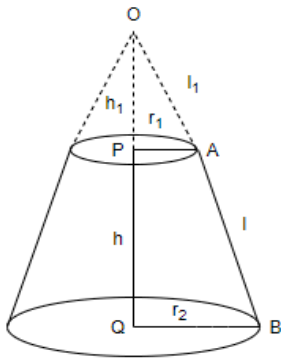
D = 650mm

L = 650mm

Volumetric capacity of Hopper V = 4,647.5m³



Frustum



$$h = 300\text{mm}$$

$$h = 300\text{mm}$$

$$r_2 = 370\text{mm}$$

$$r_1 = 60\text{mm}$$

$$V = \frac{1}{3} \pi r^2 h$$

$$= \frac{1}{3} \pi [R^2 + R + r^2] h$$

$$= 7,245.4\text{m}^3$$

The pulley weight

The pulley is made from mild steel materials with density of 7850kg/m^3 and diameter of 100mm and 50mm length. The determination of weight is necessary for easy of load bearing capacity of the engine.

$$V = A \times L$$

$$= \frac{\pi d^2}{4} \times L$$

$$= \frac{\pi 0.1^2}{4} \times L$$

$$= 0.000392\text{m}^3$$

$$m = 30.25\text{kg}$$

The diameter of the shaft

This is necessary to determine its strength and to further step down the speed of the engine to give greater output. The diameter of the shaft is given by the following formula

$$d^3 = 16 / \pi S_s \sqrt{(k_b M_b + K^2 M_t)^2}$$

Where S_s = Allowable stress = $40 \times 10^6 \text{Nm}$ for mild steel

$$= 40\text{Nmm}$$

K_b = combined shock and fatigue factor = 1.5

K_t = combined shock and fatigue factor applied to tensional moments for gradual applied

load = 1.0

M_b = maximum tensional moments = 4228.0Nmm

M_t = maximum tensional moments = 2159.02Nmm

$d = 10.24\text{mm} \times 2$ (factor of safety)

$$= 20.48\text{mm}$$

For standard shaft diameter choose 30mm

$$d = 30\text{mm}$$

Determinations of speed of the mixers blades

This is necessary to achieve a low speed output of the engine.

$$N_s D_s = N_E D_E \text{ _____ (1)}$$

Where:

N_s = speed of blades in rev/min

N_E = speed of motor in rev/min

D_s = Diameter of shaft pulley in mm

D_E = Diameter of motor pulley in mm

$N_s = ?$

$N_E = 1,500$ rev/min

$D_s = 75$ mm

$D_E = 86.5$ mm

For efficient

$$N_s D_s = N_E D_E$$

$$N_s = \frac{N_E D_E}{D_s}$$

$$= \frac{1500 \times 86.5}{75}$$

$$N_s = 17.30 \text{ rev/min}$$

The mixing blades speed

This is based on the member of revolution per minutes and the diameter of the shaft selected.

$$\text{Mixing speed} = \omega r \text{ (Saba, 2017)}$$

Where:

ω = Angular velocity in rad/s

r = Radius of shaft pulley = 32.5mm

$$\omega = \frac{2\pi N}{60}$$

Where N = number of turns in rev/min

$$\omega = \frac{2\pi \times 1730}{60}$$

$$= 181.19 \text{ rad/s}$$

But $V_c = \omega r$

$$= 181.19 \times 37.5$$

$$V_c = 6.795 \text{ m/s}$$

The Torque on the blades

$$P = 1.5 \text{ kw (Design)}$$

$$P = T\omega$$

Where p = motor power in Kw

T = Torque Nm

$$w = \text{Angular velocity in rad/s} = 181.19 \text{ rad/s}$$

$$= 0.0083 \text{ KNm}$$

$$T = 8.3 \text{ Nm}$$

Power required to operate the mixing blades

$$P = Tw$$

$$T = 8.3 \text{ Nm}$$

$$w = 2 \pi N / 60$$

$$P = 1503.86 w$$

$$P = 1.503.86 \text{ Kw}$$

Energy balance across the kneader

BASIS: 50Kg/batch

Assumptions:

- All figures are approximated to the nearest whole number.
- The specific heat of feed (Shea nut) is assumed to be constant within the range of the temperature used.
- Datum temperature shall be taken as 0°C and ambient temperature shall be taken as 25°C .

The specific heat of seed (Shea nut) is $1.260 \text{ kJ/kg}^{\circ}\text{C}$, (Olubumi, 1988)

The specific heat of oil (Shea butter) is $1.869 \text{ kJ/kg}^{\circ}\text{C}$ (Chijike, 2009)

Kneader

Mass of Shea nut entering = 63kg

Mass of milled kernels 60kg

Mass of dry Shea nut 50kg

Mass of curds 38kg

Mass of oil obtained 8kg

Heat content of Shea kernels entering = $MCp\Delta T$

Where M = mass of kernels

C_p = specific heat capacity of kernels

ΔT = change in temperature

Heat content of fresh seeds = 1,575kJ

Heat content of roasted Shea nut

If the heat apply to the kernels is measured at 110°C (average temperature)

Heat content of dry seed = 5,355 kJ/kg

3.3 Shea Butter Characterizations

The Shea butter obtained from the machine shall be further characterize to determine the percentage of it density, free fatty acid, moisture contents, iodine, peroxide value and the impurity as desirable quality indicators

Determination of the quality of Shea butter produced

The test was carried out at the Biochemistry Division of Nigerian Institute for Oil palm Research NIFOR using samples obtained from the machine and that purchased from the open market sold by the local processors and considering some keys desirable characteristics of the Shea butter as follows:

3.3.1 Materials and Methods

Quality Analysis

1. Colour (AOACS,1991 Official Methods)

Equipment

- i. **Colorimeter**
- ii. Lighting cabinet (consisting of two 60 watts panel lamps and each illustrating the test portion and white reference field at 45 degrees.
- iii. Colour racks: Consisting of red, yellow blue and neutral
- iv. Spillage tray
- v. Glass cells

Procedure

- i. Ensure oil is liquid at room temperature if not gently heat at 10°C
- ii. Do not conduct test under sun reflection use subdued ambient light
- iii. Ensure glass cell is thoroughly cleaned and dried. Pour oil of sufficient optical length into the glass cell
- iv. Place the cell containing the oil in the lightening cabinet close to the viewing tube (apparatus ii)
- v. Determine colour by using the colour rack in the ratio of 10 yellow to one red
- vi. Correct until an accurate colour match is obtained using the minimum number of blue and neutral not more than 9.0blue and 3.0 neutral
- vii. Record the size of cells used and the red, yellow, blue or neutral reading forming the colour match

Moisture and Impurities (AOACS, 1991 Official Methods)

Equipment

- i. Electric hot plate: The surface should have high polish or cover with heat resistant pad
- ii. Glass beaker (100-150 ml)
- iii. Desiccators

Procedure (Triplicate)

- i. Mix oil to distribute moisture
- ii. Wash the beaker dry and cool in a desiccators
- iii. Tare a beaker and Weigh 5g of oil into it
- iv. Heat the oil on the hot plate, rotating the beaker gently by hands to avoid splattering
- v. The endpoint will be determined by the cessation of the rising bubbles of steam as well as the absence of foams
- vi. Temperature must not exceed 130°C except at the end of test

- vii. When apparent end point have been reached heat momentarily to the point of incipient smoking. But use caution not to overheat.
- viii. Cool in a desiccators and weigh

Moisture and Volatile matter = $\frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100\%$

Initial Weight

3.4 Free Fatty Acid (FFA) AOACS,1991 Official Methods

Materials

- i. 95 ethyl alcohol: Just before use add few drops of phenolphthalein into the ethyl alcohol, Titrate with NaOH to faint put permanent pink colour
- ii. Phenolphthalein indicator solution : 1 in 95 ethyl alcohol
- iii. Standard NaOH solution: 0.1 M

To standardise NaOH: see AOCS, 1991 H 12-52

To determine 0.1M,

$$\text{Weight (g)} = 40 \text{ g mol}^{-1} \times 0.1 \text{ mol L}^{-1} \times 1.00 \text{ L} \times \frac{100}{\text{purity}}$$

Equipment

250 ml Erlenmeyer flask, Burette, Stirrer, Magnetic stirrer

Procedure

- i. Ensure oil is liquid if not heat at 10°C, mix oil thoroughly
- ii. Weigh 28.2g ± 0.2 g into a Erlenmeyer flask
- iii. Heat 50 ml of neutralise ethyl alcohol
- iv. Add hot neutralised alcohol to oil sample and 2 ml of indicator
- v. Titrate with 0.1M of NaOH shaking vigorously using the stirrer until the appearance of the first permanent pink colour of the same intensity as that of the neutralised alcohol

Calculation of FFA (Lauric)= $\frac{\text{ml of alkali (in Litre)} \times M \times 20}{\text{Mass of test portion (in KG)}}$

Mass of test portion (in KG)

M= Molarity of NaOH

To convert to FFA to acid value multiply by 1.99 (milligram of KOH / 1g oil)

2. Saponification Number (AOACS,1991 Official Methods)

Materials

- i. Standardized hydrochloric acid 0.5M

Standardization of hydrochloric acid AOAC, 1991 H 14-52

- ii. Alcoholic KOH: Dissolve 34g of KOH low in carbonate in 20ml of deionised water and dilute to 1litre with 95 -100 ethanol. Cool to a temperature of 15oC or below the solution should remain clear.
- iii. Phenolphthalein indicator solution: 1 in 95 ethyl alcohol

Equipment

250 ml alkali resistant Erlenmeyer flasks with ground-glass joint, Condenser with fitting joint to the Erlenmeyer flask, water bath or hotplate with varying heat control, filter paper, Pipette, boiling chips

Procedure

- i. Melt the oil if not in liquid form (not more than 10°C should be used). Mix test portion
- ii. Filter through dry filter paper to remove any impurities and moisture
- iii. Weigh 2g of filtered oil into the Erlenmeyer flask.
- iv. With a pipette add 25ml of alcoholic KOH allowing the pipette to drain for at least 10 seconds
- v. Prepare a blank by adding 25 ml alcoholic KOH without oil into an Erlenmeyer flask
- vi. Connect the condenser, add some boiling chips to flask with occasional shaking and boil gently for 60 minutes. Allow to slightly cool
- vii. Rinse the condenser into flask with distilled water
- viii. Add 1ml of phenolphthalein indicator
- ix. Titrate sample and blank with 0.5 M HCL until the pink colour just disappears

Calculation

$$\text{Saponification Value} = \frac{(B-S) \times M}{W} \times 56.1$$

W

B = Volume of 0.5M of HCL required to titrate blank (ml)

S = Volume of 0.5 M HCL required to titrate sample (ml)

M = Molarity of HCL

W = Mass of test portion in grams

3. Peroxide Value (IUPAC 2.501)

Equipment

3ml glass scoop, flask with ground neck and stopper of about 250 ml capacity dried beforehand and filled with

an inert gas (Nitrogen or preferable carbon dioxide, burette, stirrer

Materials

- i. Chloroform freed from oxygen by bubbling a current of pure dry inert gas through it
- ii. Glacial acetic acid freed from oxygen by bubbling a current of pure dry inert gas through it
- iii. Potassium iodide saturated aqueous solution recently prepared (everyday) by, dissolving an excess of KI in recently boiled distilled water (note presence of undissolved KI pellets). Store in dark when not in use
- iv. 10 starch solution
- v. 0.01 N or 0.002N sodium thiosulphate standardized just before use

$$V1 = \frac{C2 \times V2}{C1}$$

C1

$$C2 = 0.002 \text{ or } 0.01$$

V_2 = Volume required i.e 100ml

C_1 = initial concentration as stated by suppliers

V_1 = volume required to make up v_2 i.e volume to be collected

C_2 = wt/ mol mass x volume

Wt = given in bottle i.e HCL = 37 (wt/wt)

Volume = 100/specific gravity

Procedure

- i. Ensure that sample is taken and stored away from the light, kept cold and contained in completely filled glass containers, hermetically sealed with ground stopper or cork stopper
- ii. The test shall be carried out in artificial light
- iii. Unstopper a flask and weigh quickly 3g of oil into it stopper the flask
- iv. Add 10 ml of chloroform, dissolve quickly by stirring
- v. Add 15 ml of acetic acid
- vi. Add 1 ml of KI solution
- vii. Insert the stopper quickly
- viii. Shake for 1 minute
- ix. Leave for exactly five minutes away from light at a temperature of 15 to 25 °C
- x. Add about 75ml of distilled water if colour is deep titrate with thiosulphate to lighten colour before adding indicator. If colour is light immediately add indicator
- xi. Add 0.5 ml starch solution as indicator
- xii. Titrate with 0.002N sodium thiosulphate shaking vigorously until the blue gray color disappears in the aqueous (upper layer). *Note:* for Doe-120, titrate until the lower layer has a "milky" appearance.
 - i. Repeat procedure for blank. If blank is more than

If blank exceeds 0.25 ml for 0.002N or 0.05ml for 0.01N replace contaminated reagents

Calculation

$$P.V = S-B \times N \times 1000$$

Weight of sample

4. Fatty Acid Composition (FAC) AOACS,1991 Official Methods

Step 1

Preparation of Methyl Esters

Apparatus

50 and 25 ml flat bottom boiling flask, fitting water cooled condenser, 250 ml separating funnels, 200 ml boiling flask, boiling chips, 10ml pipette, test tube, methyl red indicator

Reagents

- i. BF_3 -methanol reagent 12-15 (commercially available) use fresh and refrigerate when not in use
- ii. 0.5 M NaOH in methanol (use equation from peroxide value) or dissolve 2g of NaOH in 100 ml methanol containing not more than 0.5 (m/m) of water
- iii. Saturated sodium chloride in water
- iv. Petroleum ether (redistilled bp 30-60°C)
- v. Heptane gas chromatographically clean
- vi. Sodium sulphate (Na_2SO_4) anhydrous reagent grade
- vii. Methyl red indicator: 0.1 in 60 ethanol
- viii. Nitrogen gas: High purity
- ix. Hexane
- x. Reference standard preferable with similar composition to coconut oil

Procedure

- i. Introduce 500 mg of oil into the 125 ml bottom flask.
- ii. Add 6ml of 0.5 M methanol NaOH put a boiling chip
- iii. Attach a condenser and boil the mixture on a steam bath until the fat globules go into solution (about 5- 10 minutes)
- iv. Add 7 ml of BF_3 methanol through the condenser and continue boiling for 1 minutes
- v. Add 2-5 ml Heptane and boil another 1 minutes
- vi. Remove from heat and remove condenser
- vii. Add about 15 ml of saturated NaCl
- viii. Stopper the flask and shake vigorously for 15 second while the solution is still rapid
- ix. Add more saturated NaCl to the flask in order to bring the level of liquid to the neck of the flask.
- x. Allow to separate and transfer the upper layer (heptane solution) into ground neck test tube. Test with pH meter for neutrality if not neutral wash with 10 ml of water or until neutral each time taking the upper layer.
- xi. Add a little anhydrous sodium sulphate to remove any trace of water put about 1 ml of the heptane solution into a vial or ground neck test tube. This can be injected directly into a GC
- xii. To get dry esters, Transfer the salt solution and heptane phase into a 250 ml separating funnel
- xiii. Extract twice with 50 ml portion of petroleum ether or until the water is neutral
- xiv. Wash the combined extract with 20 ml water until free of acid. Each time discard the bottom layer
- xv. Transfer about 1 ml of heptane solution into a test tube
- xvi. Add a small amount of sodium sulphate
- xvii. The dry heptane solution may then be injected directly in the GC

Packaging and labeling samples



Fig. 2: Shea Butter Finished Production Process

Table 1: The results desirable characteristics are shown below

Test	Open market Shea butter	Machine produced Shea butter
Moisture content	4	4
FFA	8	3
Impurity level	4	2
Seponfication value	210mg/Koh/g	198mg/Koh/g
Unsaponfiable matter	22.2	19.8
Refractive index at 25 ⁰ C	1.9	1.5
Vitamins	A and E	A and E
Iodine value	55.214g/100g	45.612g/100g
Acidic value	4.5MgKoh/g	3.2 MgKoh/g
Peroxide value	6.25meg/kg	9.84meg /g
Colour	Grayish	Cream yellow

The results in table 1 shows the desirable characteristics and comparism of the open market Shea butter and machine produced Shea butter. The results show that both the open market Shea butter and the machine Shea butter have the same moisture contents of 4%, and vitamins A and E. However, free fatty acid (FFA) of the open market Shea butter is 8%, while the free fatty acid (FFA) of the designed machine produced 3%. The impurity level of the Open market is higher with a value of 4%, while that of the designed machine Shea butter is 2%. The seponfication value of the 210mg/Koh/g is the average value for open market Shea butter, while seponfication value of the 198mg/Koh/g is the average value for the developed machine produced market Shea butter. The unsaponfiable matter has a value of 22.2% for the open market Shea butter, while unsaponfiable matter has a value of 19.8% for the developed machine produced market Shea butter. The Refractive index at 25⁰C has a value of 1.9% for the open market Shea butter, while Refractive index at 25⁰C has a value of 1.5% for the developed machine produced market Shea butter. The Iodine value of the 55.214g/100g is the average value for open market Shea butter, while Iodine value of the 45.612g/100g is

the average value for the developed machine produced market Shea butter. The acidic value of the 4.5mg/Koh/g is the average value for open market Shea butter, while the acidic value of the 3.2mg/Koh/g is the value for the developed machine produced market Shea butter. The peroxide value of the 6.25meg/kg is the average value for open market Shea butter, while peroxide value of the 9.84meg/kg is the average value for the developed machine produced market Shea butter. This shows that the peroxide have of the machine is higher and more preferable. Finally, the colour of the open market Shea butter is grayish in colour, while colour of the developed machine produced Shea butter is cream yellow.

The above results significantly proof that machine produced Shea butter is the best practices of Shea butter processing system, it is quite superior to the one purchased at the open market.

Packaging and labeling of the Shea butter produced were done using 500g and 200g rubber containers sold at N1500 and N1200 respectively. Its tagged NIFOR Shea Butter Prime Natural. This is fully commercialized at the Finance and Account. Dept. of the Nigerian Institute For Oil palm Research NIFOR Headquarters at Benin city, Edo State.

Conclusion

In conclusion the study has performed significant results on Shea butter production process system by the redesigned of the kneading machine that is cheap, effective and affordable to the rural Shea butter processors using a stainless steel materials in the construction. The experimental results were used to optimize the parameters that aid the kneading machine to achieved Shea butter in a significant reduced time and optimal yields.

The studies of the local methods of traditional Shea butter processing has revealed the varied and inconsistent Shea butter processing practices across the selected LGAs and the research has been able to adopt a uniform processing method to be adopted by rural processors in meeting the international standards.

The characterization of the Shea butter produce such as Moisture content, Free Fatty Acid, Impurity level, Sapomification value, Iodine value, etc met the desirable characteristics requirement at international market when compared with Shea butter produced at the local markets. This is significant milestone in achieving prosperity through foreign earnings of the local processors.

The result shows that Shea paste kneading processing increase the quality standard and enhance the production capacity thereby reducing and saves time, reduce the work rate and increased the marginal profits of the local processors and this has been commercialized by NIFOR.

In conclusion, the research was able to eliminate the manual traditional method of Shea butter production process to improved Shea butter processing system.

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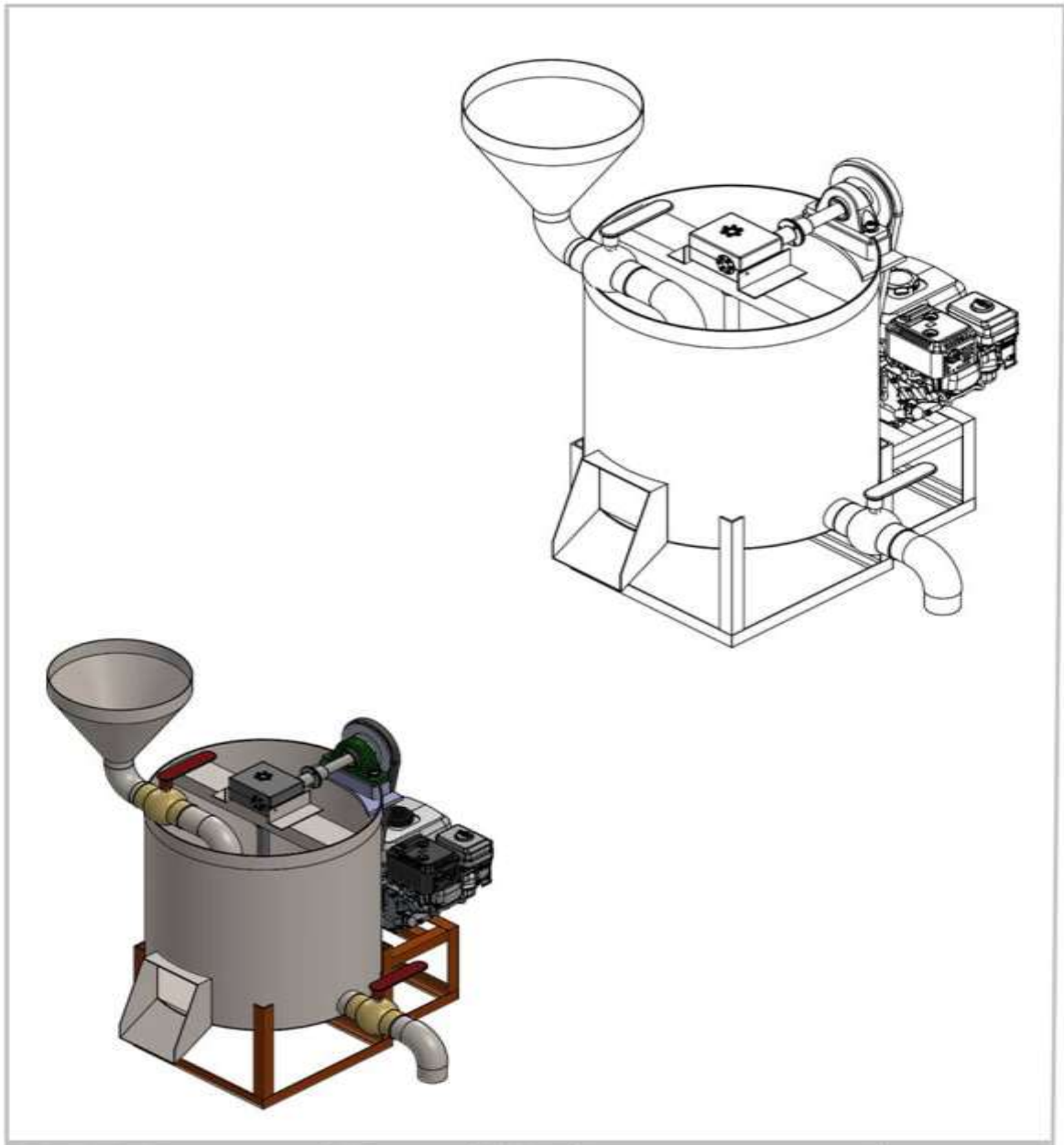
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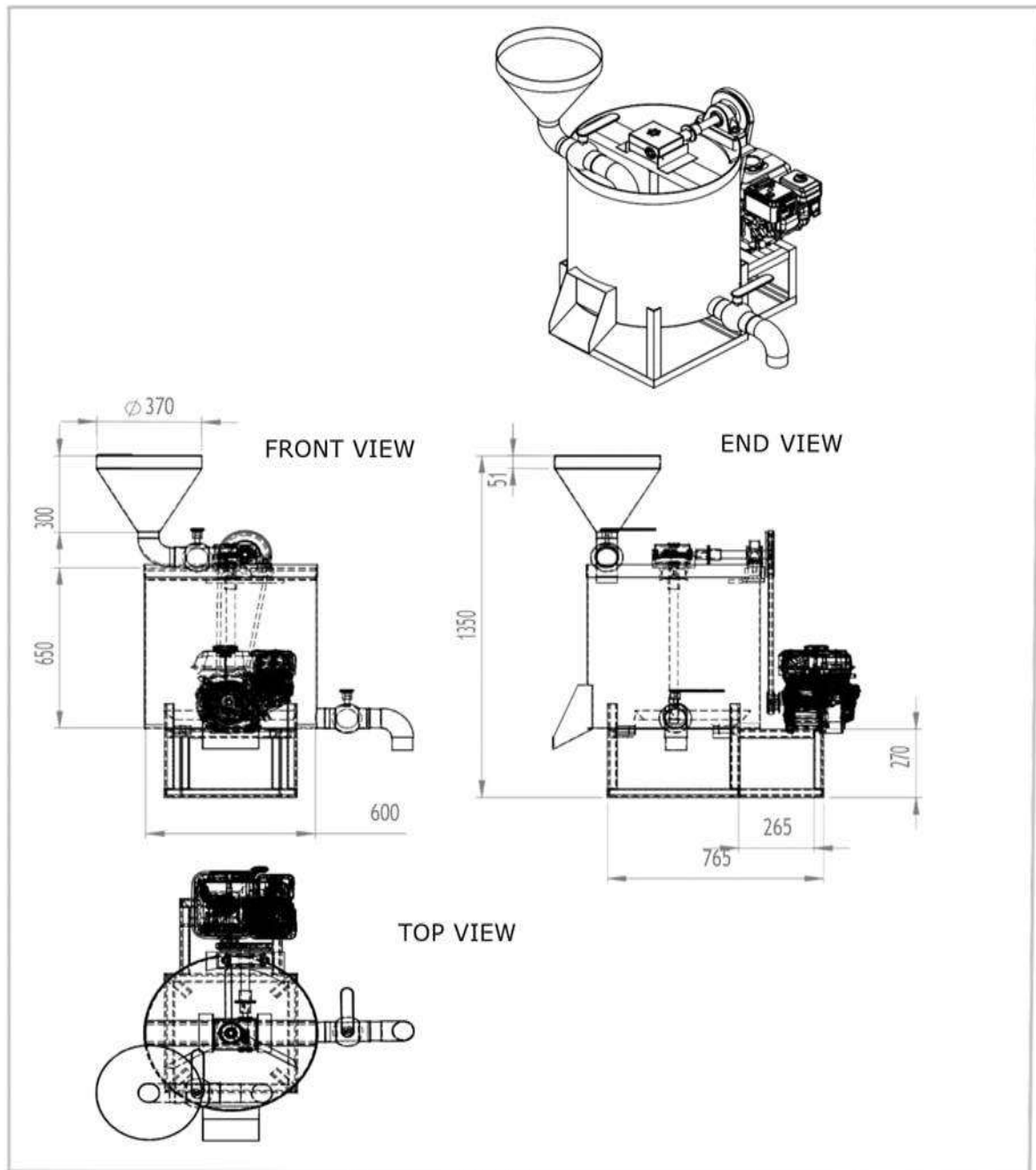
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APPENDIX

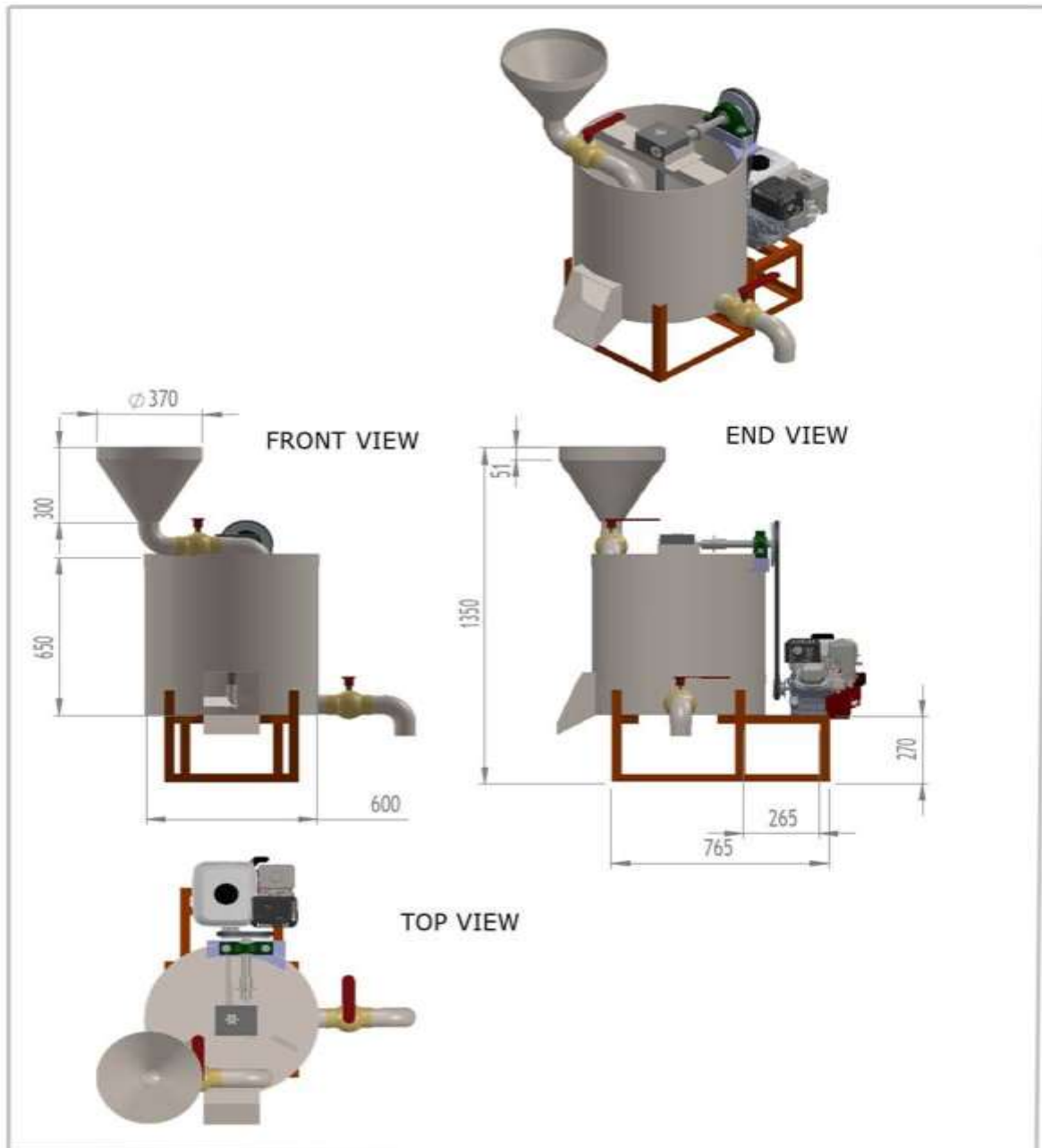




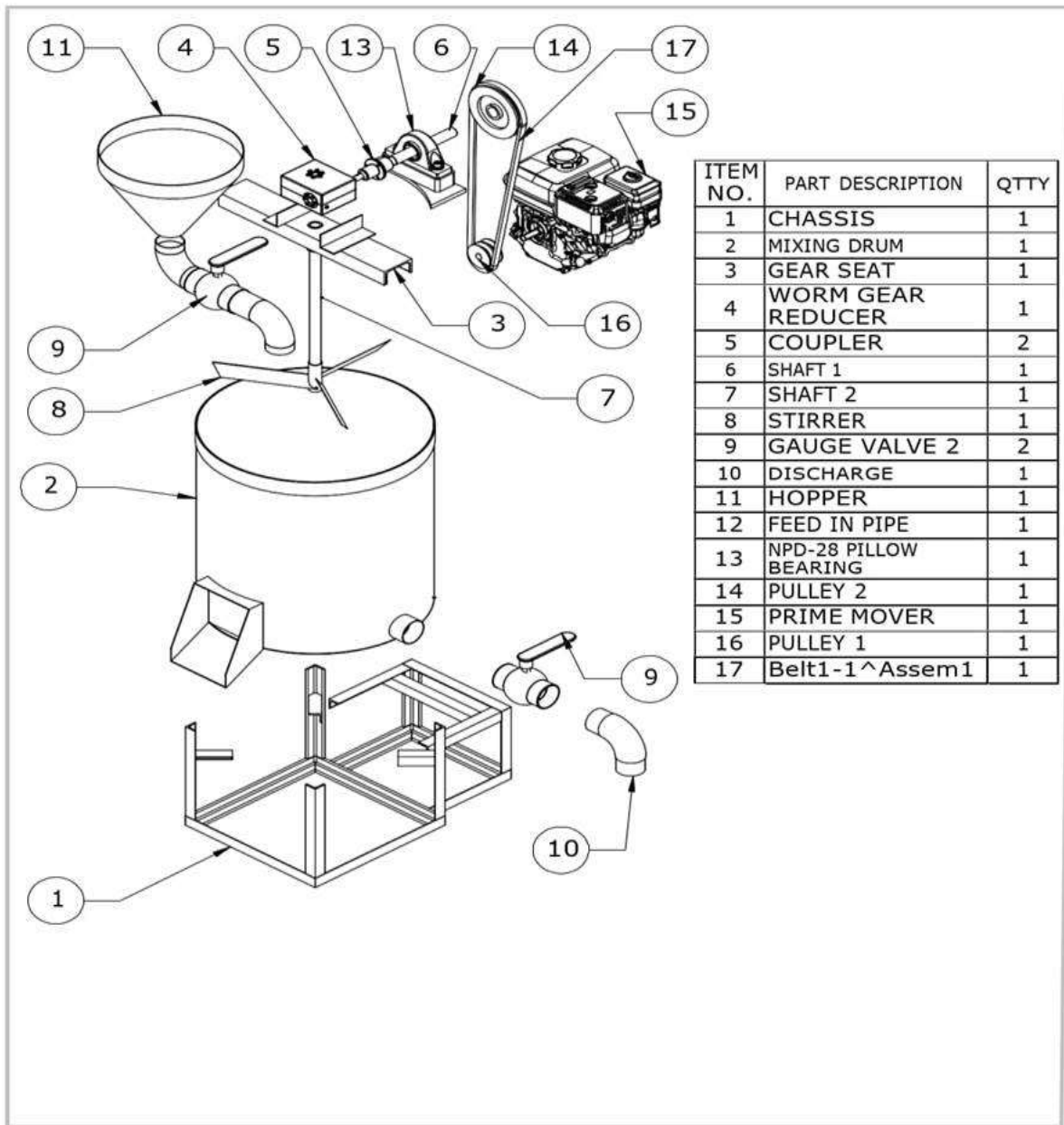
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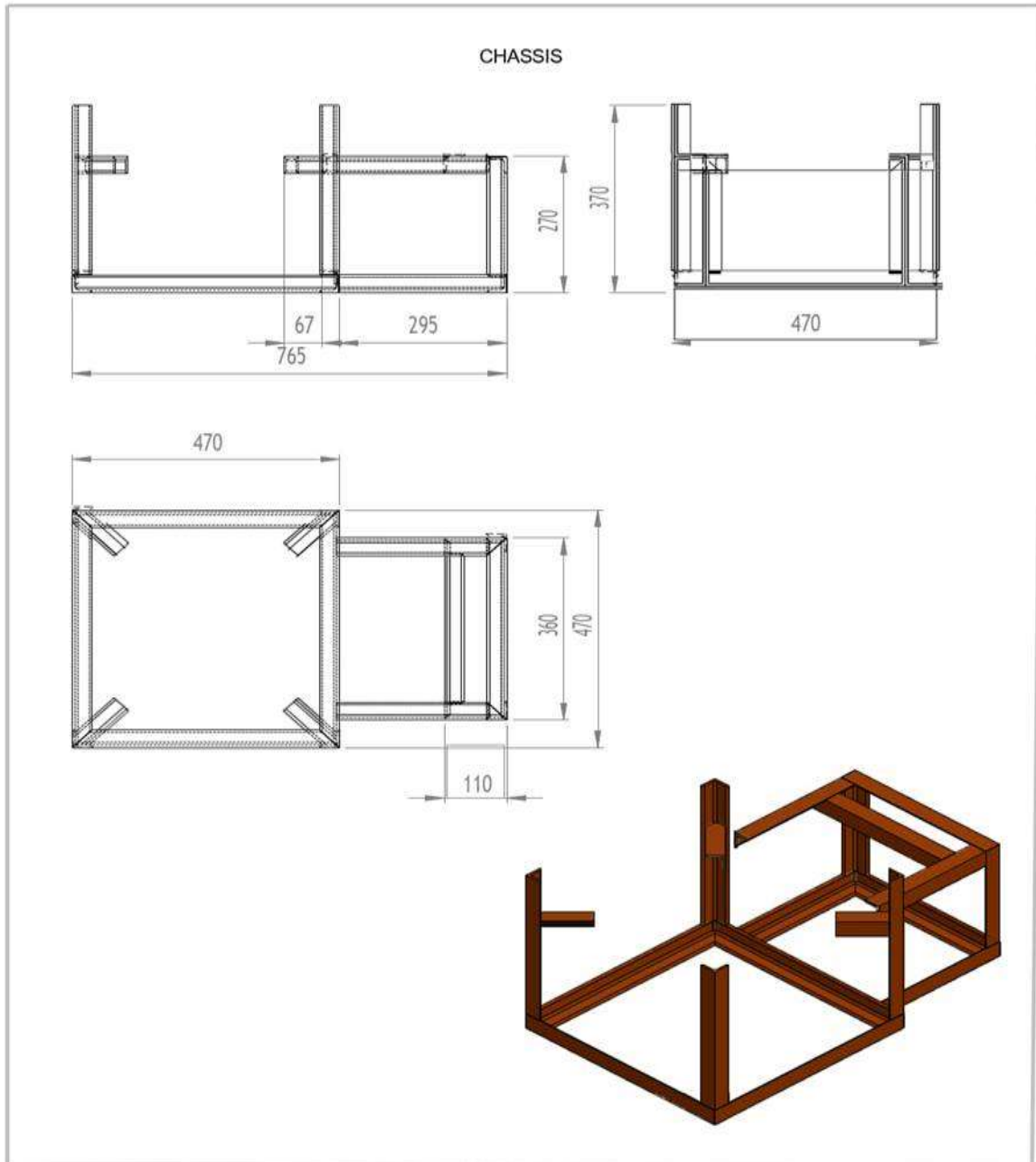


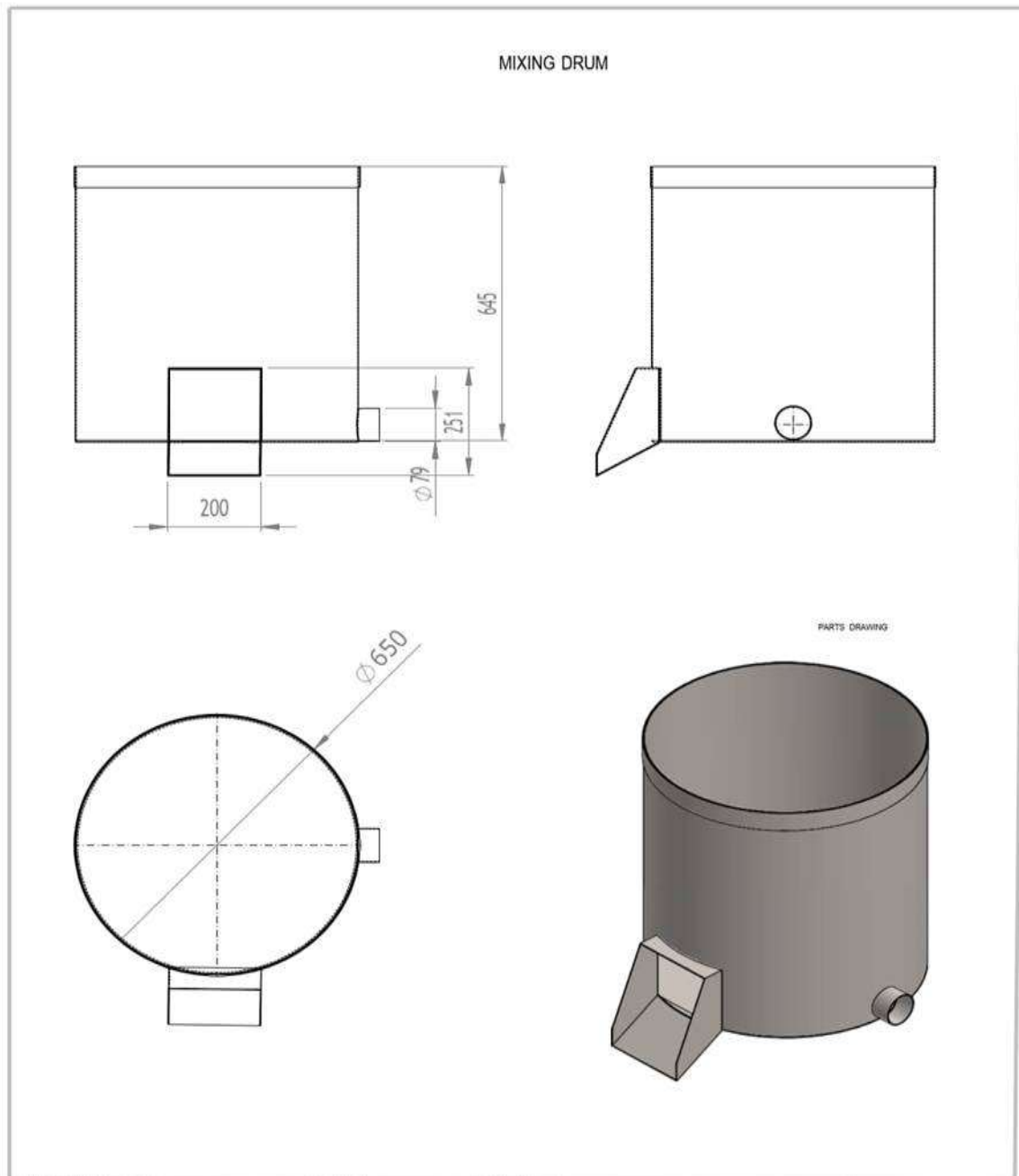
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ITEM NO.	PART DESCRIPTION	QTTY
1	CHASSIS	1
2	MIXING DRUM	1
3	GEAR SEAT	1
4	WORM GEAR REDUCER	1
5	COUPLER	2
6	SHAFT 1	1
7	SHAFT 2	1
8	STIRRER	1
9	GAUGE VALVE 2	2
10	DISCHARGE	1
11	HOPPER	1
12	FEED IN PIPE	1
13	NPD-28 PILLOW BEARING	1
14	PULLEY 2	1
15	PRIME MOVER	1
16	PULLEY 1	1
17	Belt1-1^Assem1	1







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