Development of Cashew Nut Shell Liquid Expeller

A. F. Adisa[1*], E. O. Aina[1], T. M. A. Olayanju[1], S. O. Ismaila[2]
[1]*Agricultural and Bioresources Engineering Department, Federal University of Agriculture, Abeokuta, Nigeria.*
[2]*Mechanical Engineering Department, Federal University of Agriculture, Abeokuta, Nigeria.*
Corresponding author email: alexadisa@yahoo.co.uk

Abstract
The shell of the cashew nut in its natural state is leathery and contains thick vesicant oil called Cashew Nut Shell Liquid (CNSL) which is known for its innumerable applications and its ability to undergo all the conventional reactions of phenols. Maintenance of an oil expeller calls for machinery and equipment which are rarely found in small repair shops and so, local manufacturer of expellers would be unlikely available at rural areas. A machine for expelling CNSL using locally available materials was developed which consists of a frame, compression chamber, perforated cylinder, hopper and funnels. The cashew nut shells were sampled, cleaned, and prepared for tests. The mass of liquid extracted was 4.1 kg with extraction efficiency of 82%, machine capacity was 0.41 kg/min with highest percentage liquid recovery of 20.5% at pressing duration of ten minutes and moisture content 14.00-16.99% wet basis. The pressing duration of 2 minutes and moisture content of 14.00-16.99%, machine capacity was highest.

Keywords: *Development, CNSL, expeller, output capacity, efficiency.*

1.0 INTRODUCTION

Cashew tree is a fast growing and blossoming tree that produces conically shaped nut which is attached to the lower portion of the cashew apple and it hangs at the bottom of the apple. Within the outside shell the cashew seed has the edible kernel or nut which in its raw form is soft, white and meaty. When roasted, its colour and taste changes while when salted it is found the most delicious nut. Cashew nut shell liquid (CNSL), which is extracted from the shells, is caustic and causes burns on the skin, mucous membranes of the mouth and throat severely, when in contact with, or the irritating fumes emitted during roasting. This liquid has many uses such as paints, laminating resins, rubber compounding resins, cashew cements, and polyurethane based polymers, surfactants, epoxy resins, foundry chemicals, all of which makes it an intermediate for chemical industry (Mandal, 2012).
Cashew is known for its adaptability to seasonally wet and dry tropical climates and has the capacity to grow and yield satisfactorily on well-drained, light - textured soils with minimum inputs. This indicates that cashew has a very good adapting capacity to wide ecological variation.

1.1 Cashew nut processing

Processing of cashew nuts can be defined as the recovery of the kernel (edible meat portion) from the raw nuts by manual or mechanical means. It consists of moisture conditioning, shelling, drying, peeling, grading and packing (Mandal, 2012). The nut consists of a coriaceous epicarp, spongy mesocarp containing a viscous resinous liquid and stony endocarp, which is white kernel covered with a thin testa membrane. The processing of the nuts may be done by primitive method or through the factory processing machine.
Traditional way of cashew nut processing is burning of raw nuts for a short time on an open fire or roasting in a pan, just enough to burn the outer shell and drive off the volatile shell liquid (CNSL) that usually ignited. When left cooling, the shells are cracked with a small wooden rod and the kernels are extracted. With this process, scorching of the part of the kernels (particularly the tips) is almost inevitable resulting in poor quality, such kernels are suitable

only for domestic consumption but not fit for export, often contaminated by the vesicant shell liquid. This open pan roasting is still common in Tamil Nadu, West Bengal and Kerala in India but gradually disappearing (Mandal, 2012).

1.2 Modern Methods of deriving Oil

Oil can be derived from an oil seed through mechanical or solvent extraction methods (Oyinlola and Adekoya, 2004). Mechanical expression of oil has to do with the application of pressure (with the use of hydraulic or screw presses) to squeeze oil out of the oil-bearing material. However, in solvent extraction, solvent such as naphthalene is usually applied to displace oil from the material. Mechanical expression is, however, preferred because it is economical when compared with the solvent process. The pre-treatment operations known over time to aid oil yield in mechanical oil expression include heat treatment, moisture conditioning and size reduction (FAO, 2000; Oyinlola and Adekoya, 2004).

Expellers use a metal screw rotating horizontally and it feeds the oil-bearing products into a barrel-shaped outer casing which have perforated walls. The oil-bearing products are continuously fed into the expeller that crushes, grinds and presses the oil out as it passes through the machine. The pressure ruptures the oil cells in the oil-bearing product and oil flows through the perforated walls in the casing and is then collected in a trough underneath the perforated walls (Philip *et al.,*2002). The residue cake from the compressed oil-bearing material from which oil has been expressed, comes out through the cake outlet and this allows for greater oil expression which reduces wear and tear on the machine.

The cashew nut liquid extracted from the nut shell represents approximately 25% of the cashews weight (Mazzetto *et al*., 2009) and 30-35% of the nut shells weight (Kumar *et al*., 2009). Two basic types of CNSL extraction processes are those that involve heating and those that are done in cold or room temperature. The heating process (roasting) can be achieved by open recipients or drums (Morais *et al*., 2010). The cashews can also be heated by the actual CNSL in a process denominated as thermo – mechanic (*hot oil process*) (Mazzetto *et al*., 2009). In the cold, the CNSL can be obtained by extrusion, in solvents or by pressing. The cashew's liquid obtained by the cold is denominated as natural CNSL and when extracted in hot is denominated technical AQ21`CNSL. Maintenance of an oil expeller calls for high skill machinery and equipment which are rarely found in small repair shops nor at the village/ small town level. In Nigeria, after juice is extracted from cashew fruit, the nuts are removed for domestic and industrial usage then cashew nut shell is discarded away as waste or burnt. This study was part of the effort of turning waste to wealth by developing a suitable machine for CNSL extraction which was carried out at Federal University of Agriculture, Abeokuta, Nigeria. This was development of a machine that will express the liquid in the cashew nut shell without injury to skin as observed in manual processing method.

2.0 MATERIALS AND METHODS

2.1 Design Considerations and Assumptions

The considerations and assumptions made for designing the cashew nut shell liquid expeller was that the driving shaft of the compression chamber and material must be able to withstand the combined torsion and bending moment based on maximum shear theory. Also the maximum load on the hopper must not exceed 20 N considering the expeller's hopper volume capacity to be handled per batch of loading for this prototype machine.

2.1.1 Hopper design (No load)

The hopper is in the shape of a pyramid and it was calculated using eqn. (1), (Khurmi,2009)

$$V_{hopper} = \frac{1}{3}(A_o h_o - A_i h_i) \quad (1)$$

Where,

V_{hopper} = Volume of hopper, m^3

A_o, A_i = Area of base, 0.303 ; 0.15 m^2 respectively.

h_o, h_i = Height of outer, inner hopper, 0.38; 0.1 m respectively

hence $V_{hopper} = 1.66 \text{ X } 10^{-4} m^3$

The hopper weight (W_h) was calculated using eqn. (2), (Khurmi,2009)

$$W_h = \rho \text{ x } V_{hopper} \text{ x } g \quad (2)$$

hence W_h = 13.03N

Where,

ρ = Density of the hopper material (Galvanize steel), 7850 kg/m^3

The cashew nut shell weight (W_c) was calculated by eqn. (3), (Khurmi,2009)

$$W_c = \rho_c \text{ x } V_{hopper} \text{ x } g \quad (3)$$

hence W_c = 0.8N

Where,

Wc = Weight of the cashew nut shell, N

ρ_c = density of cashew nut, 481.83 kg/m^3

g = Acceleration due to gravity, 10 m/s^2

2.2 Hopper Design (Under load)

Weight on the hopper under load (W_L) was calculated as:

$$W_L = W_h + W_c \quad (4)$$

hence W_L = 14N

2.3 Design of Compression Chamber

Was calculated as stated in section 2.1 using eqn. (5) (Khurmi,2009)

$$V_{cylinder} = [\pi(r_o^{2-} r_i^2)h - (lxbxt)opening] \quad (5)$$

hence $V_{cylinder} = 9.22 \text{ X } 10^{-4} m^3$

Where,

$V_{cylinder}$ = Volume of cylinder, m^3

r_o, r_i =Rradii of outer and inner cylinder, 0.105 and 0.1025 m respectively

h = Height of cylinder, m

l = Length of cylinder, 0.15 m

b = Breadth of cylinder, 0.15 m

t = Thickness of cylinder, 0.0025 m

W = weight of the cylinder, N

The cylinder weight (W) was determined using eqn. (6), Khurmi (2009)

$$W = \rho \text{ x } V_{cylinder} \text{ x } g \quad (6)$$

Hence, W = 72.38 N

Where,

ρ = density of the cylinder material, (Galvanized steel), 7850 kg/m^3

g = acceleration due to gravity, m/s^2

2.4 Design of Hopper Shaft

Expellers use a metal screw rotating horizontally and it feeds the oil-bearing products into a barrel - shaped outer casing which have perforated walls. The oil-bearing products are continuously fed into the expeller that crushes, grinds and presses the oil out as it passes through the machine. The pressure ruptures the oil cells in the oil-bearing product and oil flows through the perforated walls in the casing and is then collected in a trough underneath the perforated walls (Philip *et al.,* 2002). This was to design shafts on which the screw auger with knife for nut shell size reduction and pressing to achieve oil expelling was mounted.

Force and bending moment calculations were carried out as follows:

W_f = 10 N (half of the hopper capacity/weight on each of bearing)

L = 0.1 m = 100 mm

X = 0.19 m

Maximum bending moment acts at C and D (bearings at each end of the shaft)

M= W_f X L

= 10 X 0.1 = 1 Nm.

2.5 Torque Requirement Design

Torque (T) was calculated using eqn. (7) Khurmi (2009)

$$T = W_L \times \text{shaft gear radius (selected)} \quad (7)$$

hence T = 5.6 Nm

2.6 Design for Power Requirement

Power was calculated using eqn. (8), (Khurmi, 2009)

$$\text{Power} = \frac{2\pi NT}{60} \quad (8)$$

Where:

N = speed, rpm

T = Torque, Nm

N = 100 rpm

Power = 58.68 W

2.7 Shaft Diameter Design

Shaft diameter was determined using: 9, (Krutz *et al.,*1984)

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_m M)^2 + (K_T T)^2} \quad (9)$$

Where,

M = Maximum bending moment, 1Nm

T = Maximum torque, Nm

S_s = Allowable shear stress = 41.379 x 10^6 N/m^2

K_m and K_T = Shock loading factors, 2.0 and 1.5 respectively

d = Shaft diameter, m

W = Weight acting on the wheel, N

L = Distance outside the wheel base, m

Hence, $d = 0.022m$ $= 0.02m$

2.8 Taper Screw Auger Design

Taper screw auger was obtained using eqn. (10), (Lower *et al.,* 1994)

$$CFTHR = \frac{(D^2 - d^2) P_a \ x N}{215 \ X \ 10^{-4}} \quad (10)$$

hence CFTHR = 36.8m^3/h

Where,

CFTHR = Material being moved by a full auger, m^3/h

D = Diameter of the screw, 0.2 m

d = Diameter of the shaft, 0.02 m
P_a = Pitch of the auger, usually the same as D, m
N = Speed of the shaft, 100 rpm.

2.9 Design of Compression Chamber Thickness

Compression chamber thickness was obtained using eqns. (11) and (12), Khurmi (1999)

$$t = \frac{P X c}{2\sigma t1lX\eta} \quad (11)$$

$$P = \frac{F}{Ab} \quad (12)$$

Where,
t = Thickness of the cylindrical shell, 1.5 mm but 2.5 mm chosen
$P = \frac{Force}{Area}$ = Intensity of internal pressure, 0.25 N/mm^2 = 0.25 MPa
c = Internal diameter of the cylindrical shell, mm
$\sigma t1$ = Circumferential or hoop stress of the material of the cylindrical shell, MPa = 16 MPa.
Where,
l = Length of the cylindrical shell, mm
η = Efficiency of the joint (%) = 0.85
F = Force on compression chamber, 20 N
Ab = Area of compression chamber, 78.6 mm^2

2.10 Design of Knife Thickness

Knife thickness was obtained using eqn. (13), Akinoso (2006).

$$T_k = \frac{P X dc}{2\sigma t} \quad (13)$$

hence T_k = 1.2 mm, but 2 mm was chosen
Where,
T_k = Knife thickness, mm;
P = Intensity of internal pressure, MPa
d_c = Diameter of cashew nut shell, mm = 5.89mm (Brunauer *et al*., 1999)
σt = Circumferential or hoop stress of the material to be cut, MPa = 665MPa
A_c = Area of cashew nut shell, mm^2 = 0.395mm^2 (Brunauer *et al*., 1999)
F_c = Force required to cut cashew nut shell, N = 107N (Brunauer *et al*., 1999)
P = 270 MPa.

2.11 Fabrication of Cashew Nut Shell Liquid Expeller

Figure 1 shows the isometric view, Figure 2 shows the orthographic view of the cashew nut shell liquid expeller. Figure 3 is the picture of the constructed machine. Expellers use a metal screw rotating horizontally and it feeds the oil-bearing products into a barrel - shaped outer casing which have perforated walls. The oil-bearing products are continuously fed into the expeller that crushes, grinds and presses the oil out as it passes through the machine. The pressure ruptures the oil cells in the oil-bearing product and oil flows through the perforated walls in the casing and is then collected in a trough underneath the perforated walls (Philip *et al.,* 2002). The residue (cake) from the compressed oil-bearing material from which oil has been expressed, exits the unit through the cake outlet and this allows for greater oil expression and reduces wear and tear on the machine.

2.12 Performance Evaluation of the Machine

The performance of the machine was evaluated for liquid extraction using cashew nut shell obtained from the University cashew processing factory, Abeokuta. The cashew nut shells were cleaned, sampled and prepared for tests. The shells were grouped, handled separately but were given the same pre-treatment of moisture conditioning to obtain various moisture groupings as 14-16.99% w.b. (group A), 17-19.99% w.b. (group B) and 20-22.99% w.b. (group C) for time interval of 2, 4, 6, 8 and 10 minutes. Electric oven dryer (General-Model 5222 NE, 230 V) was used to dry and weighing was carried out with Amput electric scale (sensitivity 0.01 g). The shaft speed was measured with Tachometer (Lutron DT-2234B). The evaluation of the expeller was carried out in order to determine the extent to which moisture content and pressing duration affected the performance indices. Conditioning of samples was

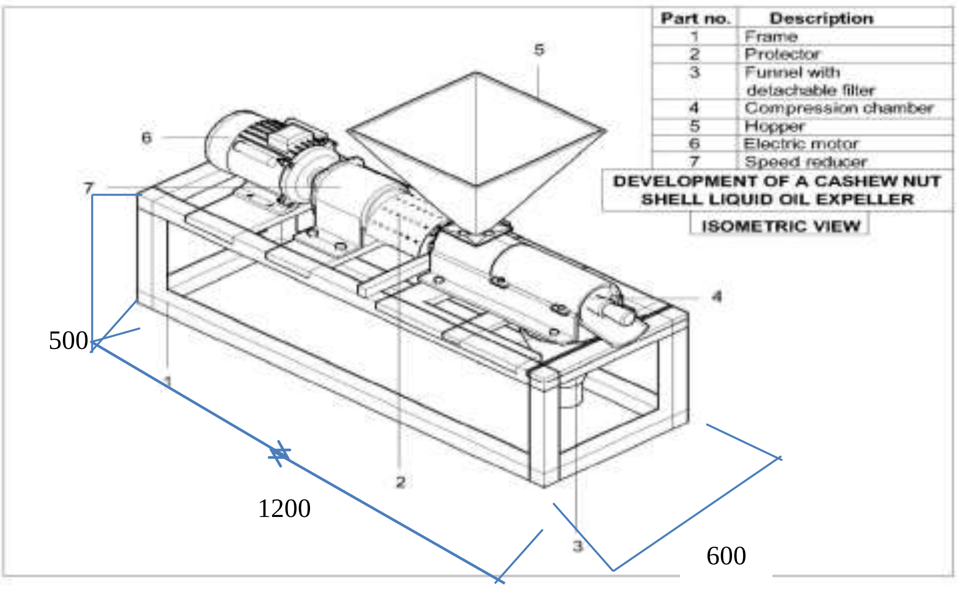

Fig. 1: Isometric View of the Cashew Nut Shell Liquid Expeller

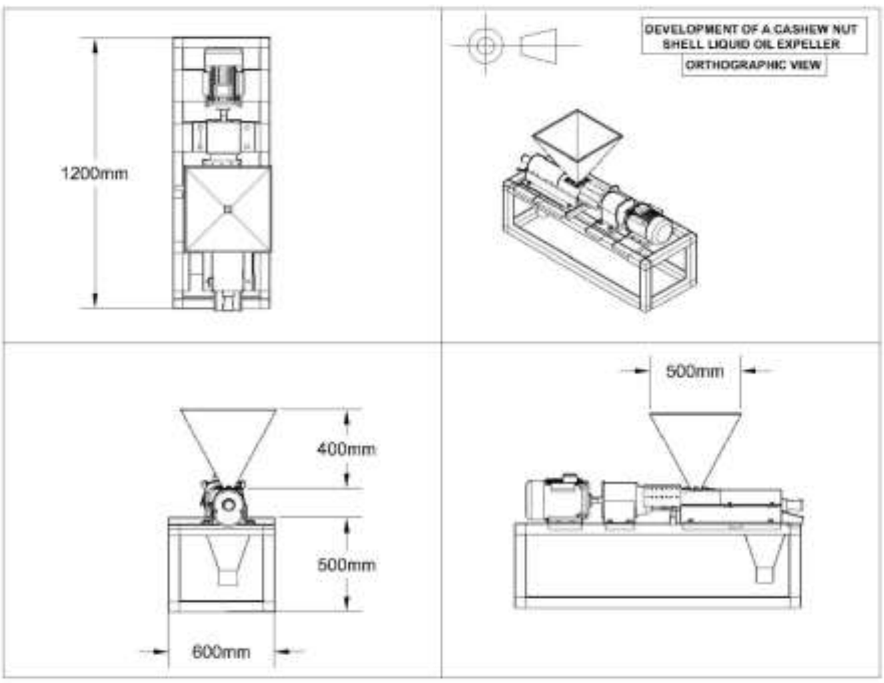

Figure 2: Orthographic View of the Cashew Nut Shell Liquid Expeller

Figure 3: Fabricated Cashew Nut Shell Liquid Expeller

done by drying the measured sample with electric oven as earlier stated at 103°C for 5 hours (ASAE, 1998) until there was a constant weight and a measured quantity of water was added to the samples to give it the required moisture content using equation 13, Akinoso (2006). Each sample was sealed in a separate polythene film after the addition of water. The samples were kept at 5°C in a refrigerator for a day to enable the moisture distribute uniformly throughout the samples.

$$Q = \frac{As\ (bs - as)}{(100 - bs)} \qquad (14)$$

Where,
As = Initial mass of the sample, kg
as = Initial moisture content of the sample, % (w.b.)
bs = Final (desired) moisture content of the sample, % (w.b.)
Q = Mass of water to be added, kg

For each treatment combination, fifteen samples each of 1, 2, 3, 4 and 5 kg of cashew nut shell were used to carry out the tests and this was done in two replicates. Stop watch was used to take the pressing time duration and at the end of the expression, the quantity of liquid obtained was weighed.

2.2 Performance Evaluation Computation

The performance evaluation of the cashew nut shell liquid expeller was carried out on the basis of the following indices:

2.2.1 Mass of liquid extracted determination

Mass of liquid extracted (ML) at moisture content A, B, C, MLa,b,c (kg) was calculated by eqn. (15), (Ojomo *et al.,* 2012)

$$ML = M_{CL} - M_C \qquad (15)$$

Where,
ML = Mass of liquid extracted, kg

M_{CL} = Mass of container and liquid, kg
M_C = Mass of container, kg

2.2.2 Feed rate determination

Feed rate (FR) at moisture content A, B, C, FRa,b,c, (kg/min) was calculated by eqn. (16), (Ojomo *et al.,* 2012)

$$FR = \frac{Mcns}{Tt} \quad (16)$$

Where,
FR = Feed rate, kg/min
M_{cns} = Mass of cashew nut shell, kg
T_t = Time taken, min

2.2.3 Machine capacity determination

Machine capacity (MC) at moisture content A, B, C, MCa,b,c, (kg/min) was calculated by eqn. (17), (Ojomo *et al.,* 2012)

$$MC = \frac{Mle}{Tt} \quad (17)$$

Where,
MC = Machine capacity, kg/min
M_{le} = Mass of liquid expelled, kg

2.2.4 Extraction efficiency determination

Extraction efficiency (EE) at moisture content A, B, C, EEa,b,c (%) was calculated by eqn. (18), (Ojomo *et al.,* 2012)

$$EE = \frac{Mle \ x \ 100}{Mcns} \quad (18)$$

Where,
EE = Extraction efficiency, %

2.2.5 Percentage liquid recovery determination

Percentage liquid recovery (PR) at moisture content levels A, B, C, PRa,b,c (%) was calculated by eqn. (19), (Ojomo *et al.,* 2012)

$$PR = \frac{EE \ x \ 25 \ \%}{100} \quad (19)$$

Where,
PR = Percentage liquid recovery, %
A = 14 – 16.99% (w.b.)
B = 17 – 19.99% (w.b.)
C = 20 – 22.99% (w.b.)

3.0 RESULTS AND DISCUSSION

Table 1 shows that the mass of liquid extracted increased with increase in pressing duration and decrease in moisture content. For 1kg sample of cashew nut shell, 0.6kg of liquid was extracted at 10 minutes pressing duration and at 14.00 – 16.99% (w.b.) while at the same pressing duration but moisture content 17.00 – 19.99% (w.b.) and 20.00 – 22.99% (w.b.), 0.5 and 0.4 kg respectively were the mass of liquid extracted. Also, the mass of liquid extracted for 1kg sample at 2 minutes pressing durations and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.) and 20.00 – 22.99% (w.b.) moisture contents were 0.2, 0.1 and 0.1 kg respectively.

Machine capacity decreased with increase in moisture content and pressing duration as shown in Table 1. The machine capacities obtained for 1kg sample of cashew at 10 minutes pressing duration and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents were 0.06, 0.05 and 0.04 kg/min respectively while for 1kg sample at 2 minutes pressing duration and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents, the machine capacities were 0.10, 0.05 and 0.05 kg/min respectively. For 2kg sample of cashew nut shell, the machine capacities obtained at 10 minutes pressing duration and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents were 0.14, 0.10 and 0.07 kg/min respectively while for 2kg sample at 2 minutes and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents, the machine capacities were 0.20, 0.15 and 0.10 kg/min respectively.

Table 1 shows that extraction efficiency greatly increased with an increase in pressing duration and decrease in moisture content. The extraction efficiencies obtained for 1kg sample of cashew nut shell at 10 minutes pressing duration and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents were 60%, 50% and 40% respectively while for 1kg sample, the extraction efficiencies obtained at 2 minutes pressing duration and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents were 30%, 20% and 10% respectively.

Percentage liquid recovery also increased with an increase in pressing duration and decrease in moisture content as shown in Table 1. For 1kg sample of cashew nut shell at 14.00-16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents and 10 minutes pressing duration, the percentage oil recovery were 15%, 12.5% and 10% respectively while at 2 minutes pressing duration and 14.00 – 16.99% (w.b.), 17.00 – 19.99% (w.b.), 20.00 – 22.99% (w.b.) moisture contents, the percentage oil recovery were 7.7%, 5% and 2.5% respectively.

Table 2 is the CNSL expeller critical operating parameters obtained from the test result. It is very useful to guide the operator in setting this prototype machine for operation and what the machine can produce under stated parameters. The expected oil content in kg of cashew nut shell is 25% of total nut shell weight (Mazzetto *et al*., 2009).

Table 2: Critical operating parameters of the cashew nut shell liquid expeller

Performance parameters	Mean values
Mass of liquid extracted (kg)	4.1
Machine capacity (kg/min)	0.5
Extraction efficiency (%)	82
Percentage oil recovery (%)	20.5
Pressing duration time (min)	10
Moisture content (w.b.)	14.00 - 16.99
Sample mass (kg)	5

Table 1: Variation of Machine Performance Indices with Moisture Content and Duration

Mass (Kg)	Time (Min)	Mass of liquid extracted (Kg)			Feed rate (Kg/Min)			Machine capacity (Kg/Min)			Extraction efficiency (%)			Percentage of oil recovery (%)		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
1	2	0.2	0.1	0.1	0.50	0.50	0.50	0.10	0.05	0.05	20	10	10	5.00	2.50	2.50
	4	0.3	0.2	0.1	0.25	0.25	0.25	0.08	0.05	0.03	30	20	10	7.50	5.00	2.50
	6	0.5	0.4	0.3	0.17	0.17	0.17	0.08	0.07	0.05	50	40	30	12.50	10.00	7.50
	8	0.6	0.5	0.4	0.13	0.13	0.13	0.08	0.06	0.05	60	50	40	15.00	12.50	10.00
	10	0.6	0.5	0.4	0.10	0.10	0.10	0.06	0.05	0.04	60	50	40	15.00	12.50	10.00
	2	0.3	0.2	0.1	0.50	0.50	0.50	0.15	0.10	0.05	30	20	10	7.50	5.00	2.50
	4	0.3	0.3	0.2	0.25	0.25	0.25	0.08	0.08	0.05	30	30	20	7.50	7.50	5.00
1	6	0.4	0.3	0.2	0.17	0.17	0.17	0.07	0.05	0.03	40	30	20	10.00	7.50	5.00
	8	0.4	0.4	0.3	0.13	0.13	0.13	0.05	0.05	0.04	40	40	30	10.00	10.00	7.50
	10	0.5	0.4	0.3	0.10	0.10	0.10	0.05	0.04	0.03	50	40	30	12.50	10.00	7.50
	2	0.3	0.2	0.3	1.00	1.00	1.00	0.15	0.10	0.15	15	10	15	3.75	2.50	3.75
2	4	0.6	0.4	0.4	0.5	0.5	0.5	0.15	0.10	0.10	30	20	20	7.50	5.00	5.00
	6	0.9	0.6	0.5	0.33	0.33	0.33	0.15	0.10	0.08	45	30	25	11.25	7.50	6.25
	8	1.1	0.8	0.7	0.25	0.25	0.25	0.14	0.10	0.09	55	40	35	13.75	10.00	8.75
	10	1.3	1.1	0.9	0.20	0.20	0.20	0.13	0.11	0.09	65	55	45	16.25	13.75	11.25
	2	0.4	0.3	0.5	1.00	1.00	1.00	0.20	0.15	0.25	20	15	25	5.00	3.75	6.25
	4	0.5	0.6	0.8	0.50	0.50	0.50	0.13	0.15	0.20	25	30	40	6.25	7.50	10.00
2	6	0.8	0.4	0.6	0.33	0.33	0.33	0.13	0.07	0.10	40	20	30	10.00	5.00	7.50
	8	1.2	0.7	0.5	0.25	0.25	0.25	0.15	0.09	0.06	60	35	25	15.00	8.75	6.25
	10	1.4	1.0	0.7	0.20	0.20	0.20	0.14	0.10	0.07	70	50	35	17.50	12.50	8.75
	2	1.3	1.2	1.1	1.50	1.50	1.50	0.65	0.60	0.55	43	40	37	10.75	10.00	9.25
	4	1.6	1.4	1.2	0.75	0.75	0.75	0.40	0.35	0.30	53	47	40	13.25	11.75	10.00
3	6	1.9	1.6	1.5	0.50	0.50	0.50	0.32	0.27	0.25	63	53	50	15.75	13.25	12.50
	8	2.1	1.8	1.7	0.40	0.40	0.40	0.26	0.23	0.21	70	60	57	17.50	15.00	14.25
	10	2.3	2.1	1.9	0.30	0.30	0.30	0.23	0.21	0.19	77	70	63	19.25	17.50	15.75
	2	1.4	1.2	1.1	1.50	1.50	1.50	0.70	0.60	0.55	47	40	37	11.75	10.00	9.25
3	4	1.5	1.3	1.2	0.75	0.75	0.75	0.38	0.33	0.30	50	43	40	12.50	10.75	10.00
	6	1.8	1.4	1.2	0.50	0.50	0.50	0.30	0.23	0.20	60	47	40	15.00	11.75	10.00
	8	2.2	1.7	1.5	0.40	0.40	0.40	0.28	0.21	0.19	73	57	50	18.25	14.25	12.50
	10	2.4	2.0	1.7	0.30	0.30	0.30	0.24	0.20	0.17	80	67	57	20.00	16.75	14.25
	2	1.9	1.7	1.5	2.00	2.00	2.00	0.95	0.85	0.75	48	43	38	12.00	10.75	9.50
	4	2.2	1.9	1.7	1.00	1.00	1.00	0.55	0.48	0.43	55	48	43	13.75	12.00	10.75
4	6	2.6	2.1	1.9	0.67	0.67	0.67	0.43	0.35	0.32	65	53	48	16.25	13.25	12.00
	8	2.9	2.2	2.1	0.50	0.50	0.50	0.36	0.28	0.26	73	55	53	18.25	13.75	13.25
	10	3.1	2.4	2.2	0.40	0.40	0.40	0.31	0.24	0.22	78	60	55	19.50	15.00	13.75
	2	2.0	1.8	1.7	2.00	2.00	2.00	1.00	0.90	0.85	50	45	43	12.50	11.25	10.75
4	4	2.3	2.0	1.8	1.00	1.00	1.00	0.58	0.50	0.45	53	50	45	13.25	12.50	11.25
	6	2.5	2.2	1.9	0.67	0.67	0.67	0.42	0.37	0.32	63	55	48	15.75	13.75	12.00
	8	2.7	2.4	2.1	0.50	0.50	0.50	0.34	0.30	0.26	68	60	53	17.00	15.00	13.25
	10	3.0	2.5	2.2	0.40	0.40	0.40	0.30	0.25	0.22	75	63	55	18.75	15.75	13.75
	2	2.5	2.1	1.8	2.50	2.50	2.50	1.25	1.05	0.90	50	42	36	12.50	10.50	9.00
5	4	2.9	2.4	2.1	1.25	1.25	1.25	0.73	0.60	0.53	58	48	42	14.50	12.00	10.50
	6	3.5	2.9	2.4	0.83	0.83	0.83	0.58	0.48	0.40	70	58	48	17.50	14.50	12.00
	8	3.9	3.4	2.8	0.63	0.63	0.63	0.49	0.43	0.35	78	68	56	19.50	17.00	14.00
	10	4.2	3.9	3.1	0.50	0.50	0.50	0.42	0.39	0.31	84	78	62	21.00	19.50	15.50
	2	2.4	2.1	1.9	2.5	2.5	2.5	1.20	1.05	0.95	48	42	38	12.00	10.50	9.50
	4	2.7	2.3	2.1	1.25	1.25	1.25	0.68	0.58	0.53	54	46	42	13.50	11.50	10.50
5	6	3.6	2.9	2.3	0.83	0.83	0.83	0.60	0.48	0.38	72	58	46	18.00	14.50	11.50
	8	3.8	3.1	2.8	0.63	0.63	0.63	0.48	0.39	0.35	76	62	56	19.00	15.50	14.00
	10	4.1	3.6	3.1	0.50	0.50	0.50	0.41	0.36	0.31	82	72	62	20.50	18.00	15.50

Note: Moisture conditioning was 14 – 16.99% w.b. (group A), 17 – 19.99% w.b. (group B) and 20 – 22.99% w.b. (group C)

4.0 CONCLUSION

A cashew nut shell liquid expeller was designed, fabricated and evaluated for its performance. It was found to be efficient in extracting cashew nut shell liquid. Generally, moisture content of the cashew nut shell and pressing duration influenced the machine performance indices. The mass of liquid extracted, extraction efficiency and percentage oil recovered increased with increase in pressing duration and decreased with increase in moisture content. Meanwhile, machine capacity decreased with increase in moisture content and pressing duration. Pressing duration of 10 minutes at moisture content of 14.00-16.99% (w.b.) gave the best mass of liquid extracted, best extraction efficiency and best percentage oil recovery. However, pressing duration of 2 minutes at moisture content of 14.00-16.99% (w.b.) gave the best machine capacity. The machine was relatively cheap, easy to operate and maintain because the parts can be sourced locally, not sophisticated. The total cost of machine produced was N75,000.00 (US$ 250.00).

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