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Development and Performance Evaluation of a Small-Scale Roselle (*Sobo*) Drink Processing Plant

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Abstract: *Food and drink are among the most basic human needs. In North-Western Nigeria alone, 23 fruit juices or soft drinks are being locally processed. Roselle (Sobo) drink is one of the most popularly accepted and consumed soft drinks in Nigeria. However, its production remains crude and local. Few researchers have attempted to mechanize its production process; however, their works had not yielded an acceptable mechanized system of processing the drink. Therefore, the present research work tries to address this problem by developing an improved small - scale Roselle Drink production system that can serve as a datum for producing safe Sobo drink, acceptable to the Nigerian society. The plant was designed, fabricated and tested. In so doing, suitably applicable and locally available engineering materials were selected. The plant has 1.6m length, 0.525m breadth, 1.5m height and a net weight of 118kg. Its capacity per batch is 20 litres; beverage discharge capacity 6L/min, total energy consumption 61kW, delivery efficiency of 99%, thermal efficiency of 96% and beverage processing capacity of 60 L/hr. the performance of the plant, Sobo drink was done with the three varieties of Roselle – dark-red (coded "A"), pale-red ("B") and the white ("C") under the temperatures of 60^{0}C (coded "1"), 50^{0}C ("2") and the prevailing room temperatures ("3"). Palatability tastes on the products, as regards taste, visual appeal (colour) and aroma were carried out. Results obtained indicated that product A2 (dark-red Sobo produced at 50^{0}C) has the highest cumulative acceptability of 80%, while product C3 (white Sobo produced at room temperature) has the lowest at 39%. However, the ANOVA test analysis showed that the difference between A2 and B3 (pale-red Sobo produced at room temperature) is not significant, in contrast to between A2, B3 and C3. The research has succeeded in developing a system, at small-scale level, for producing a safe and acceptable Sobo drink free from health hazards; hence, solving that lingering problem; just as it has succeeded in laying down foundations for establishing Sobo drink production industry in Nigeria, which, as an agrarian economy, can be gainfully explored.*

Keywords: *Development, Roselle (Sobo), Improvement, Drink, Consumption*

INTRODUCTION

Roselle (*Sobo* or *Zobo*) drink is one of the most widely consumed non- alcoholic drinks in many parts of Nigeria today. It is presently prepared locally, chilled and served either for family consumption, or commercial purposes. *Sobo* drink is excitingly served as a refreshment on ceremonial occasions. It is also served preciously in some hotels and restaurants, just as it competes favourably with other soft drinks in kiosks and students' cafeterias (Gotomo, 2009, Mera 2004; Maigari, 1979). In short, by observation, the cheap *Sobo* suffices an average Nigerian when compared to the expensive carbonated drinks (Rufa'i, 1998). According to Ezeala *et al.*, (2012) and Nwachukwu *et al.*, (2007), *Sobo* drink has also gained wide acceptance in Nigeria because of its medicinal values, which are lacking in the expensive carbonated drinks. *Zobo* Hibiscus tea is especially popular in the North and West of Nigeria (Tersoo, 2018). In fact, many houses now package the drink in sachets for sale in villages, towns and cities in West Africa (Alegbejo *et al.*, 2003; NAFDAC, 2007).

Not only in Nigeria, *Sobo* (Roselle) drink is widely consumed in the whole Arab world (as normal or tea drink), India and Malaysia. In Malaysia, Roselle concentrates even sells higher than other juices (Omolayole, 2002, Gotomo, 2009; Salunkhe, 2018). However, with all its obvious popularity and acceptance among various classes of people in this country and beyond, *Sobo* drink's processing methodology in this country mostly remains crude and traditional – mainly by housewives in their matrimonial homes (as shown in plate-I). Hence, the need arises to convert the crude process into a scientifically upgraded one, through developing a mechanical system of processing the popular drink –thereby developing an indigenous technology and an indigenous product.

Plate-1. Common method of *Sobo* drink processing in Nigeria.

MATERIALS AND METHODS

In this study It was put forward by Upahi (2000) that the focus of any engineering design is to ensure functionality, durability and affordability. Similarly, it was quoted by Gotomo (2009), and Ubami *et al.*, (2011) that any product or service competes in its market according to (its) performance, appearance, price, delivery, reliability, durability, safety and maintainability. All these factors depend fundamentally upon the design of the product or service. Therefore, the present research work gave these factors due consideration.

2.1 Design Considerations

Hygiene has been given utmost importance, being that the plant is for a consumable product. Hence, the Hazard Analysis and Critical Control Point (HACCP) concept, as well as the Food and Agriculture Organization's (FAO's) "Good Manufacturing Practices" (GMPs) (FAO, 2019; Omolayole, 2002; Shehu, 2006) were stood by. In other words, all necessary hygienic rules were regarded. Other design considerations are customer or market needs and satisfaction, safety of operation, simplicity of operation, maintainability, efficiency, durability, anatomy of the *Sobo* calyces, aesthetics, affordability and portability.

2.2 Design Calculations

Calculating the Average Pumping Power Needed for the System

According to Hannah and Hillier (1980), the work done in lifting a mass M of liquid through a height h is Mgh. If the time taken to do this is t, then average rate of doing work, or average power

$$P = \frac{Mgh}{t} \quad (1)$$

Where P = power, M = mass of liquid, g= acceleration due to gravity, h= height and t =time.

If the rate at which liquid is being pumped through a vertical height h (m) is M (kg/s), then, the vertical power (or minimum power required) is;

$$P = \frac{Mgh}{1000} kW \quad (2)$$

Based on the relations in equations (1) and (2), the power needed was calculated as follows:

Data:	Maximum water capacity	=	20 litres
	Discharge capacity	=	35 lpm

$Discharge\ for\ 1\ litre = \frac{60}{35}$ (Since 60s = 1 min)

$= 1.7\ litres\ per\ second \cong 2\ litres\ per\ second$

Average pumping power =?

Losses could be neglected (Hannah and Hillier, 1980, Rajput, 2008).

1 litre has a mass of 1kg (Gotomo, 2009, Hannah and Hillier, 1980)

$\therefore\ In\ this\ respect, mass\ of\ water\ M\ raised = \frac{20\ litres}{2\ seconds} = 10\ litres/s$, or 10kg/s

From eq. (2),

$$Average\ power = \frac{Mgh}{1000} = \frac{10 \times 9.81 \times 1}{1000} = 0.098kW = 98\ Watt$$

$But, 1\ Watt = 0.00134hp$

$\therefore 98 \times 0.00134 = 0.131 h.p.$

Hence, the available stainless-steel pump of 1h.p. was quite efficient.

2.2.1 Determination of Delivery Pipes' Diameter

The uniform diameter of the delivery pipes employed was calculated as follows; as laid down by Rajput (2014):

Data:	(i). Distance of the reservoir from the tank	=	2m
	(ii). Estimated consumption per day	=	30 litres = 30dm^3 and 30dm^3 = 0.03m^3
	(iii). Total predicted machine capacity/day	=	100 litres = 0.1m^3
	(iv). Predicted machine pumping time/day	=	5 batches/day
		=	30 mins x 5
		=	150minutes (2hrs, 30mins)

$$Discharge, Q = \frac{Quantity\ of\ water}{Time\ taken} = \frac{0.1}{150 \times 60} = 1.1 \times 10^{-5} m^3/s$$

(v). Loss of head due to friction, $h_f = 18m$ (Rajput, 2014)

(vi). Coefficient of friction, $f = 0.007$ (Rajput, 2014)

Mean velocity of flow,

$$V = \frac{Q}{A} = \frac{1.1 \times 10^{-5}}{\frac{3.142}{4} \times D^2} = \frac{1.4 \times 10^{-5}}{D^2}$$

Using the formula: $h_f = \frac{4fLV^2}{D \times 2g}$ (Rajput, 2008), the dimeter can be calculated.

Where h_f = Loss of head due to friction

f = Coefficient of friction

L = Length of the pipe

V = Mean velocity of flow
D = Diameter of the pipe.

∴ Substituting the values in the above formula,

$$18 = \frac{4 \times 0.007 \times 2 \times (\frac{1.4 \times 10^{-5}}{D^2})^2}{D \times 2 \times 9.81}$$

$$18 = \frac{4 \times 0.007 \times 2 \times \frac{(1.4 \times 10^{-5})^2}{D^4}}{D \times 2 \times 9.81}$$

$$18 = \frac{4 \times 0.007 \times 2 \times (1.4 \times 10^{-5})^2}{4} \times \frac{1}{D \times 2 \times 9.81}$$

$$18 = \frac{4 \times 0.007 \times 2 \times (1.4 \times 10^{-5})^2}{D \times D^4 \times 2 \times 9.81}$$

$$18 \times D^4 \times D \times 2 \times 9.81 = 4 \times 0.007 \times 2 \times (1.4 \times 10^{-5})^2$$

$$D^5 \times 18 \times 2 \times 9.81 = 4 \times 0.007 \times 2 \times (1.4 \times 10^{-5})^2$$

$$D^5 = \frac{4 \times 0.007 \times 2 \times (1.4 \times 10^{-5})^2}{18 \times 2 \times 9.81}$$

$$D^5 = \frac{1.0976 \times 10^{-11}}{253.1\ 6}$$

$$D^5 = 3.108 \times 10^{-14}$$

$$D = \sqrt[5]{3.108 \times 10^{-14}} = 1.988 \times 10^{-3} m = 19.88 mm \cong 20 mm\ diameter.$$

Hence, 20mm diameter pipe was used

2.2.2 Major Components Fabricated and Their Modes of Fabrication

The plant has 42 major components, out of which 20 were fabricated ones, while others were either semi-fabricated, or purchased. Table 1 enumerates the fabricated ones.

Table-1 Major Components Fabricated, Their Materials and Methods of Fabrication

S/N	Component	Dimension (mm)	Material(s)	Fabrication Method(s)
1.	Main frame (Chassis)	1600 x 550 x 550	Angle iron:75x75x6	Arc welding
2.	Inner frames	1200 x 750 x 350	Square pipe:25x25x1	Arc welding
3.	Process tank works	520 x 270 (diam.)	Stainless steel	Gas welding
4.	Storage tank	515 x 320 (diam.)	Stainless steel	Beating, seaming
5.	Residue can	300 x 200 (diam.)	Stainless steel	Procured
6.	Water tank frame	350 x 350 x 940	Angle iron:38x38x3	Arc welding
7.	Liquid pump resting base	344 x 340	Angle iron: 40 x 40 x 4	Arc welding, boring
8.	Calyces tube	250 x 50 (diam.)	Stainless steel	Rolling, boring, etc
9.	Agitator rod	260 x11 x (diam.)	G.I. rod	Cutting
10.	Agitator blades	60 x 25 x 2	Stainless steel	Gas welding
11.	Ingredients cupboard	270 x 350 x330	Iron sheet	Arc welding
12.	Apparatus drawer	360 x 260 x 330	Iron sheet	Arc welding
13.	Coupling discs	70 (diam.) x 2	Iron sheet	Cutting, drilling
14.	Electric sockets board	450 x 12 x 10	Plywood	Sawing, punching
15.	Reservoir cage	270 x 270 x360	Angle iron:40 x 40 x 2	Arc welding
16.	Castor plates	80 x 80 x 2	Iron plate	Shearing, drilling
17.	Secondary filter	70 x 22 (diam.)	Muslin cloth	Tailoring
18.	Delivery system	20mm diam.	PVC pipe, materials	Cutting, gluing
19.	UV light sterilizer cage	150 x 100	Flat bar:25x2	Cutting, drilling

20.	Aesthetics panel	1600 x 525 x950	Rectangular steel pipe:75x25x2	Arc welding

2.2.3 Materials Selection and Costing

Different locally available angle iron pieces, rectangular and square steel pipes, flat bars, iron plates and rods, stainless steel sheets etc. were used for the fabrication. Care was taken to ensure that the parts of the System that come in contact with the water or with the drink are either of stainless steel or PVC, so as to avoid corrosion.

Total material costs (Birnin Kebbi market, from July, 2020 to March, 2022) = N373.700.00

Other Related Costs

i. Total labour costs (workmanships) = N200,500.00
ii. Logistics costs = N631,000.00

Energy Costs (Machines Used)

The estimated energy consuming equipment and costing is as listed in Table-2

Table-2 Estimated energy cost

S/No.	Equipment	Rating (kW)	Hours	Total Energy consumed (kWh)
1.	Lathe machine	7.90	2	15.80
2.	Pedestal grinding machine	1.80	4	7.20
3.	Arc welding machine	3.00	120	360
4.	Gas welding apparatus	-	3	-
5.	Hand drill	1.80	2	3.60
6.	Pillar drilling machine	1.10	2	2.20
7.	Sensitive (Bench) drilling machine	0.45	3	1.35
8.	Paint spraying machine	0.50	4	2.00
9.	Bench shearing machine	-	2	-
10.	Heavy spring hanging stand	-	2	-
11.	Plant (the line) testing operations	3.42	5	15.6
		Total	=	407.75kWh

Electricity charge = N53.42 per kWh for commercial heavy consumption rate (Kaduna Electric, 2022).
Hence, power energy charge = 407.75x53.42 = ₦21,782.00

Therefore, the total cost of fabricating the plant = materials cost + energy cost + labour cost + logistic cost= ₦141,750.00 + ₦168,800.00 + ₦64,150.00+ ₦21,782.00 + ₦200,500.00 + ₦631,000.00 = ₦1,227,982.00 + 15% expected increase in price cost = ₦1,227,982.00 + ₦184,197.30 = ₦1,412,179.30
GRAND TOTAL = ₦1,412,179.30 (As at November, 2022).

Plate-2 illustrates the image of the developed modified Sobo drink plant.

Plate-2 Image of the modified developed Sobo drink plant

2.3 Operational Guidelines

The followings are its operational guidelines of the modified developed Sobo drink plant:

i) Make sure that all the switches of the plant are off and then connect the major electrical cable to the mains.

ii) Pour clean water manually into the liquid pump for priming, through the priming until the unit is full. Open the intake valve along the delivery pipe.

iii) Put on the liquid pump switch. Clean water will start gushing into the calibrated water tank. Put off the switch as soon as the desired amount of water is attained.

iv) Open the clean water valve for the desired amount of clean water to be supplied into the process tank. Close the valve when the desired amount is passed.

v) Wash the intended measured amount of the dried calyces (to be used) with separate clean water, twice or thrice and pass it manually via the funnel into the calyces tube.

vi) Set the temperature knob of the process tank to the desired degree (26 - 50°) and carefully put on the heating device (of the process tank) to start heating the water, which extracts the constituents. Allow the heating to proceed for about 20 minutes.

vii) Hold the handle of the funnel and pull up the calyces tube so as to dispose of the extracted calyces residue into the residue can and return the tube back into its initial position.

viii) Measure and add any intended additive (sweeteners, preservatives, e.t.c.) through the funnel. For best result, the addition should be carried out meticulously, in smaller portions, simultaneously with the mixing.

ix) Put on the agitator-motor switch to mix the ingredients thoroughly for about 30 seconds.

x) Use the attached tap of the process tank for quality control of the beverage.

However, if need arises for further addition of any of the ingredients, or any neutralization; it is to be carried out at this juncture. Example, cleaner cold water could be added for cooling, and ingredients added to match up the desired quality.

xi) After attaining the desired quality of the beverage, open the valve at the process tank – storage tank delivery pipe to pass the beverage in to the storage tank.

xii) The processed drink is now ready. Use the discharging unit tap to serve as desired.

2.4 Performance Test Evaluation

As carried out by Gotomo (2009), Ezeala *et al.,* (2012), Ismail & Akanni (2017), preliminary tests, palatability (and other) tests were carried out as follows:

The following preliminary tests were carried out on the Line after construction:

A) Testing the individual components before assembling

B) Testing for workability of the Line after assembling

i. Testing the performance of the Line with 10 litres of cold water (26^{0}C)

ii. Testing the performance of the Line with 10 litres of hot water (50^{0}C)

iii. Testing the performance of the Line with Roselle (*Sobo*) calyces only

iv. Testing for full-blown *Sobo* drink production (5 litres).

Palatability Tests

Palatability (Acceptability) Tastes were carried out on the product with respect to its visual appeal (colour), taste and aroma. The 3 varieties of Roselle calyx were used respectively and 12 judges were used individually to judge each product (see Fig. 1).

RESULTS AND DISCUSSION

At the end of the tedious efforts, an improved Roselle (*Sobo*) drink production system has been successfully developed processed *Sobo* drink has been hygienically produced (Plate II).

Plate-2 A sample of *Sobo* drink produced by the plant

3.1 General Specifications of the Plant

After all necessary works, adjustments and calculations, the specifications of the improved plant are:

i.	Length	=	1,600mm (1.6m)
ii.	Breadth	=	525mm (0.525m)
iii.	Height	=	1,500mm (1.5m)
iv.	Net weight	=	118kg (1.158kN)
v.	Liquid pump head	=	45m
vi.	Liquid pump discharge capacity	=	1.17 litres per sec)
vii.	Agitator angular velocity	=	31 rad/s

viii.	Line's liquid discharge capacity	=	6 litres per minute
ix.	Total energy consumption	=	61kWh

3.2 Sub-Systems of the Improved Line

The systems of the improved line are;

i. The delivery system
ii. The electrical system
iii. The processing system
iv. The filtration system
v. The drainage system
vi. The discharging system
vii. The main frame

Considering the aforementioned price of the plant (N1,412,179.30) as shown in materials costing, above, it is noteworthy that the present (December, 2023) price of the popular imported liquid packaging machine in Nigeria is N1,700,000.00. Hence, from here, we can understand the economic importance of prioritizing indigenous products like the present *Sobo* plant over the imported ones!

3.3 Palatability Taste Results

Table-3 Palatability Scores of Products A1 (Dark-red *Sobo* produced at 60^{0}C)

S/N of Judges	Acceptability scores			Total (30)
	Taste (10)	Colour (10)	Aroma (10)	
1	7	9	8	24
2	7	8	9	24
3	5	5	7	17
4	1	3	1	5
5	5	7	6	18
6	5	7	5	17
7	7	7	10	24
8	4	1	3	8
9	10	10	8	28
10	6	10	4	20
11	9	7	8	24
12	5	9	4	18
Total	71/120	83/120	73/120	227/360
Percentage Score	48.3%	69%	60%	63%

Table-4 Palatability Scores of Products A2 (Dark-red *Sobo* produced at 50^{0}C)

S/N of Judges	Acceptability scores			Total (30)
	Taste (10)	Colour (10)	Aroma (10)	
1	9	9	8	26
2	7	7	7	21
3	5	5	4	14
4	7	10	10	27
5	5	7	7	19
6	9	10	8	27
7	8	8	10	26
8	10	10	10	30
9	10	9	10	29
10	7	8	10	25

11	7	5	10	22
12	8	6	9	23
Total	92/120	94/120	103/120	289/360
percentage Score	77%	78%	86%	80%

Table-5 Palatability Scores of Products A3 [Dark-red *Sobo* produced at room temperature (26^0C)]

S/N of Judges	Acceptability scores			Total (30)
	Taste (10)	Colour (10)	Aroma (10)	
1	9	8	8	25
2	8	7	8	23
3	10	9	10	29
4	10	10	10	30
5	8	8	8	24
6	4	3	5	12
7	10	10	10	30
8	5	7	2	14
9	2	8	3	13
10	10	7	6	23
11	4	6	8	18
12	5	6	6	17
Total	85/120	89/120	84/120	258/360
percentage score	71%	74%	70%	72%

Results obtained for all the tests shows that the acceptance was above 50%. However, Product A2 (Dark-red *Sobo*) has the highest palatability test result of 80% while Product A1 (Dark-red *Sobo*) has the least palatability test result of 63%. This indicates that Product A2 (Dark-red *Sobo*) is likely to be more accepted that the other products.

3.4 The ANOVA Test Analysis Result

The cumulative palatability taste result shown that product A2 (Dark-red *Sobo* produced at 50^0C) has the highest acceptability (80%), followed by product B3 (Pale-red *Sobo* produced at room temperature) – 77%. The least is C3 (White *Sobo* produced at room temperature) which scored 39%. However, after the ANOVA Test Analysis, as shown in Table 6, it is shown that the difference of acceptability between A2 and B3 is not significant. But, between A2 and C3 it is significant; just as it is between B3 and C3, as shown by the Duncan's Multiple Test Range for the three variables (test, colour and aroma) combined together.

Table-6 The ANOVA Test Analysis Result of the Combined *Sobo* Variables

Source	Sum of Squares	*df*	Mean Square	F- value	Pr > F
Between	150.4156	8	18.80195	6.53	< .0001
Within	285.1759	99	2.88056		
Total	435.59156	107			

$F_{cal} = 6.53$ F (0.005) = 2.10 F_{cal} (6.53) > F_{tab} (2.10) Reject

As expressed already, all the nine coded products were intermittently distributed to the selected judges with a questionnaire (Appendix I) for tasting and scoring each product in terms of its taste, colour (visual appeal) and aroma, which totally gave the product's acceptability or palatability score.

Going by the data in tables 3 – 5; it is evident that product "A2" has the highest acceptability score – as 80%, while product "C3" takes the least score (39%). The second most acceptable product is B3 with 77%. It could be recalled that A2 stands for the *Sobo* drink produced by the plant at 50^0C from the dark – red variety. From the foregoing, it is evidently clear that the present finding confirms Gotomo's (2009) findings that *Sobo* drink produced at 50^0C is optimal both in terms of the residence (extraction) and acceptability simultaneously. Hence, it can be inferred or deduced that:

i. Producing *Sobo* drink at 50^0C is better – whether for domestic or commercial needs. Using dark-red variety is better than the pale-red, let alone the white – in terms of public acceptability. This could be attributable to the visual appeal, which is also a function of the red colour pigment vividly denser than in the pale-red variety. Likewise, quick extraction in which the dark-red variety is three times faster than the pale-red variety. Moreover, comparison of the summations of the colour scores between "A" products and "B" products reveals that "A" products (i.e. dark-red variety *Sobo* products) have 74% acceptability, while "B" products (pale-red *Sobo* products) have only 56%! Faster extraction at all experimented temperatures is indeed another merit of the dark-red variety over the pale-red. For example, best extraction for the former was achieved within 16 hours, at room temperature ranges of 25^0C-33^0C, but for the later, it took 2 days (48 hours) at room temperature. Probably, that might be another reason why local *Sobo* drink producers always insist on it, as highlighted in Gotomo (2000) & (2009).

ii. Production at about 50^0C is equally safe, as it is below the denaturation temperature of the Roselle calyces, as put forward by Abubakar (2001). It is also worthwhile to reduce to record that product "C" (white variety product) has not been, to the best of what is known, considered for the main *Sobo* drink production. It is mostly applicable in salads, paps and some preservative medicinal applications, as quoted in Gotomo (2009). In this present case, it was only equally and extensively engaged together with the remaining two varieties for research purpose solely.

CONCLUSION

In conclusion, a small – scale Roselle (*Sobo*) drink plant has been developed in an improved status, that is capable of processing the popular native drink hygienically and scientifically, in a mechanized way; using locally available suitable engineering materials. Also, the improved plant or system was evaluated using three varieties of *Sobo* calyces and found suitable for production of *Sobo* drink hygienically to an acceptable standard.

CONFLICT OF INTEREST

The authors declare no competing interest

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APPENDIX I
AHMADU BELLO UNIVERSITY, ZARIA
DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING
FACULTY OF ENGINEERING

DESIGNED QUESTIONNAIRE FOR PALATABILITY TASTES OF SOBO DRINK PROCESSED BY AN IMPROVED ROSELLE (SOBO/ZOBO) DRINK PRODUCTION MACHINE

Dear Respondent,

We are grateful for your positive response, which is very helpful to our research work. The purpose of the questionnaire and the given products is to understand the validity or otherwise of our product. Please, taste the given product(s) and score each one appropriately based on your judgement on its taste, colour and aroma, etc. All your responses would be regarded confidential and be used for academic research purposes.

Name (optional): ____

Age ______________ Gender Male ☐ Female ☐

Present Address: ____

____

PRODUCT	SCORES (0-10)			
	TASTE (X/10)	COLOUR (X/10)	AROMA (X/10)	TOTAL
A1				
A2				
A3				
B1				
B2				
B3				
C1				
C2				
C3				

1. Please, from the tasted products, which one do you like best?
   I like product ____________________ best.
2. Please, why do you like it best?

____

____

3. Comment or advice (if any)

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