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A conceptual process scheme for sorrel drink production

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ABSTRACT

In this study a conceptual process scheme of an integrated plant for producing sorrel (zoborodo) drink and animal feed ingredients from the calyces of *Hibiscus sabdariffa* is discussed. The process description entails sorting, drying, size reduction, immersion leaching, filtration, sterilization and packaging. A high quality sorrel drink and valuable animal feed are expected from the proposed production process.

Keywords: ***Hibiscus sabdariffa, sorrel drink, zoborodo, process development, feed ingredient, process flow chart, operating conditions.***

INTRODUCTION

Sorrel drink, popularly called "zoborodo" in Nigeria is a non-alcoholic drink, which is obtained from the calyces of *Hibiscus sabdariffa*, by a solid-liquid extraction process, leaving the calyces pulp as the raffinate. *Hibiscus sabdariffa* is a tropical and subtropical annual or biannual herb that probably originated from West Africa [1,2]. It is grown in the Central and North Eastern parts of Nigeria and in African countries such as Niger, Mali, Senegal, Sudan and Egypt [3]

In Nigeria, it usually starts flowering in March and the first harvest is in May. The calyces should not be dried above 43^0 C and the drying ratio is 10:1.1 [4].

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Apart from its use for producing sorrel drink, the calyces are used in producing jams, jelly, tea, marmalades, wine, syrup, salad, and natural colourant [5]. It is also used in herbal preparations. The reddish calyces are referred to as sorrel (English), isapa (Yoruba, Nigeria), zoborodo (Hausa, Nigeria) and bissap (Wollof, Senegal).

The drink which is typically made up of about 1 % solid contains anthocyanins and other alkaloids, vitamin C, and minerals among other things as reported by Akanya [3] and Aboki [6]. The calyx (pulp) is made up of protein, carbohydrate, fat, alkaloids and minerals such as Ca, Mg, K, Na, Fe and Zn [3,7,8]. The sorrel (zoborodo) drink has become popular all over Nigeria during the last decade or so. It is produced when the calyces are boiled in water for

10-20 mins, under largely non-standard and unhygienic conditions, turning the pulp residues into environmental pollutants [9]. As a result of the mode of production of the drink, its shelf life has been observed to be very short (about 48hrs). Previous works by Onuorah and Hadiza [9], Akanya *et al.* [3] and Aboki [6] indicated high microbial load of this drink, which substantial numbers of Nigerians consume regularly in large quantities. A process plant for the drink has been reported in Brazil and its solid concentrate has been produced in Australia [10].

The technical know-how of the processes involved is still a guarded-secret. For the safety of the teeming population of our nation, which consumes this drink, it is necessary to improve the quality of the drink and increase its shelf life. Bench scale investigations carried out by Onuorah and Hadiza [9] and Aboki [6] have shown that this is possible.

However, there is no known mechanised manufacturing outfit for the drink in Nigeria as at present. Therefore, there is the need for effort to be intensified in this direction. Considering the available bench scale data, process flow sheeting development would be a worthwhile effort to enable eventual design, fabrication, installation and operation of a plant for processing sorrel drink.

The work reported here gives the conceptual process scheme for sorrel drink and animal feed ingredient production from the calyces of *Hibiscus sabdariffa*.

PROCESS DEVELOPMENT

The major aspects of development of a given process route are the selection of process and operating conditions. The flow sheet representing the process route is a sequence of equipment (in which unit operations take place) and through which process streams, utilities and signals (for control) flow. The operating conditions of the component process units as well as the flow rates of the streams are also indicated in process flow charts.

Selection of process conditions would include specifying the materials in the process cycle, equipment (for specific unit operations) and process cycle (batch or continuous). Specifying the characterizing variables such as temperature, pressure, composition and flow rate of streams is what is involved in selection of operating conditions. Development of process routes is done before process design of the plant is carried out. The process development usually starts at the conceptual level based partly on data from bench scale experimentations. The resulting plant design can subsequently be scaled up to commercial plant level. The development of process technology, therefore would involve knowledge of process conditions and operating conditions.

Process Conditions

The process objectives are to produce sorrel drinks which are safe for human consumption over a long period of time, and convert the pulp residue (solid raffinate) into useful byproducts such as animal feed ingredient, sucrose, ethanol, etc. The process conditions for producing the drink and animal feed ingredient are discussed subsequently.

Sorrel drink

Solvent to be used is potable water that meets the usual quality specifications. Of the desirable characteristics of the solvents [11] non-toxicity, solubility, non-impairment of quality of extracts and low price make water the preferred solvent of choice for the process.

A batch process is preferred because of the expected low capacity of the plant. Increased demand may necessitate employment of continuous process. For this reason and because of the fact that calyces can disintegrate during extraction, immersion leaching, which makes use of a version of air agitated vessel called Pachuka tank is to be used. The typical capacity given by Miller [11] can be reduced to accommodate the lower expected throughput. Hildebrandt extractor can be used for continuous process [11].

Animal feed component

Two possible routes are suggested. One uses thin-film dryer or drum dryer and the other route uses tray dryer for drying. The pulp residue coming out of the extractor is wet and of low pH. It thus needs to be neutralized, and thereafter dried. The pH adjustment could be achieved by fermentation as detailed by Ojokoh [12] . The pulp needs to be pulverized before neutralization, if thin-film drying or drum drying is to be used. In this case, the neutralized pulp has to be dried at low temperature to ensure preservation of the important components like vitamins and proteins. Thin-film drying would necessitate intermittent continuous operation because of the low capacity envisaged. The dried materials is then stored or bagged for subsequent use in the production of animal feed. Where drying is to be done in a tray-dryer, neutralization is carried out on the wet pulp before being dried in the dryer; the dried matter is grounded and then stored.

Operating Conditions

From studies by Ogueri, [13], Aboki [6]; Akanya [3] and Onuorah & Hadiza[9] at bench scale on sorrel drink production, the following operating conditions are recommended for sorrel drink and animal feed component production.

Sorrel drink

Composition of zobo drink and its quality specifications are given in Tables I and II respectively. Temperature of extraction is between 60-100 ^{0}C at residence time of 10-25 mins using reagent (solid: solvent) ratio of 1:5 [13]. Terminal stream composition is expected to be 0.5-1.0 g/L. The feed rate depends on the cycle being employed. For a continuous leaching process, the flow rate of solvent and that of the mixed stream will be determined by the capacity of the plant, the reagent ratio and ratio of underflow to overflow (i.e. liquid holdup of the solid and the extract).

TABLE I: Typical Physicochemical Properties of Sorrel Drink

Test Parameters	Mean Value
pH	2.4
Vitamin C,mg/100ml	55
Protein Content, mg/100ml	4
Total Ash, %	0.35
Total Solid Matter, %	9.66
Water Content, %	90.34

Source: [3]

TABLE II: Quality Standard Specifications for Juice Drink

Substance	Maximum Level, mg/kg
Arsenic, mg/kg	0.2
Lead, mg/kg	3
Copper, mg/kg	5
Zinc, mg/kg	5
Iron, mg/kg	5
Tin	25
Sugar Content	

Source: [14]

Animal feed ingredient

The pulp residue (raffinate) left after extracting the sorrel drink is rich in valuable minerals, vitamins, proteins and carbohydrate (See Tables III and IV). However, due to the presence of some organic acids, the pH of the residue is low. It is thus necessary to raise the pH of the materials to make the dried product useful as an ingredient in animal feed formulation. A pH in the range of 5.5 to 6.5 is desirable, to ensure effective utility by animal [15]. Size-reduction is necessary before neutralization at ambient temperature, to increase the surface area made available, and hence, faster pH adjustment. The slurry is then dried either with thin-film or drum dryer at the temperature which prevents thermal degradation of the pulp's components (such as vitamins and alkaloids). Either of the two dryer is able to handle slurry mixture as we have here [16]. However, drum dryer is cheaper though it exposes the material to thermal degradation more than thin-film dryer [16,17].

FLOWSHEETING

The unit operations selected for producing sorrel drink (containing 1 % solid) and animal feed components from dry calyces are discussed below: block flow diagrams of the process given in figures 1a and 1b, while

Sorrel Drink

The unit operations selected for producing sorrel drinks are pre-treatment (sorting and drying), size reduction, leaching, filtering, sterilization and packaging.

- **Sorting** of the calyces going into storage tank (SB-102) is to be done manually by inspection. This will be appropriate for the scale of production anticipated.

- **Drying** will reduce the moisture content of the calyces from about 20 % (during wet season) to 5 %. Tray dryer (TDR-101), which operates at 40 ^{0}C maximum temperature, is recommended. Residence time is dependent upon the wetness of the calyces. Storage containers lined with Low Density Poly Ethylene (LDPE) is recommended to prevent absorption of moisture while the calyces await further processing.

TABLE III: Typical Composition of *Nigerian Hibiscus Sabdariffa* Calyces

Substances	Calyces Type		
	Green	Red	Dark Red
Crude Protein, %	17.9	17.4	8.6
Ether Extract, %	3.2	2.1	2.9
Crude Fibre, %	11.2	8.5	9.8
Ash, %	6.6	6.5	6.8
Ascorbic Acid, mg/100g	86.5	63.5	54.8
Moisture (FW), %*	88.3	86.5	85.3
Calcium, mg/100g	1209	1583	1602
Potassium, mg/100g	1850	2060	2350
Sodium, mg/100g	9.5	5.5	6.5
Iron, mg/100g	32.8	37.8	34.6
Zinc, mg/100g	5.8	6.5	6.3
Magnesium, mg/100g	235	316	340

Source: [7] * From fresh calyces

TABLE IV: Typical Composition of American *Hibiscus Sabdariffa* Calyx

Substance	Value, %
Protein	3.5
Water	10
Glucosides	63.5
Cellulose	11
Ash	12

Source: [6]

- **Size reduction** is required to enhance better interaction between the solvent and the calyces. Therefore, dried calyces (5 % moisture) will be comminuted using shredder (SR-101) to produce maximum particle size of about 11.2 mm. The shredder may be connected to a screen in an external circuit, to remove very fine particles.

- **Immersion leaching** is recommended because of the tendency of the calyces to break up during leaching. Air agitated Pachuka tank (MSX-101) is recommended for this purpose using the operating conditions and items specified in Section 3.1.

- **Filtration** is required to separate the extract from the pulp. The extract is passed to the sterilization tank and the solid residue to neutralization tank or wet-mills. Filter press (F-101) is suggested here.

- **Sterilization** was carried out using a chemical preservative called sodium benzoate (Aboki, 2004) in a stirred tank (STT-101). Other additives such as sweetener, spices and flavours are added as required by quality specifications (see Table II). Pasteurization with or without limited carbonation are possible alternative means but chemical sterilization is selected here to foreclose the need to consume the bottled juice once uncorked.

- **Packaging** can be done, with machines, in plastic bottles of sizes ranging between 0.25 and 1.0 L The packaging area will include bottle washers and sterilizers (FL-101).

washers and sterilizers (FL-101). Before packaging, dilution of the extract which is typically 10 % solid is carried out to reduce the solid content to 1 % [3]. This stage would include bottle-filling, carbonation (optional), capping, rinsing and pasteurization (optional).

- **Quality control** sampling is recommended on raw materials (for moisture and appearance), leachate and the final product (i.e. sterilized sorrel drink), among others as detailed in Figures 1a and 1b.

Animal Feed Ingredient

The solid (pulp) residue obtained from the leaching operation (extraction tank) MSX-101 is processed to give animal feed ingredients, the composition of which is expected to be as given in Table III. To achieve this, the pulp (85 % moisture content wet basis) is carried through dewatering, drying and size reduction, using any of the following process options:

The first option involves neutralization (probably through fermentation), dewatering, drying and size reduction.

- **Neutralization** is done with appropriate reagents to attain pH 5.5-6.6 as indicated in Figure 1a.
- **Dewatering/Draining** is required to reduce the water content from 85 % to 50 % using a dewatering device. In the alternative, the wet pulp could be drained.
- **Drying:** Tray dryer is selected to produce the dry solid matter (5 % moisture content on wet basis).
- **Size reduction:** Hammer mill is selected to reduce the size of the dried solid to 0.5mm maximum particle size.
- **Packaging:** The milled material is to be packed in batches of 50kg and 100kg in sacks or in the alternative, stored in bigger container for animal feed formulation at site.

The second option involves size reduction, neutralization, drying and packaging processes as represented in Figure 1b.

- **Size reduction:** Wet milling of the pulp is carried out using appropriate mill (GR-102)
- **Neutralization:** Adjustment of the pH from 2.5 to between 5.5 and 6.5 is achieved in a tank (GR-102).
- **Drying:** Pre-concentration process may precede this step, depending on the water content of the slurry. Thin-film or drum drying (DDR-101) at about 80^0 C ensures that thermally sensitive materials are protected. Final moisture content of product is about 5 %.
- **Packaging:** This can be done as itemized in Option One, using packaging device (BX-102).
- **Quality control** sampling needs to be done on the feed going into the dryer for pH, and water content determination, among other things as shown in Figure 1b. The final product must meet the specified standard quality as given in Table V.

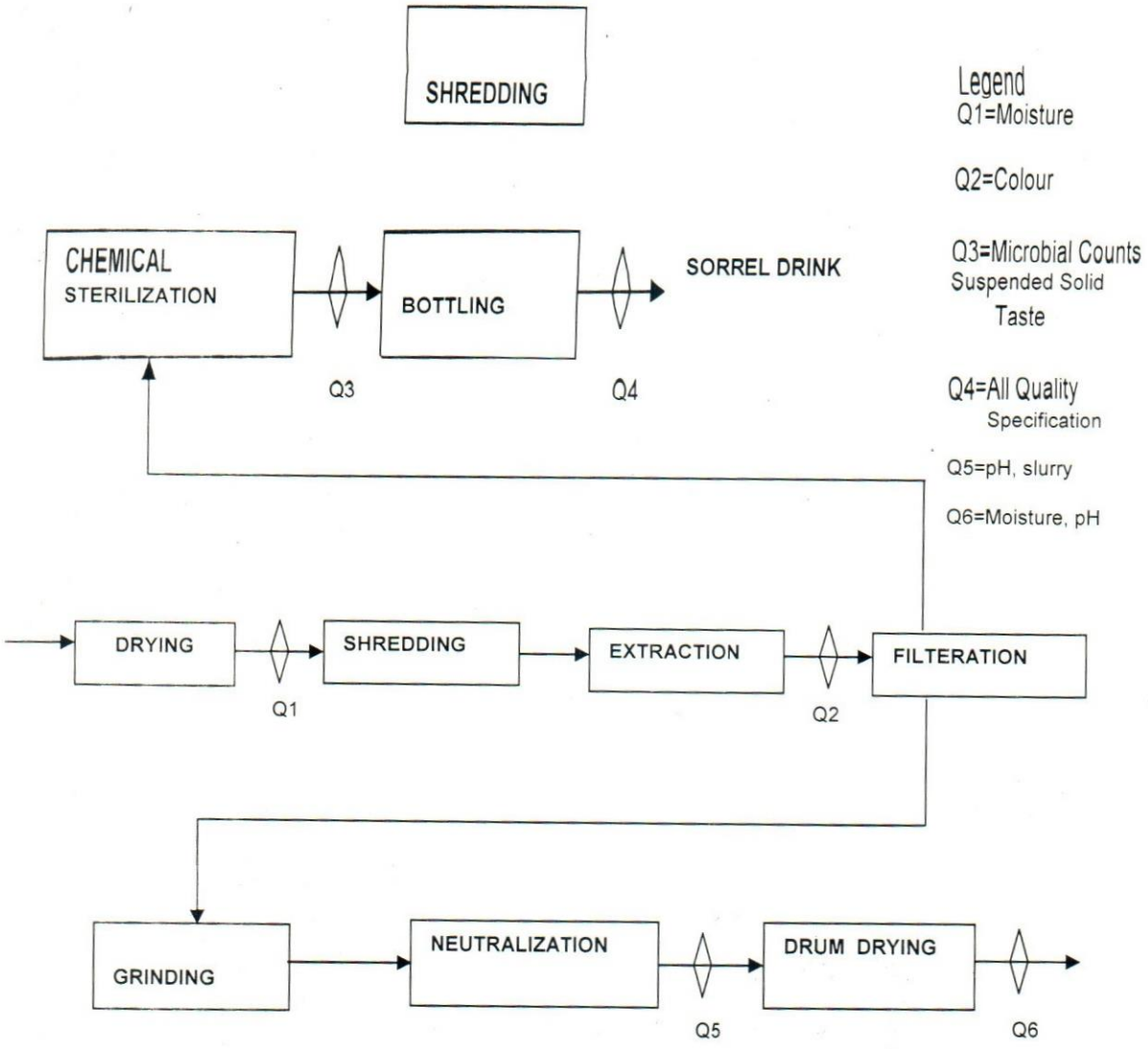

FIGURE 1a: FLOW DIAGRAM FOR PROCESSING DRY CALYCES THROUGH DRUM/THIN FILM DRYING

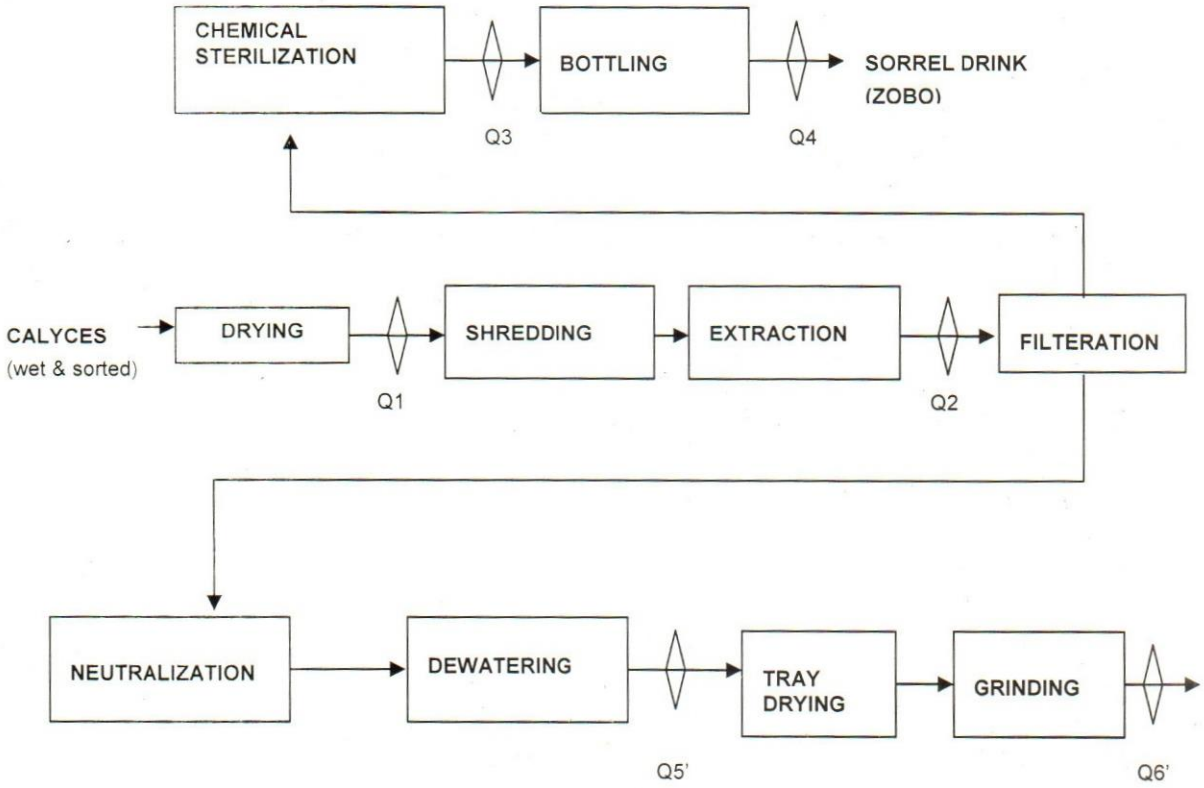

FIGURE 1b: FLOW DIAGRAM FOR PROCESSING DRY CALYCES THROUGH TRAY DRYING

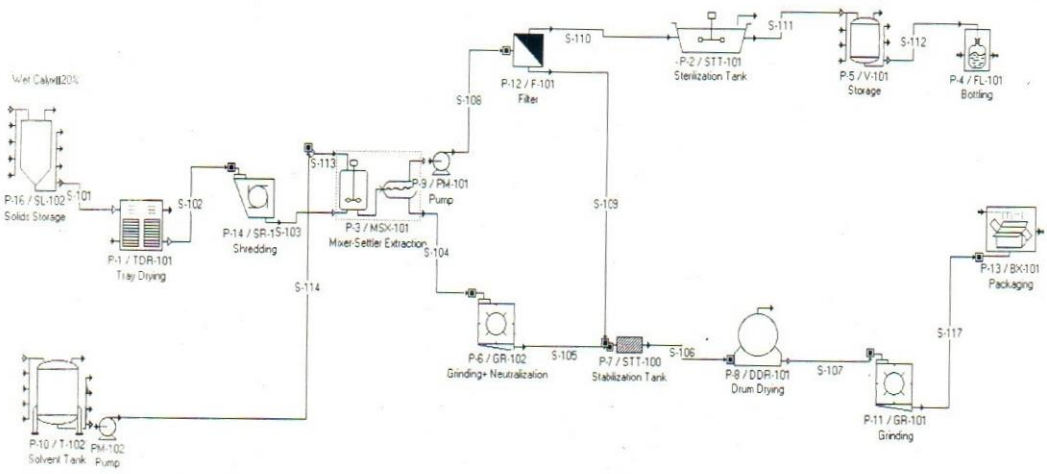

FIGURE 2: FLOW DIAGRAM FOR PROCESSING *HIBISCUS SABDARIFFA* CALYCES

QUALITY SPECIFICATIONS

The sorrel drinks and the animal feed ingredients produced need to meet the quality specifications for fruit drink as given by Standard Organization of Nigeria (see Tables II). For the feed ingredient, pH between 5.5 and 6.5 as well as wholesomeness is important. Essential sampling points on the plant are indicated in Figures 1a and 1b, as Q1, Q2, etc. Quality specifications of importance are discussed briefly for sorrel drink and animal feed ingredients.

Sorrel Drink

Of importance are the microbial count, colour, suspended solids, and mineral contents such as lead, iron, zinc and arsenic, which are not expected to be more than 3, 5.5, and 0.2 mg/g, respectively

Animal Feed Ingredient

This product is to serve as the source of energy, some of the protein requirement as well as other vital nutritional supplements such as vitamins, iron, magnesium etc. Quality specifications for pH, microbial count, colour, carbohydrate, protein, vitamins, and minerals are important. pH should be almost neutral, while lead, arsenic and cyanide should be less than 3 mg/100 g, 0.2 mg/100 g and 2.5 mg/100 g respectively.

SELECTION OF MATERIALS OF CONSTRUCTION

For processing the sorrel drinks, the vessels, dryer compartment, trays and storage container should be made of stainless steel (S316), which meets the standard for preparing food products. Some of the containers could be made of high-density polyethylene (HDPE). Materials for other components of the plant could be made of cast iron, copper or aluminium.

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