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DESIGN OF A ROTARY ROASTER FOR CASSIA SIEBERIANA SEEDS

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ABSTRACT
Two kilogram capacity roaster was designed and fabricated for purpose of roasting cassia sieberiana seeds, obtained from an African plant, which is capable of being used as coffee substitute. During the testing of the roaster, physical changes on the seeds were monitored and found to be temperature and time dependant. Best samples of roasted cassia sieberiana was obtained at 200°C roasting temperature after 15 minutes.

Keywords : Cassia sieberiana; roaster, coffee and temperature.

INTRODUCTION

Cassia sieberiana DC. (Caesalpiniaceae) is an African plant regarded as Weed (Hutchinson and Dalziel, 1928; Burkill, 1995). It has fruit which is about 1.0-1.5cm in diameter and 30-90cm long (Burkill, 1995). Unclassified information had it that C. sieberiana seeds had been roasted and used as beverage by certain people of Western part of Nigeria. Also our preliminary investigation revealed that roasted C. Sieberiana seeds possessed flavour that resembled roasted coffee flavour.

The importance of roasting operation in food preparation is the generation of characteristic flavour (Pattee et. al. 1995; Maria et. al., 1996) and colour (Park et. al., 1995) which consumers require for acceptance of such foods. Roasting of Food crops brings about thermal degradation of the chemical components (Pyrolysis) at relatively high temperatures (Maria et al., 1996, Park et. al., 1995; Pattee, et al., 1995). This is usually accompanied by caramelization of sugars, polysaccharides and Maillard reaction's which consequently lead to physical changes such as colour, flavour, size as a result of internal production of gases mostly carbon (iv) oxide and weight (Sievtz, 1963).

Weight loss occurs in two stages and this relates to evaporation of water and pyrolysis of dry matter. As the rate of water loss falls off, the rate of gas evolution rises rapidly and the point of transition between the two stages occurs at the onset of pyrolysis (Sievtz, 1963). Roasting of food crops can be accomplished by using either hot air or a metal surface to heat up the materials to the temperature at which pyrolysis occurs and this must be abruptly stopped using cool air (Gell and Porto, 1996) to avoid charring of the foods.

Roasting operation for food crops is done traditionally in hot sand in a flat bottomed frying pot over a hot flame until they are brown. The seeds are then separated by sieving from the hot sand, Oguntunde (1987) suggested that infrared heating could be utilized in roasting operation to improve the traditional technique. During a roasting operation, the seeds must be kept moving otherwise they will either roast unevenly or burn when the desired degree of roasting has been attained, the seeds must be cooled down using cool air to halt the pyrolysis.

It is considered worthwhile to carry out study on characteristics of roasted C. sieberiana seeds which could be a suitable coffee analogue.

2. DESIGN OF COMPONENT UNIT

Unit design of the component parts were done taking into consideration the specific function of each unit. The main units are roasting chamber, transmission shaft, power requirement and operation capacity (Figures.1&2).

2.1 Roasting Chamber

– It was a perforated cylindrical high carbon steel (Figure 1). The holes are made to accommodate smallest beans of material to be roasted Sieberiana cassia has minor diameter of 3.85mm (Burkill 1995) and the holes are made to be 3mm. For effective heat transfer, co-efficient of opening of 40% is chosen

$$Co = \frac{D^2}{(D+d)^2}$$

where

Co – coefficient of opening = 40%
D – diameter of hole = 3mm
d – distance between adjacent hole = 1.743mm

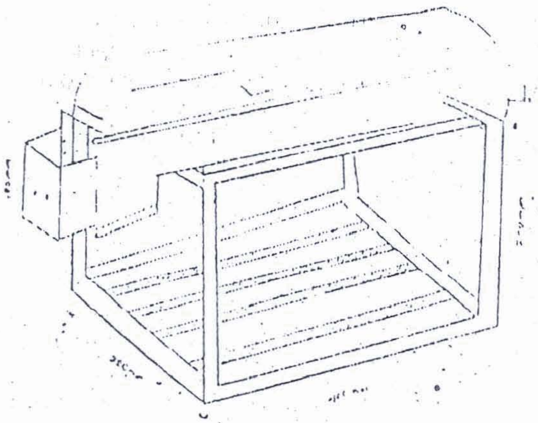

Fig. 1: Isometric View of the Rotary Roaster

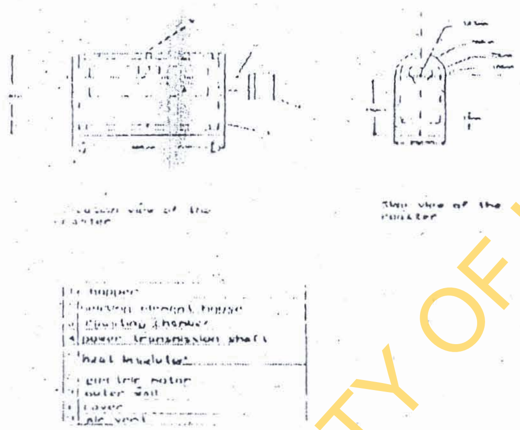

Fig. 2. Orthographic Views of the Rotary Roaster

2.2 **Transmission Shaft** – using American society of mechanical engineer (ASME) code equation for solid shaft having little or no axial loading, the permissible diameter was calculated as follows.

$$d^3 = \frac{16}{S_s\pi}\sqrt{M^2 + T^2}$$

Where
d – permissible shaft diameter (m)
M-maximum bending moment (Nm) = 13.13Nm
T- maximum torque(Nm) = 20Nm
S_s- Yield strength (Pascal) = $72x10^6$ Pa
π- constant
d = 0.0119m ≈ 12mm

therefore a 15mm diameter shaft was used.

2.3 **Power requirement** - power required to rotate the roasting chamber was determined to be

$$w_c = 2\pi N / 60$$
$$P = T.w_c$$

Where
P – power (Watts)
w_c - angular speed (rad/sec)
N – speed (rpm) = 10 rpm
T – torque (Nm) = 20Nm

P = 20.93 watt
To give allowance for power use in driving pulleys and shafts, the rated power was 25Watts.

2.4 **Operation Capacity** – The operating capacity was based on the available heat energy. Quantity of heat energy required for roasting 2kg of cassia seberianna was calculated from the energy equation

$$Q = MC\theta$$
$$t = Q / P$$

where
Q – quantity of heat required (KJ)
M- mass of material (Kg) = 2kg
C- specific heat capacity (J/kg) = 1.507 J/Kg
θ- change in temperature (^{0}C) =275 ^{0}C
t-time of roasting (sec)
P- power (KW) = 1KW
Q – 828.85 KJ
t -. 828.85 seconds ≈ 14minutes
therefore 6kg will be roasted in an hour.

2.5 **Design Specification**
Capacity -2kg/hr
Size
i overall dimension (200*300*400)mm
ii.roasting chamber (100*300)mm
Shape
i overall rectangle
ii roasting chamber cylindrical
Construction material
i High Carbon Steel
ii Mid Steel
iii Clay
Roasting temperature - 300°C
Energy source – Electric Energy
Power drive – Manual & Electric motor

3. TESTING

A batch of cassia sieberiana seeds was obtained from University of Ibadan Teaching and Research farm. The seeds were cleaned, stored, packaged in moisture proof polyethylene and stored under refrigeration (4°C) for further use. Moisture content of the seeds was determined according to ASAE (1998) method.

The roaster was switched on and the desired temperatures of roasting were attained before the introduction of known quantity of beans into the roasting drum. The cylinder was then given a rotary motion to provide tumbling of the beans inside the drum in order to ensure the evenly roasting of beans. After 5minutes of rotation, the beans were discharged. The weight loss was determined using ASAE (1998). Also the increases in size of the beans were measured according to Madhyan *et al.* (1987). This procedure was repeated for 10, 15, 20, 25 and 30minutes for the same quantities of the beans.

4. RESULTS

The results of the characterization of the roaster are shown in Table 1 & 2. The rate of weight loss during roasting increased with increase in roasting temperature. The moisture content of the green seeds was 9.10% on dry basis. Also the size of the seeds increased with increase in time and temperature of roasting.

Visual observation revealed that the samples were of uniform brown colour after each roasting, thus they were evenly roasted. Also aroma and flavour that are known with roasting of coffee beans were detected and perceived during roasting operation of C. sieberiana seeds.

5. CONCLUSIONS

A rotary drum roaster that can handle 2kg of C. sieberiana seeds per batch was designed and constructed. The roaster can be adopted for any grains materials having minor diameter greater than 3mm. Thus it can be referred to as a multipurpose. The roaster, however, has been characterized for C. sieberiana seeds, and it is capable of making an impact on the improvement/upgrading of traditional roasting operation especially in developing countries of West Africa.

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Table 1: Results of investigation of characteristics of roasted C. sieberiana

Roasting time (min)	Percentage weight loss at different temp. of roasting (°C).			Percentage Swelling at different temp of roasting °C		
	190	200	210	190	200	210
5	2.2	6.2	6.2	6.8	9.1	9.1
10	3.1	6.5	7.0	16.8	18.2	18.2
15	7.2	8.3	12.2	22.7	22.7	22.3
20	9.3	10.9	14.7	27.3	31.8	45.5
25	12.3	16.3	17.8	38.6	45.5	54.6
30	14.2	18.1	21.2	50.0	50.0	63.6

Table 2: Results of investigation of characteristics of roasted C. sieberiana

Roasting time (min)	Percentage Swelling at different temp. of roasting (°C).			Percentage Swelling at different temp of roasting °C		
	190	200	210	190	200	210
5	6.8	9.1	9.1	6.8	9.1	9.1
10	16.8	18.2	18.2	16.8	18.2	18.2
15	22.7	22.7	22.3	22.7	22.7	22.3
20	27.3	31.8	45.5	27.3	31.8	45.5
25	38.6	45.5	54.6	38.6	45.5	54.6
30	50.0	50.0	63.6	50.0	50.0	63.6