Design and fabrication of Coconut Juice Extraction Machine
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Abstract
The design and fabrication of a machine used to extract coconut juice from coconut meat, has been accomplished. Detailed design was made to determine size specifications of the machine components. The machine was fabricated in accordance with design specifications. The performance of the extractor in terms of operating time, amount and quality of coconut juice extracted was determined. A 77 percent extraction efficiency was recorded with the machine at operating speed of 1500 rev/min.

Keywords: Coconut juice, Coconut Meat, Design, Fabrication, Efficiency

1.0 Introduction
Coconut has numerous nutritional benefits. Fresh coconut juice is one of the major sources of electrolyte and can be used to prevent dehydration, for instance in cases of diarrhea or strenuous exercise. In some parts of the world, coconut juice is intravenously used to hydrate critically ill patients, especially in emergency situations.
Other health benefits of coconut juice includes:
➢ Reduces risk of heart diseases,
➢ Increase metabolism and promotes healthy thyroid function,
➢ Rejuvenates the skin and prevents body wrinkles

Natural coconut flavor can be produced (Theivendirarajah et al 1979) by grinding coconut meat from which the germ eye is removed until a pulp of coconut fiber and coconut liquor is obtained. The pulp is separated into the flavor liquor and fiber, with the liquor containing less than 2 percent fiber. The liquor is then heated under enzyme deactivation conditions to deactivate any deleterious coconut enzymes. It is then concentrated by condensing the liquor to more than 25 percent solids or by spray drying to a free flowing powder. Coconut fat can be extracted (Krishnamurthy et al, 1983) (coconut contains about 68 percent fat) and used as cooking fat and in margarines. Desiccated coconut contains about 70 percent oil.

Due to numerous health benefits of coconut juice, its demand is very high. In fact coconut juice is a very essential raw material in pharmaceutical industries. Coconut juice commercialization is therefore a promising opportunity for the entrepreneur.

In spite of its numerous health benefits and uses however, fresh coconut juice is scarcely available in the market. As people become aware of the health benefits and numerous uses of juice, its demand is increasing at a fast rate. How then do we meet with the growing demand of the product? The problem is certainly not that of unavailability of coconut, but lack of efficient and faster means of extracting the juice for commercial purposes.

2.0 Design Concept
Fig. 1.0 shows the assembly drawing of juice extractor. Table 1.0 and Fig. 2.0 show the component parts and the orthographic views of the machine respectively.
Fig 1.0. Assembly Drawing of Coconut Juice Extractor.
1.0 DESIGN ANALYSIS

3.1 Capacity
Design is made for 170 kg of coconut meat per hour. If process time per batch is 5 minutes, thus quantity of coconut meat processed per batch will be 14 kg.

3.2 Inlet Hooper Design
Density of coconut meat (Evwarape, 1989), \( p = 7000.04 \, \text{kg/m}^3 \)
Mass of coconut meat per batch, \( m = 14 \, \text{kg} \)
Volume of coconut meat, \( v = 14/7000.4 = 0.002 \, \text{m}^3 \)

Designing for 10% top clearance
Volume of Inlet Hopper \( = 0.002 + (0.1 \times 0.002) = 0.0022 \, \text{m}^3 \)
Shape of Hopper: Trapezoid
Let, \( L_1 = 160 \, \text{mm}, W_1 = 100 \, \text{mm} \)
\( L_2 = 90 \, \text{mm}, W_2 = 60 \, \text{mm} \),
Where \( L_1 \) and \( L_2 \) represent the top and base lengths of the hopper, and
\( W_1 \) and \( W_2 \) are the top and base widths of the hopper respectively.
Volume of Hopper, \( V = \frac{1}{2} (W_1 L_1 + W_2 L_2)h \)
Where \( h \) = Height of hopper
But \( V = 0.0022 \, \text{m}^3 = \frac{1}{2} (0.1 \times 0.16 + 0.09 \times 0.06) \, h \)

\[ H = 2 \times 0.0022/0.016 + 0.0054 = 0.206 \, \text{m} \]

3.3 Size of Grater
Shape: Cylindrical
Diameter of Grater, \( D = \) Base width of inlet hopper -2 mm clearance
This will give 1 mm greater clearance thereby allowing only coconut meat particle
Size of less than 1 mm to pass through).
Thus, \( D = 60 \, \text{mm} - 2 \, \text{mm} = 58 \, \text{mm} \)
Length of Grater, \( L = \) Base length of inlet hopper -2 mm clearance
\( = 90 \, \text{mm} - 2 \, \text{mm} = 88 \, \text{mm} \)
Thus, size of grater: \( L = 88 \, \text{mm}, D = 58 \, \text{mm} \)

3.4 Grater Shaft Design
Choosing a 2-horse power motor at 1500 rev/min (average power requirement for graters, Eugene, 1976);
Torque transmitted = \( (9550 \times \text{KW}) \, \text{Rev/min} \)
(Deutchman, 1975)
Weight of coconut meat acting vertically on the grater, \( w = 14 \, \text{kg} = 137.34 \, \text{N} \)
Weight of pulley, \( w_p = 1.73 \, \text{kg} = 17.168 \, \text{N} \)

Let \( R_a \) and \( R_o \) = Reactions at bearing at A and D respectively
Taking moments at point D;
### Table 1.0 Component Parts of the Machine

<table>
<thead>
<tr>
<th>S/N</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cam Profile</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Cam Shaft</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Cam Follower</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Compression Spring</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Pressure Disc</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Pressure Screen</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Collector Tank</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Pulley</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>V-Belt</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Grater Shaft</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Grater Column</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Electric Motor</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Ball Bearing</td>
<td>4</td>
</tr>
</tbody>
</table>

![Fig.2.0 Orthographic view of the Juice Extractor](image-url)
Design and fabrication of Coconut Juice Extraction Machine

\[ R_x = 0.262 = 17.168 \times 0.212 + 137.34 \times 0.106; \]
\[ R_x = 69.458 \text{N} \]

Taking equilibrium of all vertical forces;
\[ R_A + R_B - 17.168 - 137.34 = 0; \]
\[ R_B = 85.05 \text{N} \]

From the shear force and bending moment diagram (Fig. 3.0),
Maximum Bending Moment (at C),
\[ M_B = M_C = 9.02 \text{N-m} \]

But equivalent twisting moment,
\[ T_e = (C_w M_x) + (C_w M_y) \]
\[ = 12 \text{Khrumi, 2004} \]

Where \( C_w = C_t = 1.0 \) = Shock factors respectively.

\[ T_e = 13.14 \text{N-m} \]

\( n \) = Shaft size,
\[ d^3 = 16T_e/\pi \text{max} \]
where \( \text{max} \) is the maximum shear stress, 42 x 10^6

\[ d = 0.01168 \times 12 = 0.18 \text{mm}; \text{ Use 16 mm shaft (for safety).} \]

3.5 Cam Shaft Design

Velocity Ratio = (Speed of motor pulley) / (Speed of grater pulley) = 1:1

Thus: \( \pi D_1 N_1 / 60 = \pi D_2 N_2 / 60 \)

Where \( D_1 \) and \( D_2 \) = Diameter of motor and grater pulleys respectively;
\( N_1 \) and \( N_2 \) = Rev/min of electric motor
\( D_1 = D_2 N_1 / N_2 \); but \( N_1 / N_2 = 1:1 \), thus \( D_2 = D_1 = 75 \text{ mm} \)

For the cam shaft pulley; Velocity Ratio:
\( \pi D_2 N_4 / \pi D_3 N_3 \)

Where \( D_1 \) and \( D_2 \) are diameter and rpm of cam pulley respectively.
\( N_4 = D_2 N_2 / D_1 = 75 \times 1500 / 225 = 500 \text{ rev/min} \);

Thus velocity ratio of cam shaft pulley to the grater pulley = 1:3

Torque transmitted by cam shaft,
\[ T = 9550 \times X \text{KW} \]

\[ T = 9550 \times 1.5 / 500 = 28.65 \text{ N-m} \]

Neglecting weight of the cam shaft,

Weight of pulley \( W_p = 4 \times 9.81 = 39.24 \text{ N} \)

Weight of the cam, \( W_c = 3 \times 9.81 = 29.43 \text{ N} \)

Let \( R_A \) and \( R_B \) = reactions at bearing at A and B

Taking moments about \( D_1 \),
\[ R_x = 0.262 = 39.27 \times 0.212 + 29.43 \times 0.106; \]
\[ R_B = 43.658 \text{N} \]

Equilibrium of vertical forces
\[ R_A + R_B = 39.24 - 29.43 = 0; \]
\[ R_B = 25.012 \text{ N-m} \]

From the shear force and bending moment diagrams (Fig. 4.0),
Maximum Bending Moment, \( M_B = 2.651 \text{ N-m} \)
Equivalent Twisting Moment,
\( T_e = (C_w M_x) + (C_w M_y) ^{1/2} \)

Where \( C_w \) and \( C_t \) are shock factors for bending and torsional moments respectively.

For gradual load application on the cam, \( C_w = 1.5 \); \( C_t = 1.0 \)

\[ T_E = (1.5 X 2.651)^{1/2} + (1 X 28.65)^{1/2} \]

\[ T_E = 28.925 \text{ N-m} \]

Shaft size,
\[ d^3 = 16T_e/\pi \text{max} \]
\[ d = 0.01152 \times 15.20 = 0.18 \text{mm}; \text{ use cam shaft size, d = 18mm (for safety).} \]

2.0 Performance Test

Weight of coconut juice extracted by traditional method = 21.20kg

Weight of coconut meat = 14kg

Weight of hot water = 11.30kg

Efficiency, \( = 21.20 \times 100% / (14 + 11.3) = 84% \)

(i.e. Using traditional method)

4.1 Efficiency of the Juice Extractor

Weight of hot water at 77o C = 11.30 kg

Weight of coconut meat = 14kg

The machine was operated at different speeds by use of a variable pulley system. The following result was obtained.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Pulley Diameter(mm)</th>
<th>Input Coconut Meat + Hot water (kg)</th>
<th>Output Coconut Juice (Kg)</th>
<th>Output Coconut Juice (Kg)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>36</td>
<td>3,125</td>
<td>25.30</td>
<td>14.0</td>
<td>55</td>
</tr>
<tr>
<td>2.</td>
<td>50</td>
<td>2,250</td>
<td>25.30</td>
<td>16.0</td>
<td>63</td>
</tr>
<tr>
<td>3.</td>
<td>75</td>
<td>1,500</td>
<td>25.30</td>
<td>19.5</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 2.0 Performance Test Result of the Juice Extractor
Thus, the highest efficiency 77% is achievable at the rotational speed of 1,500 rev/min of the machine.

1.0 Conclusion and recommendation

The coconut juice extractor could process about 14 kg of coconut meat in five minutes and with 77% juice extraction efficiency. This is easily achievable especially when juice extraction is aided with the addition of hot water about 77°C.

The following recommendations are made for further improvement on the machine:
1. Two cam follower return springs should be used. This is to guarantee full return of the cam follower at each stroke.
2. The cam follower should be re-designed with a larger lift angle of about 120° as against the present 90°
3. A heating chamber should be incorporated in the design to provide hot water for easy extractor of the juice
4. Second extraction may be done to improve juice recovery

The above recommendations are likely to improve the extraction efficiency of the machine.

References


