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Design And Fabrication Of Palmyrah palm Jaggery Disintegrating Unit

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Abstract: *A continuous type palm jaggery disintegrating unit was developed for disintegration of raw jaggery. It consists of a feed hopper, disintegrating assembly, metallic rollers attached with number of pegs, discharge outlet, power transmission system and main frame operated by 0.5 Hp motor. The disintegrating process was achieved by the use of a set of pegs attached with in metallic rollers, which beats and crush the feeds into smaller sized particles. Thus, it was tested by varying the following parameters: speed of the roller at 25, 35 and 45 rpm, feed rate at 100, 250 and 500 kg/h and clearance between pegs and roller at 10, 15 and 20 mm were used for the performance evaluation with the help of design expert software. The highest recovery efficiency of 92.50 was achieved at speed of 45 rpm, with the feed rate of 100 kg/hr and 10 mm clearance between pegs and roller. The optimum operating conditions for the disintegrating unit were found at 35 rpm speed with 15 mm clearance between pegs and roller and 250 kg/hr feed rate. The results however indicated that the new machine can perform better in terms of products with improved design.*
Keywords*: Disintegration, palmyrah palm jaggery, recovery efficiency*

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I. Introduction

Gur (Palmyrah Jaggery) is a natural, traditional sweetener made by the concentration of palm sap or juice. It is an unrefined non-centrifugal sugar consumed in Asia, Africa, Latin America and the Caribbean. Palm Jaggery (called Karupatti vellam or panavellam) is quite popular in the southern districts of Tamil Nadu.

In recent times, different forms of jaggery are available in the market viz., solid, liquid and powder or granular forms. Price of palm jaggery is determined by its quality, colour, flavour and texture. The demand of palm jaggery granules is growing rapidly due to ease in use, handling, packaging and storage. Raw jaggery which is large and solid at room temperature gains the moisture after three to four months and reduces the market value of the jaggery. The jaggery granules have same characteristics of taste, sweetness and molecular structure as that of raw jaggery. The overall life and quality of powdered jaggery is much better when compared to the available raw jaggery.

Raw palm jaggery contains a lot of impurities. In order to remove these impurities jaggery needs to be processed further by using a series of unit operations. So as to carry out these processes, the lump blocks of palm jaggery should be disintegrated in to small sizes.

Currently manual disintegration is being carried out in industries which are crude, unhygienic, labour intensive and time consuming process. With the intention of alleviating these constraints in the processing field, a continuous type palm jaggery disintegrating unit was fabricated.

II. Materials And Methodology

i) Design of palmyrah palm jaggery disintegrating unit;
The diameter of shaft, length of the pegs and power requirement were calculated using standard procedures.

1. Diameter of disintegrating roller

L/D -3 to 4

D-Diameter of the disintegrating roller, mm
L -Total length of rotor shaft, mm
To attain a length to diameter ratio of 4, Hence, the minimum diameter of the roller assumed as 182.5 mm, based on this each roller diameter was chosen as19.8 cm.

2. Length of the peg (Lp)

Length of pegs was selected in such a manner that the peg was able to pass up to the middle of the jaggery. Based on the physical properties mean height and diameter was obtained as 41±0.69 mm and 93±0.49

mm respectively. Based on the preliminary trails, maximum size of final disintegrated jaggery required was fixed as 30 mm; accordingly the length of the peg (Lp) was taken to be 30±5 mm diameter as 10 mm.

3. Power requirement

$$Hp = 2\pi N_1 T/4500$$

Hp - horse power;
N_1 - rotor shaft speed, rpm;
T - torque, kg-m

Torque = force x distance
From the experiments conducted using drop test method, the maximum force required was calculated was19 kg.
Distance = diameter of roller(d)/2 + Length of peg (L_P)/2
Actual power requirement =Calculated Hp/ Mechanical efficiency

Hence, standard 0.5 Hp motor was selected.

4. Design turning moment

$$(M_e * i / \eta) * K_{ov}$$

M_d- design turning moment;
I - transmission ratio
η - transmission efficiency
K_{ov} - coefficient of overloading
M_e - sturning moment of drum

Transmission ratio (i) = motor rpm (N_2)/ roller rpm (N_1)

It was assumed that transmission efficiency of 80 per cent and coefficient of overloading as 1.5 and substituting these values of K_{ov}, i, η and M_e
Maximum permissible turning moment was calculated by using the formula (Khurmi, 2001).

Maximum permissible turning moment = $f_s * \pi/19 * (d^3)$
f_s - maximum permissible shear stress of the material of the metal roller, kg/cm^2
d - diameter of the roller, cm
The design turning moment of the roller (M_d) was well below the maximum permissible turning moment (f_s). Hence, the design was assumed to be safe.

5. Design of shaft

$$M_d = (f_s * \pi * d_s^3)/ 16$$
d_s - diameter shaft, cm
Hence, the next standard size of 2.8 cm was selected.
Assuming uniform distribution of load on the shaft, maximum bending moment at the centre of the shaft

$$M = WL^2/8$$
w - weight per unit length, kg/m
L - length of the shaft, m

Maximum bending stress in the shaft (f) = **M/Z**
Z - modulus of section = I_p /R
I_p - polar moment of inertia of the shaft
R - radius of the shaft, cm
$$I_p = \pi d_s^4/32$$
The bending stress in the shaft was well below the permissible level for mild steel, Hence the design of shaft was consider as safe.

ii) Description and Operation of the Disintegrating unit

It consisted of simple components namely feed hopper, disintegrating assembly, metallic roller, discharge outlet, eccentric mechanism, power transmission system and main frame operated by motor. Power supply was switched on to start the electric motor to run the disintegrating unit. As the disintegrating unit attained the required speed, jaggery was fed in to the feed hopper and operated at desired clearance. The broken jaggery was drawn into the discharge section from the disintegrating section by the impact shearing actions of the rotating rollers. The different sizes of disintegrated jaggery were collected at the outlet. The main principle of the unit is based on impact and shearing actions in order to obtain maximum recovery efficiency.

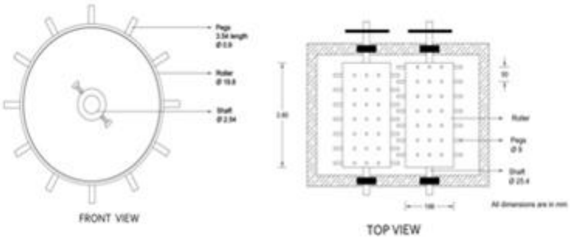
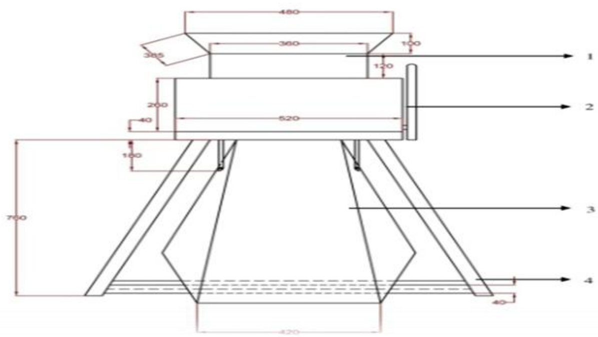


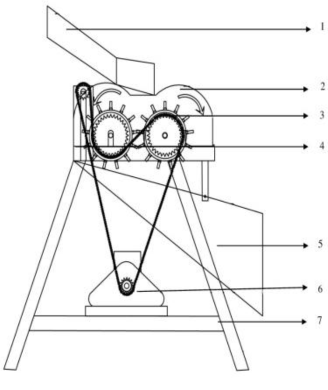
Fig. 1 Disintegrating assembly

Fig.2 schematic diagram of disintegrating assembly



1-Feed hopper, 2- Disintegrating assembly, 3- Discharge outlet, 4- stand

Fig.3 Front view of Palmyrah palm jaggery disintegrating unit



1-Feed hopper, 2- Disintegrating assembly, 3- Pegs,4- Metallic rollers,5- Discharge outlet, 6- Motor,7- leg

Fig.4 Side view of Palmyrah palm jaggery disintegrating unit

Fig: 5 Palmyrah palm jaggery disintegrating unit

Experiments were conducted to identify the process variables and their levels for the disintegrating of jaggery, studies were carried out by changing the various combinations of feed rate, clearance and shaft speed with the help of design expert software (version:6.0.8).

Calculation of recovery efficiency = (weight of the disintegrated product/ weight of the feed) x 100

III. Result And Discussion

There should be good and perfect interaction of jaggery with the disintegrating roller for achieving a maximum disintegrating efficiency. Hence, optimization of selected process parameters such as speed, feed rate and clearance were done to get maximum recovery efficiency.

1) Effect of recovery efficiency on speed of the disintegrating unit

The size of the jaggery is irregular in nature and to apply uniform impact force over the jaggery is very difficult. During the preliminary experiments, it was found that more than 40 per cent of jaggery was not impacted. By reducing the speed below 45 rpm, the residential time increased and the chance of jaggery to get impact was also increased. Hence, it was decided to test the performance of the disintegrating unit with a 10 rpm speed deviation starting from 25 to 45 rpm. Result revealed that increase in disintegrating efficiency from 85% to 97.25 % for the increase in speed from 25 to 45 rpm. The low disintegrating efficiency at minimum speed of 25 rpm was due to the low impact force applied on to the jaggery which led to partial broken condition of jaggery at the outlet. At time it was stuck on the pegs due to the lower rotation of the rollers. Increased efficiency at higher shaft speed of 45 rpm was due to shorter residence time of jaggery in the disintegrating section.

Sl No	Combination	Speed (rpm)	Feed rate (kg/hr)	Clearance (mm)	Recovery efficiency (%)
1	S2F2C2	35	250	15	95.2
2	S1F2C2	25	250	15	85
3	S2F2C3	35	250	20	94
4	S1F3C3	25	500	20	80
5	S2F2C2	35	250	15	94
6	S2F2C2	35	250	15	95.6
7	S3F3C3	45	500	20	96
8	S1F2C1	25	100	10	87
9	S2F2C1	35	250	10	93
10	S1F2C1	45	100	10	97.5
11	S2F2C1	45	100	20	97.2
12	S1F2C1	45	500	10	95
13	S2F2C1	35	250	15	94.1
14	S1F2C1	25	100	20	86
15	S2F2C1	35	500	15	90
16	S3F2C2	45	250	15	95
17	S1F3C1	25	500	10	80.1
18	S2F1C2	35	100	15	96.8
19	S2F2C2	35	250	15	93
20	S2F2C2	35	250	15	96.6

Table 1 Combination of experimental results on speed, feed rate and clearance of disintegrating unit

2) Effect of recovering efficiency on feed rate of the disintegrating unit

The recovery efficiency was high at the feed rate 250 kg/h due to more residence time and all the jaggery were subjected to impact force. It was found that stickiness of the jaggery was less. Further increase in the feed rate from 250 to 500 kg/h the recovery efficiency decreased. The minimum recovery efficiency was observed at the feed rate of 500 kg/h

3) Effect of clearance on recovering efficiency of the disintegrating unit

From the studies on engineering properties of jaggery, it was found that the mean height of the jaggery was 41.1±0.69 mm and diameter was 93.0±0.49 mm. Hence, the clearance of 20 mm was kept between the roller and the tip of the pegs. So with decrease in the distance between adjustable roller and peg, more impact force was exerted on jaggery. The recovery efficiency was found to be higher at 15 mm clearance with 94 %. From the table1.1, it can be observed that there was increase in recovery efficiency from 93 % to 95.2 % with the increase in clearance from 10 to 15 mm and then started decreasing from 95.2 to 94 % with further increase in clearance from 15 to 20 mm, because of lower impact on the jaggery at a clearance of 20 mm. More breakage of jaggery was noted when the clearance was 15 mm compared to 20 mm horizontal clearance of roller.

IV. Conclusion

Table.1 presents the combination of experimental results on speed, feed rate and clearance the corresponding values of three parameters and the response based on experimental runs. Based on the above operating parameters recorded, for the best performance of the disintegrating unit, the following operating conditions are recommended. The optimum operating conditions for the disintegrating unit were found at 35 rpm speed with 15 mm clearance between pegs and roller and 250 kg/hr feed rate.

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