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Optimization of Process Parameters for Palmyrah Jaggery Production

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ABSTRACT

Palmyra palm (*Borassus flabellifer* L.) is one of the most important and an alternate source for production of jaggery. Palmyra palm jaggery is used in the preparation of ayurvedic/traditional medicines, which will reduce the chances of lung cancer, diabetes and obesity. Processing parameters like lime quantity used to prevent fermentation of neera, and its heating temperature and time were not specific leading to low quality product. In the present study, a central composite rotatable design was used to optimize the process parameters like lime, heating temperature and heating time, developed mathematical models and response surfaces for estimation of total sugars, ash and moisture content of palmyra palm jaggery. The best combination obtained to get the good quality solid palmyrah jaggery was at lime 2.1%, temperature 121°C and time 174 min. Total sugars were increased with increase in temperature and time, but lime has less effect. Ash content was more affected with lime, but less with the time and temperature. Moisture content was more affected by temperature and less with time and lime content. The jaggery solid has proximate composition of 8.5% moisture content, 0.17% fat, 0.98% protein, 4.5% ash and 90.6% carbohydrates. Sensory evaluation of jaggery revealed that the jaggary produced at 2.1% lime, 111°C temperature and 126 min time, has superior quality.

Key words : Central composite rotatable design , Palmyra palm jaggery.

Palmyrah palm (*Borassus flabellifer* L.) belongs to the family *Palmae,* used for tapping neera. Among 103 million palms in India, 30 % of trees are present in Andhra Pradesh (Ghosh *et al*., 1998). India produces about 6 million tonnes of jaggery annually, which accounts 70% of world production, 65-70% of the total jaggery produced from sugarcane and the remaining 30% is from palms (Rao *et al*., 2009). Palmyra palm is one of the most important and an alternate source for the production of jaggery or gur to the traditional sugarcane crop (*Saccharum officinarum*). Market price of palm jaggery is determined by quality, especially the flavor and texture. The palm jaggery industry rural in nature and production process was controlled by the experienced operators having less scientific knowledge, which leads to low quality solid jaggery production (Guerra and Mujica, 2009).

Solid jaggery from palmyrah is not commercialized as the process for the preparation was not standardized and traditional practices are exists. Even though the palmyra is an economically important palm, much attention from the agricultural research workers has not been received. Hence the present study was carried out to standardize the process for production of solid jaggery.

MATERIAL AND METHODS

Fresh neera (palm juice) was tapped from about 18 trees in the early morning between 6-7 AM using sharp knife. Fresh neera was collected in lime treated earthen pots during for the preparation of jaggery.

To avoid large number of experiments with three independent variables (lime, time, and temperature), a Central Composite Rotatable experimental Design (CCRD) was used to design the experiments to optimize process parameters. For optimizing the independent variables, fifteen experiments were carried out according to CCRD and their combined effects were studied. CCRD experiment was made with three independent variables viz., quantity of lime (X_1), heating time (X_2) and Temperature (X_3). In the study, the optimization of process variables was carried out using Design Expert 8.0.7.1 software. Table 1 gives complete experimentation using Design Expert 8.0.7.1 software.

The following parameters were studied keeping in view of its importance.

Total sugars: It is an important nutritional component which determines the sweetness of the product. The total sugars content was estimated by anthrone method (AOAC, 2005).

Ash: Ash content of food stuff represents inorganic residue remaining after destruction of organic matter. High ash content indicates presence of adulterants in food material. It was determined according to the method given by AOAC, 2005.

Moisture content: Moisture content influences the storage life and microbiological changes in food. It was determined by hot air oven method (AOAC, 2005).

Fat: Fat content in jaggery is very less and it was determined by soxhlet method (Ranganna, 1994).

Protein: Protein content was estimated by Lowry's method (AOAC, 2005).

Sensory evaluation: Sensory evaluation was done using 9-point hedonic scale method (Ranganna, 1994). The hedonic rating test is used to measure the consumer acceptability of product.

RESULTS AND DISCUSSION

Fresh neera was analyzed for pH and total soluble solids (sugar concentration) in °Brix according to lime quantity. It was absorbed that the fresh near samples contain the pH value in the range of 9-14, TSS 7-15 °Brix and lime is 0.9 – 2.5%.

Optimization of total sugars

A nonlinear second order regression equation was developed by design expert software as a function of independent real values of lime % (x_1), temperature °C (x_2) and time min (x_3) for the dependent variable total sugars (S) has been given in equation (1).

$$S = 89.99 + 1.08x_1 - 0.12x_2 + 0.037x_1^2 - 0.14x_2^2 + 0.037x_3^2 (R^2 = 0.97) \quad (1)$$

Table 1. Design of experiment for jaggery preparation with three independent variables in CCRD.

Expt. No.	Lime, % (X_1)	Temperature, °C (X_2)	Time, min (X_3)
1	1.5 (0)	124 (+1.682)	150 (0)
2	0.9 (–1)	121 (+1)	174 (+1)
3	1.5 (0)	117 (0)	150 (0)
4	2.1 (+1)	113 (–1)	174 (+1)
5	0.5 (-1.682)	117 (0)	150 (0)
6	1.5 (0)	117 (0)	190 (1.682)
7	0.9 (-1)	111 (-1)	126 (-1)
8	2.1 (+1)	121 (+1)	174 (+1)
9	2.1 (+1)	121 (+1)	126 (–1)
10	2.1 (+1)	111 (-1)	126 (-1)
11	0.9 (-1)	121 (+1)	126 (-1)
12	0.9 (–1)	111 (–1)	174 (+1)
13	1.5 (0)	117 (0)	110 (-1.682)
14	1.5 (0)	110 (-1.682)	150 (0)
15	2.5 (1.682)	117 (0)	150 (0)

Table 2. Proximate composition of solid jaggery.

Item	Moisture,% d.b	Fat, %	Protein, %	Ash, %	Carbohydrate, % (by difference)
Solid	8.50	0.17	0.98	4.5	90.60
Control	9.19	0.17	0.35	2.5	92.00

Fig. 1 (a) Response surface plots showed that the lime effect on total sugars was less. When temperature increases the total sugars increases with increase in lime. The reason behind was that the more percent of lime arrests fermentation of sap and evaporation of water with increase in temperature respectively. Fig. 1 (b) showed that the response surface plot of total sugars as lime and time indicated that the total sugar content decreased from 90.4%to90% when the lime percentage increased from 0.9% to 2.1% percent at the constant time of 126 min. Total sugars content slightly decreased from 90.4% to 85.3% percent when the time increased from 126 min to 150 min and thereafter slightly increasing trend in total sugar percentage was observed till 174 min of time. Fig. 1 (c) showed that the response surface plot of total sugars as temperature and time indicated that the total sugars slightly increased from 90% to 90.4% when the temperature rose from 113°C to 121°C at 126 min time. Total sugars content followed decreasing trend up to middle point and thereafter follows increasing trend when the time increased from 126 min to 174 min at 113°C temperature. Increase in total sugars was also observed at higher temperature and higher time and reached a maximum value of 90.8 percent at 174 min of time 121°C temperature.

Optimization of ash content

A nonlinear second order regression equation was developed by design expert software as a function of independent real values of lime, % (x_1), temperature, °C (x_2) and time min (x_3) for the dependent variable ash (A) has been given in equation 2.

$$A = 2.01 + 0.96x_1 + 0.14x_1^2 - 0.037x_2^2 - 0.037x_3^2 (R^2 = 0.98) \quad (2)$$

Fig. 2 (a) Response surface plots showed that at lower temperature, the ash content was decreased from 1.7% to 1.1% when the lime percentage increases at 113°C. When temperature increases, ash content also increases with increase in lime %. The reason behind the increase in ash content with increase in temperature may be due to heating inorganic residue increases with evaporation of water content in the form of vapours. Ash decreases with increase in lime content was due to lime arrests fermentation of sap causing incomplete destruction of organic matter. Fig. 2 (b) showed that response surface plot of ash as lime and time indicated that the ash content is not changed when the lime percentage increased. The ash content has relatively less effect of lime and more effect of time was noticed. Ash content starts decreased in parabolic paths when time increased from 126 min to 150 min time there after increased to 2.2% ash content at 174 min. The reason behind the increase in ash content with increase in time is due to the boiling inorganic residual increases. Fig. 2 (c) showed that response surface plot of ash as function of temperature and time indicated that the ash content increased from 1.8% to 2.5% when temperature increased from 113°C to 121°C at 126 min. Ash content decreasing trend while time reached from 126 min to 150 min time there after percentage of ash content increased when the time increases. Ash content finally reached a point of 1.7%, at 174 min and 113°C temperature. It was concluded that ash content was significantly affected with lime, but negligible effect with the time and temperature.

Table 3. Sensory evaluation of solid jaggery samples.

Quality attributes	S_1 (174 min, 111 °C and 0.9 %)	S_2 (150 min, 124 °C and 1.5 %)	S_3 (150 min, 117 °C and 2.5 %)	S_4 (126 min, 111 °C and 2.1 %)	S_5 (174 min, 121 °C and 0.9 %)	S_6 (150 min, 117 °C and 0.5 %)	S_7 (174 min, 121 °C and 2.1 %)	S_8 (150 min, 117 °C and 1.5 %)	S_9 (126 min, 121 °C and 0.9 %)
Colour	5	6	2	8	7	6	7	5	9
Taste	8	5	3	9	7	8	8	6	8
Flavour	9	6	2	8	7	3	4	5	4
Texture	8	6	5	9	8	7	9	6	3

Optimization of moisture content

A nonlinear second order regression equation was developed as a function of independent real values of lime, % (x_1), temperature, °C (x_2) and time min (x_3) for the dependent variable moisture content (M) has been given in equation 3.

Fig. 3 (a) shows that response surface plot of moisture content as lime and temperature indicated that the moisture content decreased from 5.3% to 4.3% when the temperature increased from 113°C to 121°C at 0.9% lime. Moisture content decreased with increase in temperature and it was

$$M = 4.98 - 0.12\,x_1 - 1.49\,x_2 - 0.017\,x_1^2 + 0.28\,x_2^2 + 0.11\,x_3^2\,(R^2 = 0.97) \qquad (3)$$

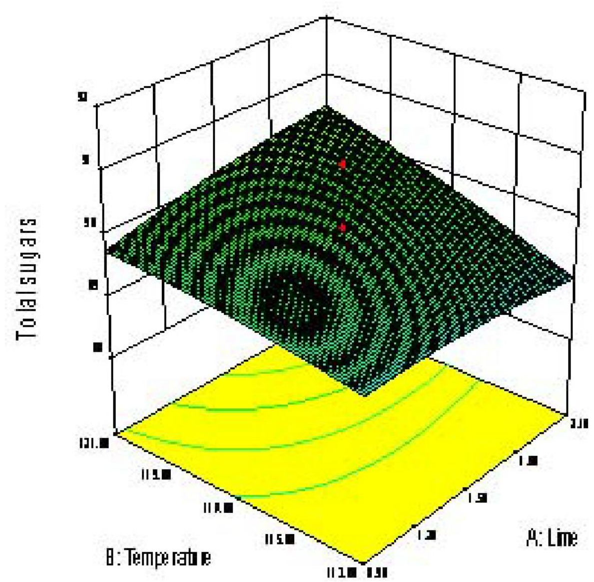


Figure 1(a). Effect of lime and temperature on total sugars at constant time 150 min.

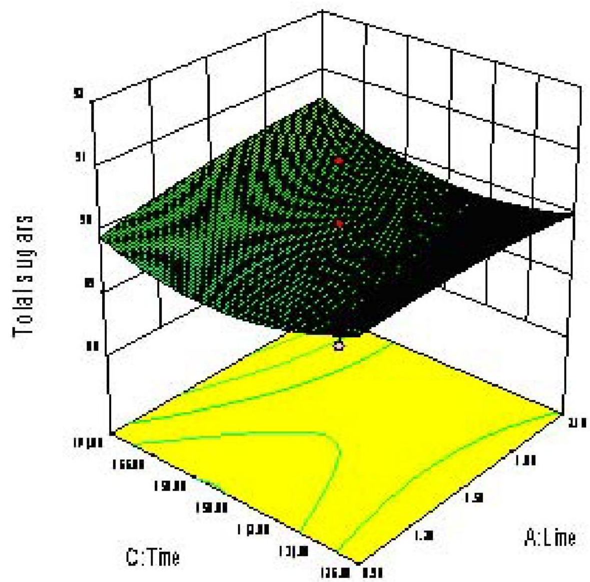


Figure 1(b). Effect of lime and time on total sugars at constant temperature 117°C.

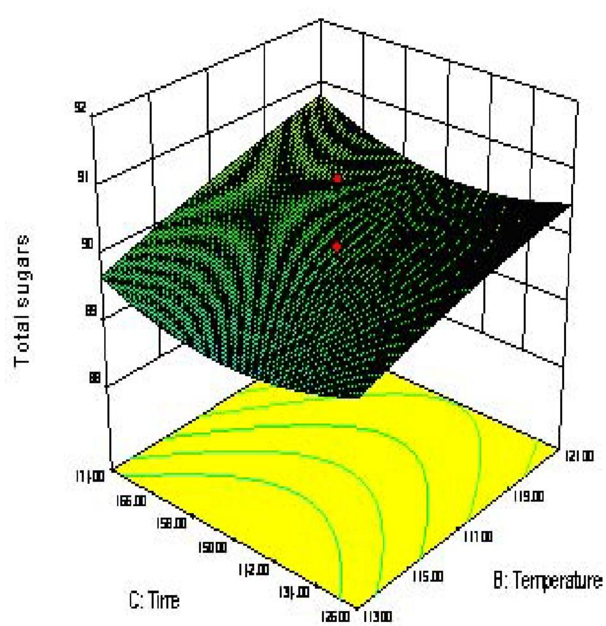


Figure 1(c). Effect of temperature and time on total sugars at constant lime 1.5%.

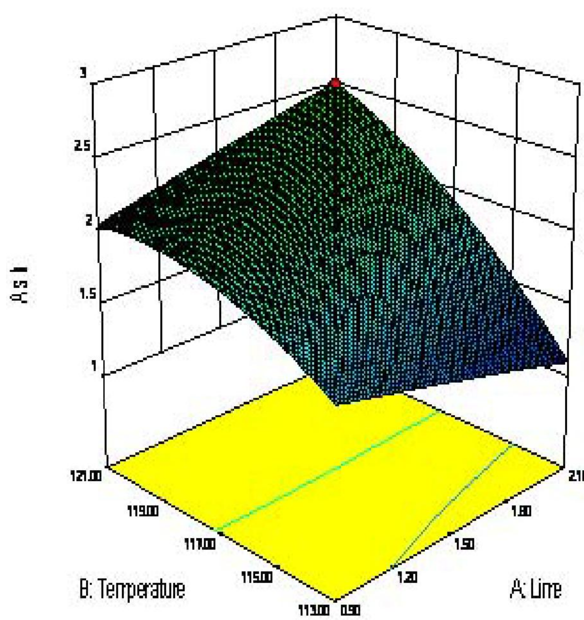


Figure 2(a). Effect of lime and temperature on ash content at constant time 150 min.

Figure 2(b). Effect of lime and time on ash content at constant temperature 117°C.

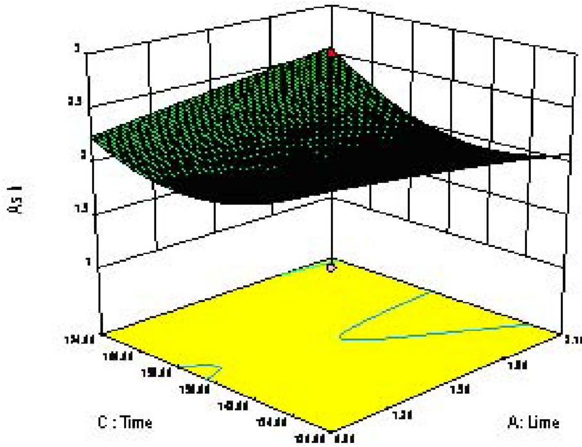


Figure 2(c). Effect of temperature and time on ash content at constant lime 1.5%.

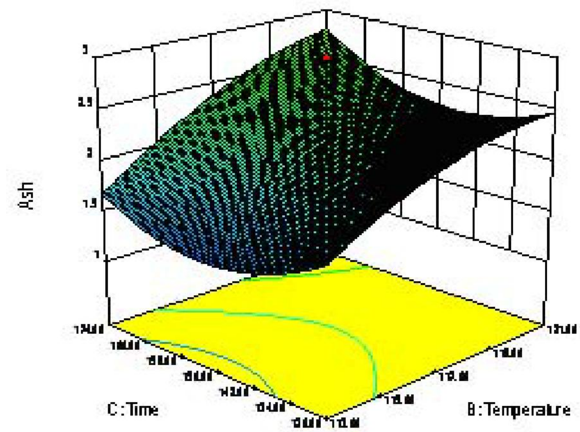


Figure 3(a). Effect of lime and temperature on moisture content at constant time 150 min.

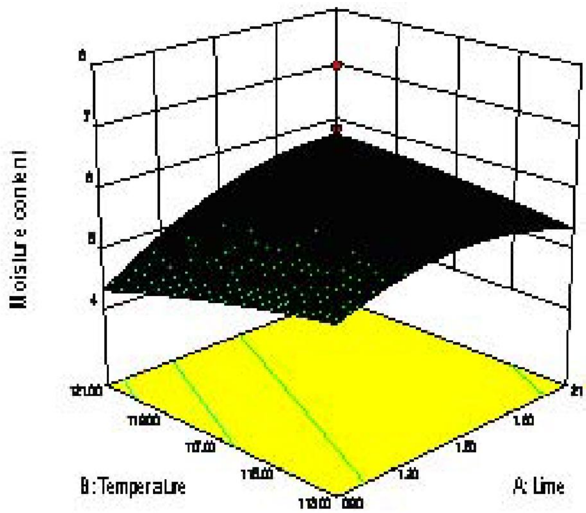


Figure 3(b). Effect of lime and time on moisture content at constant temperature 117°C.

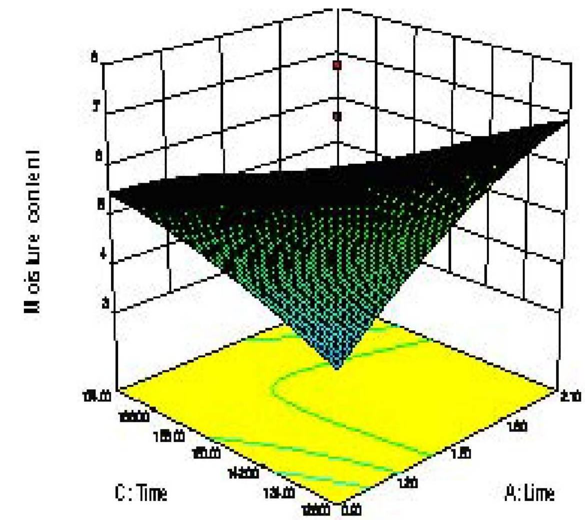
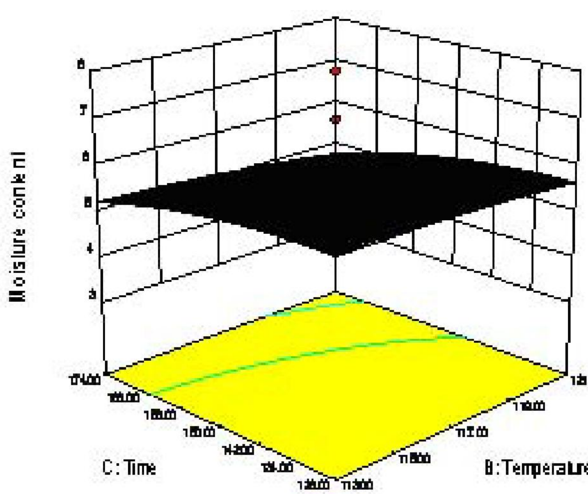


Figure 3(c). Effect of temperature and time on moisture content at constant lime 1.5%.



not changed when lime percent increased at lower temperatures but increases at higher temperatures. Fig. 3 (b) shows that moisture content increased drastically from 4.2% to 6.8%, as the lime increased from 0.9% to 2.1% lime at 126 min. At lower lime percent the moisture content increases with time but moisture content decreased at higher time and lime percent. Fig. 3 (c) shows that the moisture content of jaggery was affected by temperature and little effect with respect to both time and lime content.

Proximate Composition

The proximate composition of best quality jaggery at lime 2.1 percent, temperature 121°C and time 174 min is presented in Table 2. Variation in proximate compositions of solid and control jaggery samples can be observed from the Table 2. Moisture content of solid jaggery was less than control sample. Least moisture content in solid jaggery sample enhances its shelf life and provides better keeping quality compared to the control sample. Same fat content has been observed in solid and control samples. Higher protein content has been observed in solid jaggery compared to control sample. Ash content was higher for solid jaggery compared to control sample. Carbohydrates were higher for control sample compared to solid jaggery.

Sensory evaluation of solid jaggery

Solid jaggery samples S_4, S_5, S_7, and S_9 had higher scores for colour; S_1, S_4, S_5, S_6 and S_7 for taste; samples S_1, S_4, S_5, S_7 and S_9 for flavour; and samples S_1, S_4, S_5, and S_7 for texture / appearance (Table 3). Among all nine jaggery samples, sample S_4 scores well for all quality attributes.

Conclusion

Among fifteen combinations, the best combination suited for the preparation of solid jaggery was lime 2.1 %, temperature 121 °C and time 174 min. Sensory evaluation of jaggery inferred that the jaggery produced at 2.1 % lime, 111 °C temperature and 126 min time, scores well for all quality attributes of sensory evaluation.

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