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PERFORMANCE EVALUATION OF BRUSH TYPE PULPER FOR STANDARDIZATION OF MORINGA POD PULP EXTRACTION

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ABSTRACT

Moringa oleifera is called "miracle vegetable" because it is valued as a medicinal and functional food. The pericarp is the outer layer, which is hard in texture, astringent in taste is discarded. The moringa pod can be utilized to its maximum potential if proper value-addition through processing is developed. The manual separation of pulp from peel (pod skin) is not commercially possible due to laborious, tedious, time consuming and unhygienic practices. In current study, the pulp from moringa pods was efficiently extracted with brush type pulper. The most effective pulping parameters were 2.7 kg/min feed rate, 3 mm sieve size and 1260 rpm shaft speed where the pulp yield was 43.25%, extraction efficiency was 97.70% and the extraction losses were 1.01%.

Key words : Brush type pulper, Efficient, Functional food, Moringa pod, Pulp.

Introduction

India is the second largest producer of vegetables in the world with an estimated production of about 204 million metric tons from an area of 11.28 million hectares (NHB, 2022). Vegetables play an important role in the economy of a country. They are important sources of vitamins and minerals required for human nutrition. Pre and post-harvest losses of vegetables are the major problems in India. By adopting modern post-harvest technologies for processing of fresh vegetables, a significant quantum of vegetables which are getting spoiled can be salvaged.

Moringa oleifera is called "miracle vegetable" because it is valued as a medicinal and functional food. India being the largest producer of moringa, has an annual production of 2.1 to 2.3 MT from an area of 61,600 hectare. Moringa is an underutilized vegetable crop in India and almost all parts of the tree are edible. In literature, moringa is often called the *Power house of minerals* and *Mother's best friend*. The pericarp is the outer layer, which is hard in texture, astringent in taste is discarded. The moringa pod can be utilized to its maximum potential if proper value-addition through processing is developed. Owing to the fact that the moringa pod is available in large quantities during the harvesting season (November to March), leads to shortage in off season. The pulp can be extracted from pod and preserved for direct consumption or can be further processed to formulate value-added products.

The manual separation of pulp from peel (pod skin) is not commercially possible due to laborious, tedious, time consuming and unhygienic practices. Hence, there is need for automated pulp extraction system. A brush type pulper is commercially utilized for various fruits and vegetables. The brush type pulper can be used to extract pulp from pods. The blanched pieces of moringa fed to the pulper. The main shaft with the attached brushes squeezes and ruptures pod against the perforated screen cylinder and releases the pulp, leaving behind the broken pod covers. The pulp can be collected at the bottom, while the pod covers are discharged along the horizontal axis of the main shaft. The performance of the pulper can be evaluated in terms of pulp yield, extraction efficiency, extraction loss, and machine throughput by varying feed rate, shaft speed and sieve size (Hmar *et al.*, 2018).

The pulp extraction parameters of brush type pulper were evaluated for various horticultural produce like tomatoes, mangoes and kendu (Thirupathi *et al.*, 2006; Shah, 2015; Hmar *et al.*, 2018). With slight modification in operational parameters the brush type pulper can be used for moringa pods pulp extraction.

Materials and Methods

Matured moringa pods (var. PKM-1) were procured from the horticultural farm of the Anand Agricultural University, Anand. Raw pods were thoroughly washed in the running tap water to remove extraneous material, and other surface contaminations. The cutting of moringa pods was carried out using steel knife 64 mm pod length followed by blanching at 95°C 9.41 min to inactivate peroxidase enzyme (Ravani *et al.*, 2020).

A brush type pulp extractor was used for extraction of pulp from moringa pods. Pulp was extracted from appropriately blanched moringa pod pieces in single pass using a pulper (Khera laboratory instruments, New Delhi). The pulper was an electrical powered (2.24kW, 3HP motor) continuous type machine having rotating brush arrangement with stainless steel screen (Fig. 1). Brushes were connected with the shaft at a distance of 25 mm and placed inside the sieve to spread the blanched sample. The sieves were made up of 22 gauge stainless steel having length of 39.5 cm, inner diameter of 16.0 cm and outer diameter of 17.0 cm (Fig. 2).

The blanched pieces were fed through the hopper and pushed forward through shaft and brush. The main shaft with the attached brushes squeezes and ruptures pod against the perforated screen cylinder and releases the pulp, leaving behind the broken pod covers. Pulp extraction was due to continuous crushing, cutting and shearing operations during rotation. The pulp was collected at the bottom, while the pod covers were discharged along the horizontal axis of the main shaft. The performance of the pulper was evaluated in terms of pulp yield, extraction efficiency, extraction loss, and machine throughput by varying feed rate, shaft speed and sieve size (Table 1).

Table 1 : Variable and responses for the experiment.

Independent variables	Levels	Range
Feed rate (kg/min)	3	2 – 3 kg/min
Shaft speed (rpm)	3	1100 – 1400 rpm
Sieve size (mm)	3	0.8 – 3.0 mm
Responses		
• Pulp yield (%) • Extraction efficiency (%) • Extraction loss (%)		

Standardization was done based on feed rate (2, 2.5 and 3 kg/min), sieve size (0.8, 1.6 and 3.0 mm) and shaft speed (1100, 1250 and 1400 rpm). The time required for the process and the yield of pulp, peel and waste were recorded for calculations of various performance indices. The pulping parameters were optimized based on maximum pulp yield and extraction efficiency and minimum extraction losses using Central Composite Design (CCD). Three replications were conducted and the average values were depicted in results.

Fig. 1 : Pulper with sieve and brush arrangements.

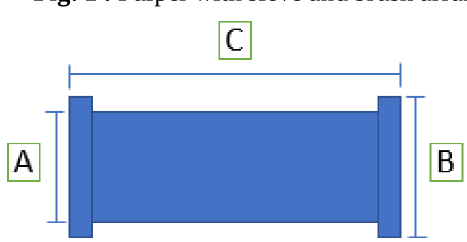

Fig. 2 : Sieve design with dimensions. **A** = Inner diameter (16 cm), **B** = Outer diameter (17 cm), **C** = SS Sieve length (39.5 cm).

Results and Discussion

A brush type pulp extractor was used for extraction of pulp from moringa. The pulper having provision for different sieves and shaft speed, was used for extraction of pulp. Effect of independent parameters *viz.*; sieve size, feed rate and shaft speed on dependent parameters *viz.* pulp yield, extraction efficiency and extraction losses were analysed and discussed in subsequent sections. The data pertaining to the effect of pulping parameters are presented in Table 2.

To visualize the combined effect of two factors on the responses, three-dimensional surface graphs were generated for each of the fitted models, keeping the third variable at centre. The analysis of variance (ANOVA) was conducted on experimental data and the significance of sieve size, feed rate and shaft speed as well as their

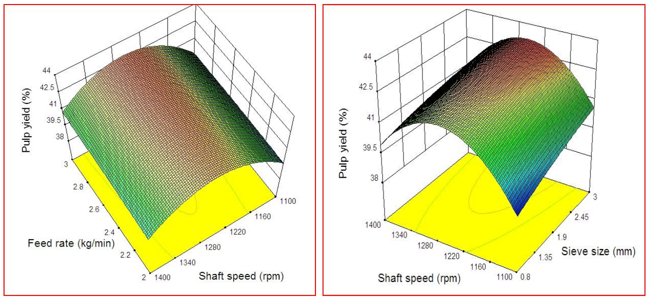

Fig. 3 : Influence of sieve size, feed rate and shaft speed on pulp yield.

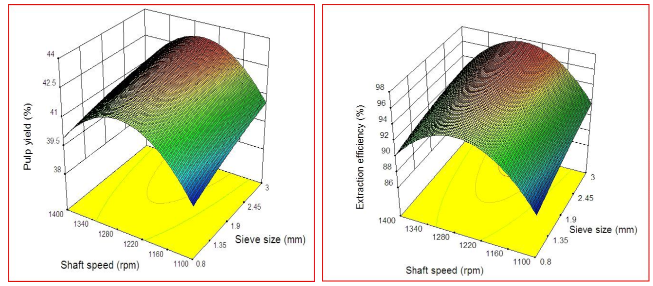

Fig. 4 : Influence of sieve size, feed rate and shaft speed on extraction efficiency.

Table 2 : Effect of pulping parameters on pulp yield, extraction efficiency and extraction loss.

Experiment no.	Feed rate (kg/min)	Sieve size (mm)	Shaft speed (rpm)	Pulp yield (%)	Extraction efficiency (%)	Extraction loss (%)
1	2.5	3.0	1100	40.55	91.62	3.71
2	2.5	1.6	1250	42.59	96.23	1.67
3	3.0	1.6	1400	40.77	92.11	3.49
4	3.0	0.8	1250	41.98	94.85	2.28
5	2.0	1.6	1100	39.65	89.58	4.61
6	3.0	3.0	1250	43.25	97.72	1.01
7	2.0	3.0	1250	42.98	97.11	1.28
8	2.5	1.6	1250	42.56	96.16	1.7
9	2.5	1.6	1250	42.67	96.41	1.59
10	2.5	0.8	1100	38.74	87.53	5.52
11	2.5	1.6	1250	42.69	96.45	1.57
12	2.5	3.0	1400	40.98	92.59	3.28
13	2.0	0.8	1250	41.56	93.90	2.7
14	3.0	1.6	1100	39.98	90.33	4.28
15	2.5	1.6	1250	42.74	96.57	1.52
16	2.5	0.8	1400	39.98	90.33	4.28
17	2.0	1.6	1400	40.05	90.49	4.21

interactions on pulp yield, extraction efficiency and extraction losses were calculated. The quadratic model was fitted to the experimental data. Statistical significance of linear, quadratic and interaction effects were calculated for each response. Influence of sieve size, feed rate and shaft speed on pulp yield, extraction efficiency and extraction loss is shown in Figs. 3 - 5.

Effect of feed rate, sieve size and shaft speed on pulp yield

Effect of process variables on pulp yield is depicted in Table 2. Pulp yield ranged from 38.74 to 43.25 %. The maximum value (43.25 %) of pulp yield was observed for experimental combination of 3 mm sieve size, 3 kg/min feed rate and 1250 rpm shaft speed. The minimum value (38.74%) of pulp yield was observed for experimental combination of 0.8 mm sieve size, 2.5 kg/min feed rate and 1100 rpm shaft.

The results showed that among linear effects, sieve size, feed rate and shaft speed had highly significant effect on pulp yield ($p<0.01$) at 1% level. Interaction effect of sieve size and shaft speed had highly significant effect on pulp yield ($p<0.01$) at 1% level. The interaction effects of sieve size, feed rate and feed rate, shaft speed were found to be non-significant. Quadratic effect of shaft speed was found to be highly significant on pulp yield ($p<0.01$) at 1% level of significance. Quadratic effect of sieve size was found to be significant on pulp yield ($p<0.05$) at 5% level of significance. Other quadratic effect was found to be non-significant (Table 3). The regression equation describing the effect of process variables on pulp yield of moringa pod is given as under.

Pulp yield (%) $= -134.88 + 2.73A + 0.51B + 0.276C - 0.068AB - 1.23BC + 1.30AC - 0.106A^2 - 0.32B^2 - 1.092C^2$

Where, A, B and C are coded values of sieve size (0.8 to 3.0 mm), feed rate (2.0 to 3.0 kg/hr) and shaft

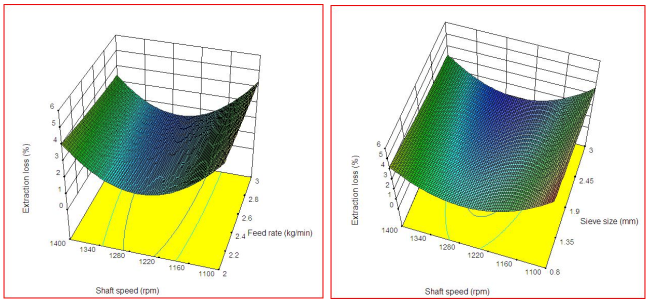

Fig. 5 : Influence of sieve size, feed rate and shaft speed on extraction loss.

speed (1100 to 1400 rpm), respectively.

From graphical presentation (Fig. 3), it can be seen that pulp yield increased with increase in shaft speed up to certain value and then decreased. With increase in feed rate and sieve size, increase in pulp yield was observed. At lower speed, feed rate and sieve size the pods were not crushed properly and due to less friction and shearing action of the machine resulting in lower pulp yield and higher losses. When the shaft speed, feed rate and sieve size increased, the pulp yield increased. This may be due to higher shaft speed resulted in more crushing and pulp moved faster. On further increase in shaft speed pods were conveyed without pulping resulting in less recovery.

With increase in feed rate, pulp yield increased and this may be due to the reason that at higher feeding rate, pulp might have filled the clearance between brush and cylinder surface completely. Hence due to more friction, more pulp might have separated which resulted into lower pulp loss. At lower feeding rate, the clearance between brush and cylinder surface might not completely filled and due to less friction, less pulp might have separated resulted into more pulp loss. The results correlated with the data reported by Hmar *et al.* (2018) for pulp extraction of Kendu. The authors designed and fabricated brush type pulp extractor and carried out performance evaluation of machine. They observed that at lower speed and feed rate, lower extraction and higher loss were noticed. Bakane *et al.* (2014) observed that on increasing feed rate and shaft speed of custard apple, the capacity and efficiency of machine increases.

Effect of feed rate, sieve size and shaft speed on extraction efficiency

Effect of process variables on extraction efficiency is shown in Table 2. Efficiency ranged from 82.64 to 92.26%. The maximum value (92.26%) of extraction efficiency of pulper was observed for experimental combination of 3 mm sieve size, 3 kg/ min feed rate and 1250 rpm shaft speed. The minimum value (82.64%) of extraction efficiency of pulper was observed for experimental combination of 0.8 mm sieve size, 2.5 kg/ min feed rate and 1100 rpm shaft speed.

Table 3 : ANOVA for effect of sieve size, feed rate and shaft speed on pulp yield.

Source	Df	Sum of Squares	Mean Square	p-value Prob > F
Model	9	31.34	3.48	< 0.0001
Sieve size-A	1	3.78	3.78	< 0.0001
Feed rate-B	1	0.38	0.38	0.0004
Shaft speed-C	1	1.02	1.02	< 0.0001
AB	1	0.005625	0.005625	0.4734
AC	1	0.16	0.16	0.0046
BC	1	0.038	0.038	0.0895
A^2	1	0.070	0.070	0.0321
B^2	1	0.026	0.026	0.1466
C^2	1	25.45	25.45	< 0.0001
Residual	7	0.069	0.009800	
Lack of Fit	3	0.047	0.016	0.1679
Total	16	31.40		
R^2		0.997		
Adj R^2		0.995		
CV (%)		0.24		

The results showed that among linear effects, sieve size, feed rate and shaft speed had highly significant effect on extraction efficiency (p<0.01) at 1% level. Interaction effect of sieve size and shaft speed had significant effect on extraction efficiency (p<0.05) at 5% level. The interaction effect of sieve size, feed rate and feed rate, shaft speed was found to be non-significant. Quadratic effect of shaft speed was found to be highly significant on extraction efficiency (p<0.01) at 1% level of significance. Quadratic effect of sieve size was found to be significant on extraction efficiency (p<0.05) at 5% level (Table 4). Other quadratic effect was found to be non-significant. The regression equation describing the effect of process variables on extraction efficiency is given as under.

Extraction efficiency (%) $= -287.72 + 5.83A + 1.09B + 0.59C - 0.15AB - 0.00262BC + 0.00277AC - 0.23A^2 - 0.67B^2 - 0.000233C^2$

Where, A, B and C are coded values of sieve size (0.8 to 3.0 mm), feed rate (2.0 to 3.0 kg/hr) and shaft speed (1100 to 1400 rpm), respectively.

Extraction efficiency increased with increase in sieve size and shaft speed. With increase in shaft speed extraction efficiency increased initially and then decreased. The increase in extraction efficiency with increase in shaft speed was due to more shearing action provided by the brush. Capacity of the pulper increased with shaft speed. However, extraction efficiency initially increased with shaft speed and then decreased. This was due increase in pulping when pods were in contact with brushes. At further increasing shaft speed, pods might have conveyed without pulping resulting in to decrease in extraction efficiency.

It was observed that extraction efficiency increased with increase in feed rate and sieve size. This may be due to the fact that at high feed rate, the quantity of pod fed to the pulper was more which forms thick layer of pulp on the roller brush and blocks the clearance between sieve and brush surface completely and pulp get extracted from sieves. More pulp was separated from peels because of more friction and shearing action resulted into higher extraction efficiency. At lower feed rate, less quantity of pod was fed to the pulper, which formed thin layer of pulp over the brush surface and did not fill the clearance between the sieve and roller brush completely. Hence, less pulp was separated from peels because of less friction and shearing action resulted in low extraction efficiency. Thirupathi *et al.* (2006) reported extraction efficiency of tomato pulper cum strainer initially increased with peripheral speed, and then decreased. Increase in extraction efficiency was observed on increasing the feed rate.

Table 4 : ANOVA for effect of sieve size, feed rate and shaft speed on extraction efficiency.

Source	Df	Sum of Squares	Mean Square	p-value Prob > F
Model	9	142.58	15.84	< 0.0001
Sieve size-A	1	17.21	17.21	< 0.0001
Feed rate-B	1	1.72	1.72	0.0004
Shaft speed-C	1	4.65	4.65	< 0.0001
AB	1	0.026	0.026	0.4734
AC	1	0.75	0.75	0.0046
BC	1	0.17	0.17	0.0895
A^2	1	0.32	0.32	0.0321
B^2	1	0.12	0.12	0.1466
C^2	1	115.82	115.82	< 0.0001
Residual	7	0.31	0.045	
Lack of Fit	3	0.21	0.071	0.1679
Total	16	142.89		
R^2		0.997		
Adj R^2		0.995		
CV (%)		0.24		

Table 5 : ANOVA for effect of sieve size, feed rate and shaft speed on extraction loss.

Source	Df	Sum of Squares	Mean Square	p-value Prob > F
Model	9	84.03	9.34	< 0.0001
Sieve size-A	1	8.42	8.42	< 0.0001
Feed rate-B	1	14.68	14.68	< 0.0001
Shaft speed-C	1	2.43	2.43	0.0020
AB	1	0.085	0.085	0.3996
AC	1	0.37	0.37	0.1033
BC	1	0.22	0.22	0.1899
A^2	1	0.18	0.18	0.2326
B^2	1	0.012	0.012	0.7479
C^2	1	56.85	56.85	< 0.0001
Residual	7	0.74	0.11	
Lack of Fit	3	0.69	0.23	0.081
Total	16	84.77		
R^2		0.99		
Adj R^2		0.98		
CV (%)		3.96		

Effect of feed rate, sieve size and shaft speed on extraction loss

Extraction loss ranged from 1.01 to 5.52%. The minimum value (1.01%) of pulp yield was observed for experimental combination of 3 mm sieve size, 3 kg/ min feed rate and 1250 rpm shaft speed. The maximum value (5.52%) of extraction loss of pulp was observed for experimental combination of 0.8 mm sieve size, 2.5 kg/ min feed rate and 1100 rpm shaft speed. Among linear effects, sieve size, feed rate and shaft speed showed highly significant effect on extraction loss ($p<0.01$) at 1% level. Interaction effect of sieve size, feed rate; feed rate, shaft speed and sieve size, shaft speed was found to be non-significant. Quadratic effect of shaft speed was found to be highly significant on extraction loss ($p<0.01$) at 1% level. Other quadratic effects were found to be non-significant (Table 5). The regression equation describing the effect of process variables on extraction loss is given as under.

Extraction loss (%) = $256.36 - 3.22A + 6.08B - 0.41C - 0.26AB + 0.00184AB - 0.00314BC + 0.00277AC + 0.17A^2 + 0.21B^2 + 0.000163C^2$

Where, A, B and C are coded values of sieve size (0.8 to 3.0 mm), feed rate (2.0 to 3.0 kg/hr) and shaft speed (1100 to 1400 rpm), respectively.

A decrease in extraction loss was observed on increasing shaft speed to some extent. Further increase of shaft speed resulted in increased extraction losses. A decrease in extraction loss was observed with increase in sieve size and increase in feed rate. This may be due to the reason that as shaft rotates with higher speed more centrifugal force might have exerted on the pods which forces pulp to come out of the larger sieve openings easily and reduces the quantity of pulp coming at peel outlet. This must have resulted in less extraction (pulp) loss on increasing shaft speed. As pulp yield and extraction efficiency increased, the extraction loss decreased and vice-versa. These results agreed with the findings for pineapple juice extractor reported by Adebayo *et al.* (2014). They reported that with increasing speed of centrifugal juice extractor and feed rate, extraction loss increased.

Optimization of pulp extraction parameters

The dependent parameters which affected the pulp extraction were feed rate, sieve size and shaft speed. For efficient pulp extraction, pulp yield and extraction efficiency should be maximum and losses should be minimum. Hence, these dependent parameters were taken into consideration for optimization of extraction parameters. With the help of Box-Behnken design and the design-expert 10.0.1.0 software, the optimization of the pulp extraction parameters was done and the optimized conditions are as follow.

1. Feed rate : 2.7 kg/ min
2. Sieve size : 3 mm
3. Shaft speed : 1260 rpm

The validation of the optimized solution was done at above levels of variables.

Conclusion

The pulp from moringa pods was efficiently extracted with brush type pulper. The most effective pulping parameters were 2.7 kg/min feed rate, 3 mm sieve size and 1260 rpm shaft speed where the pulp yield was 43.25%, extraction efficiency was 97.70% and the extraction losses were 1.01%. A significant reduction in extraction loss was observed on increasing shaft speed (5.52 to 1.01%). It was observed that the pulp yield increased significantly with increase in shaft speed up to 1260 rpm. The extraction efficiency increased significantly with increase in feed rate and sieve size. With increase in shaft speed, extraction efficiency increased initially and then decreased.

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