Article citation info:
Karate M., Kamble K., Dhawale S. 2026. Optimization of operational parameters of developed power operated raw mango cut-ting machine using response surface methodology . *Journal of Research and Applications in Agricultural Engineering* 71 (2): 72–82. https://doi.org/10.53502/jraae-241312

Łukasiewicz Poznań Institute of Technology

Journal of Research and Applications in Agricultural Engineering

Journal website: https://www.jraae.com/



Optimization of operational parameters of developed power operated raw mango cutting machine using response surface methodology

Mayur Popat Karate [a]*
Kailas Kamble [b]
Shubham Dhawale [a]

[a] Processing and Food Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, India
[b] Agricultural Process Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, India

Article info
Received: 07 July 2026
Accepted: 02 October 2026
Published: 20 November 2026

Keywords
cutting capacity
cutting efficiency
damage percent
RSM
design expert

Raw mangoes used for preparation of pickle, chutney etc. which are consumed daily. Traditionally, raw mango cutting is time consuming and labour-intensive task. To overcome such issues, a power operated machine for cutting raw mangoes was developed to enhance the cutting efficiency. To optimize the machine's performance central composite design was used using response surface methodology by Design Expert software. The study aimed to determine the optimal cutting shaft speed and feeding rate of mangoes for maximizing cutting capacity, cutting efficiency, and minimizing damage percentage. The optimal cutting shaft speed and feeding rate was found to be 34.5 rpm and 12 kg/h, respectively. The experimental results at optimal level was observed: maximum cutting capacity and cutting efficiency of 110 kg/h and of 81.98%, respectively, and minimum damage percentage of 17.26%. The average dimensions of cubes of raw mangoes were observed 35.5 mm length, 27.2 mm width and 1.7 mm thickness.

DOI: https://doi.org/10.53502/jraae-241312
This is an open access article under the CC BY 4.0 license:
https://creativecommons.org/licenses/by/4.0/deed.en.

1. Introduction

In India, the mango is often known as the "king of fruits" due to its rich nutritional profile. It is an excellent source of carotenoids, ascorbic acid, and phenolic compounds (Masibo & He, 2008), as well as vitamins A and C, carbohydrates, especially dietary fibre and essential minerals like potassium and phosphorus (Shahid et al., 2015). Mangoes are cultivated in many countries and consumed worldwide. India is a major exporter of mangoes, having exported 32,104.09 metric tons of fresh mangoes worth USD 60.14 million in the 2023-24 fiscal year (APEDA, 2025). Raw mangoes are commonly used in pickles and chutneys, which is consumed in many Indian households. Traditionally, raw mangoes are cut using manual cutters, a process that is both labour-intensive and time-consuming. These traditional cutters, typically made of mild steel, causes blackening on the cut surfaces of the mangoes (Salve et al., 2020).

In traditional raw mango cutting methods, workers must continuously hold frame with one leg, which can lead to leg strain and reduced productivity (Patil & Chendake, 2017). Studies have shown that pickles made from manually cut mango slices have a shelf life of 180 to 210 days, whereas those made from mechanically cut slices last between 300 and 365 days (Anonymous, 2019). Most raw mango processing industries perform tasks such as cutting, peeling, slicing, dicing, and grading in unhygienic conditions. Therefore, it is

* Corresponding author: mayurkarate@gmail.com

crucial to mechanize these processes by developing efficient machines that reduce processing time and cost while enhancing and maintaining hygiene (Anonymous, 2019).

Preparation of mango pickles and chutneys requires a fruit at specific stage of maturity distinct from table ripe mangoes consumption. The mango for pickling is typically harvested at the mature green stage with full physiological maturity but with white, firm and acidic flesh, has not yet developed its full sweet, aromatic profile. Meena et al., (2023) selected mango fruits those are well matured and green colour with white flesh for preparation of pickle. The raw mangoes cut into small pieces of size 1 × 0.75 × 0.5 cm. Vasugi et al., (2008) developed mango pickle by harvesting mango fruits of maturity 75 days after flowering with tender green stage before formation of stony endocarp. The firmness of the fruit for pickle mangoes was observed in range from 3.59 to 5.65 kg/cm2. BIS (1999) recommended the size of mango pieces should not less than 1 cm and not more than 2.5 cm cubes or corresponding dimensions in other shapes for pickle preparation. Nath and Chattopadhyay (2007) observed that cubes of 2 cm x 2 cm offered optimal surface area to volume ratio for adequate moisture removal and salt uptake without excessive shrinkage or toughness. Jha et al., (2013) determined textural properties of mango at different maturities. The puncture force required for green mature was observed 40 to 85 N correlating with firmness for transportation and processing. Sirisomboon et al., (2008) observed 15 to 40 N shear force required for dicing of mangoes with sharp cutting blade. Karate et al., (2023) reported that the force requires to cut the wild variety of raw mango fruit was observed in the range between 79.433 to 199.136 N.

Mandhar and Kumaran (2000) evaluated the performance of raw mango slicer and cube cutter machine. It was observed that capacity and efficiency of slicer found to be 0.7 tonnes/h and 90%. The power required for the slicer was 6 hp and the cost of the slicer was US $2500 i.e. Rs.100000. The cube cutter operated by 5 hp motor for capacity of 0.65 tonnes/h and the cost of the cube cutter was US $ 3375 i.e. 135000. Salve et al., (2020) developed pedal and hand operated raw mango cutting machine which consists of cutting unit, cutting blades, cutter guide, tray handle and pedal lever and spout and main frame. The output capacity of machine observed 55.01 kg/h and 400 kg/day with 54 per cent labour saving over traditional method. Gaikwad (2015) reported slicing and cubing capacity of 500 kg/h and 200 kg/h, respectively for developed slicing and cubing machine for raw mango with overall efficiency of 90.39% and minimum damaged percentage with 9.60%. The total cost of mango slicer and cube cutter machine was reported Rs. 59400 and Rs. 40800, respectively. Although these machines give high capacity for raw mango slicing and cutting but the cost required for such machine also high. The small to medium household farmer's business cannot afford such high cost machine with required maintenance. Therefore the attempt was made to develop a small size and cost effective power operated raw mango cutting machine which should be affordable. Also, there is not available any machine with such a mechanism which utilize for raw mango cutting.

Mechanical slicing and cube cutting of raw mangoes significantly reduce fruit damage while enhancing efficiency and accuracy. To address the above mentioned issues related to raw mango cutting and handling, a cutting machine was developed, and its performance was evaluated. The performance of this machine is influenced by operational parameters. This research aimed to optimize this parameters to achieve the best performance from the developed machine.

2. Material and methods

The developed raw mango cutting machine consist of primary cutting blade, main frame, feeding hopper, holding shaft, cutting blades, upper trough plate, bottom trough plate and power transmission unit. The CAD view of developed raw mango cutting machine shown in Fig. 1 (Karate et al., 2022). The machine was fabricated using material like MS angle, MS sheet, MS square bar, SS plate, pulley, pedestal bearing and belt. The cutting of raw mango is divided into three steps: half cutting of mangoes, slice cutting and cube cutting. The half cutting of raw mango is done manually with regular knife with cutting blade provided at the top of the machine. Half-cut pieces of the raw mango insert into the feed hopper. The holding shaft forces mango pieces on the circular blade which get converted into slice form. Cut slices fall on the trough plate which convey slices to the second holding shaft. The second holding shaft forces slices on the circular blades provided intermeshing with it which convert the slices into cube shape. The cut cubes of the raw mango collected by the bottom trough plate which provided at the bottom of the machine.

The average force required to cut the mango was observed of 130.16 N (Karate et al., 2023) for wild variety of raw mango. In raw mango cutting machine the power provided to both cutting shafts by the 1 hp electric motor. The power transmission is carried out by the belt drive to the pulley attached on the shafts.

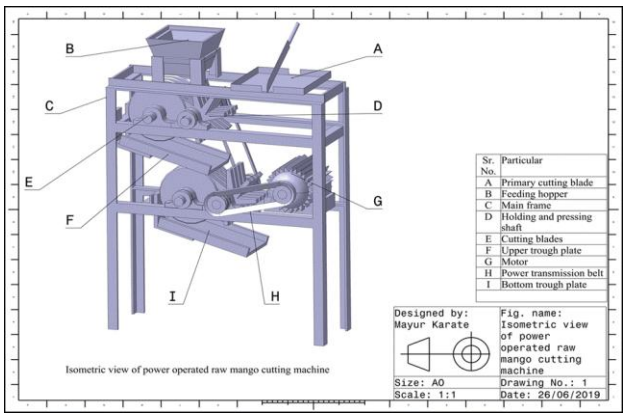


Figure 1. Isometric CAD view of developed raw mango cutting machine (Karate et al., 2022)

2.1. Experimental design

The performance evaluation of the developed raw mango cutting machine was conducted with a focus on its operational parameters. It was found that the speed of the cutting shaft and feeding rate of mangos, as an independent variable, has a significant impact on the machine's performance. Key responses such as cutting capacity, cutting efficiency, and damage percentage were analysed. The analysis was conducted using Design Expert software version 11.1.2.0 (Stat-Ease Inc., Minneapolis) by applying Response Surface Methodology (RSM) to determine the central composite design. Table 1 shows the range of levels for the independent variables. The minimum (27 rpm), central (34.5 rpm) and maximum (42 rpm) speed of cutting shaft was coded as -1, 0 and +1, respectively. The lower (5 kg/h), central (10 kg/h) and maximum (15 kg/h) feed rate of mangos coded as -1, 0 and +1, respectively. The value of α was considered 1 as design selected face cantered.

Table 1. Independent parameters and their coded levels

Variable	Units	Type	Minimum	Central	Maximum
A: Cutting shaft speed	rpm	Numeric	27.00 (-1)	34.5.00 (0)	42.00 (+1)
B: Feeding rate	kg/h	Numeric	5.00 (-1)	10.00 (0)	15.00 (+1)

Values in (_) are coded terms

The different treatment combinations for the independent parameter are detailed in Table 2. The software generated 18 experimental trials for three distinct cutting shaft speeds: 27, 34.5, and 42 rpm and three feeding rate: 5, 10 and 15 kg/h. The speed of cutting shaft was controlled by variable frequency drive (VFD) for different speed. These speed levels were determined based on preliminary trials of the machine. Speeds below 27 rpm caused raw mango pieces to stuck on the cutting discs, as the shaft lacked sufficient force to push the pieces through. Conversely, speeds above 42 rpm led to difficulties in feeding mango pieces into the cutting mechanism due to excessive speed. Therefore, the cutting shaft speed range was set from 27 rpm (the lower limit) to 42 rpm (the upper limit).

The experimental design included 18 test runs, each conducted in triplicate, as detailed in Table 2. For each response variable, an empirical model was developed using the independent and dependent parameters from the study. This model was formulated using a second-degree polynomial equation, as described by Chen et al., (2012).

$$Y_k = b_{k0} + \sum_{i=1}^{3} b_{ki} X_i + \sum_{i=1}^{3} b_{kii} X_i^2 + \sum_{i \neq j=1}^{3} b_{kij} X_i X_j \qquad (1)$$

where
Y_k = resultant response variables (%);
b_{k0} is the intercept coefficient;
b_{ki}, b_{kii}, b_{kij} are the linear, quadratic, interaction coefficient, respectively;
n is number of factors studied in experiment;
X_i, X_j are the coded independent parameters.

Table 2. Experimental responses for designed variable factor of coded and actual units

Sr. No.	Run	Coded values A: Cutting shaft speed (rpm)	B: Feeding rate (kg/h)	Actual values A: Cutting shaft speed (rpm)	B: Feeding rate (kg/h)	Response 1 Cutting capacity (kg/h)	Response 2 Cutting efficiency (%)	Response 3 Damage percent (%)
1	11	-1	-1	27	5	107.03*	76.18	18.73
2	18	-1	-1	27	5	107.07	75.98*	18.74
3	5	1	-1	42	5	107.36	77.67	19.02
4	7	1	-1	42	5	107.15	77.58	19.14
5	14	-1	1	27	15	109.14	77.07	18.9

Sr. No.	Run	Coded values A: Cutting shaft speed (rpm)	B: Feeding rate (kg/h)	Actual values A: Cutting shaft speed (rpm)	B: Feeding rate (kg/h)	Response 1 Cutting capacity (kg/h)	Response 2 Cutting efficiency (%)	Response 3 Damage percent (%)
6	10	-1	1	27	15	109.27	76.9	18.87
7	15	1	1	42	15	109.93	76.99	20.14
8	4	1	1	42	15	109.77	77.11	20.21**
9	3	-1	0	27	10	107.72	78.33	18.12
10	2	-1	0	27	10	107.59	78.78	18.22
11	9	1	0	42	10	108.31	79.96	19.26
12	6	1	0	42	10	108.15	80.15	19.21
13	13	0	-1	34.5	5	108.65	80.2	17.16
14	17	0	-1	34.5	5	108.55	80.36	17.26
15	8	0	1	34.5	15	111.17**	80.17	18.08
16	1	0	1	34.5	15	110.96	79.95	18.04
17	12	0	0	34.5	10	109.57	82.92**	17.11*
18	16	0	0	34.5	10	109.61	82.36	17.21

* and ** indicate lowest and highest values respectively

2.2. Experimental procedure

The developed raw mango cutting machine (shown in Fig. 2) was evaluated for its performance at various cutting shaft speeds through a series of test runs. The performance evaluation of machine carried out using raw mangoes of local wild variety which grown in Ahmednagar district, Maharashtra, India. The average length, width, thickness, weight and moisture content of whole mango was 164.5 mm, 84.2 mm, 66.6 mm, 164.5 g and 84%, respectively. The ratio of average values of pulp, peel and stone was 25.1: 3.46: 4.22, respectively. The cutting process is carried out in three stages, in first step, raw mangoes are partially cut manually using a regular cutter provided with the machine. Pre-cutting the mangoes was essential before feeding them into the machine, as this process allows the mangoes to be sliced and cubed more effectively in subsequent stages. Feeding whole mangoes resulted in larger slices, which complicated further processing. Additionally, the presence of the whole stone in the mangoes required more force to cut, causing the cutting shaft to stop rotating.



Figure 2. Developed raw mango cutting machine (Karate et al., 2022)

In the second stage, the partially cut mango pieces were fed through the feeding hopper, where half cut pieces were reduced into slices. The cut slices fall onto a conveyor tray, which transports them to the third cutting stage mechanism. In the third stage, these slices were further cut into small, cubical pieces which fall on collection tray and collected out from machine. The design of cutting shaft and distance between cutting discs were maintained in such a way that the dimensions of cubes obtained from machine were 25 mm in length, width and thickness, as recommended by Gaikwad (2015).

The cut mango pieces obtained were then evaluated for various metrics such as cutting capacity, cutting efficiency, and damage percentage, following the procedure outlined by Gaikwad (2015).

$$\text{Cutting capacity}\left(\frac{\text{kg}}{\text{h}}\right) = \frac{\text{quantity of mangoes (kg)}}{\text{time taken for cutting (hr)}} \quad (2)$$

$$\text{Cutting efficiency (\%)} = \frac{\text{Nt} - \text{Nd}}{\text{Nt}} \times 100 \quad (3)$$

$$\text{Damage percentage (\%)} = \frac{\text{Nd}}{\text{Nt}} \times 100 \quad (4)$$

where
Nt = No. of total mango pieces
Nd = No. of damage mango pieces

This process was repeated across 18 experimental runs including three replications, with the results from each run recorded and analysed. The dimensions of cut mango pieces (cubes) obtained from machine were measured using vernier calliper.

2.3. Optimization of operational parameter

The obtained responses for each experimental run were incorporated into experimental plan of central composite design of Design Expert software as mentioned in Table 2. Later each response was analysed according to the suggested statistical model by the software.

3. Result and discussion

3.1. Optimization of independent parameters

The study analysed the number of cut mango pieces obtained from the machine to determine various responses. The responses observed for each specific runs are shown in Table 2. The maximum and minimum cutting capacities were observed 111.17 kg/h and 107.03 kg/h, respectively. The machine substantially outperforms previously reported manually operated cutters, which typically achieve 40 to 60 kg/h (Salve et al., 2020), and multipurpose power-operated machines, which record approximately 21.22 kg/h (Patil & Chendake, 2017). The cutting efficiencies ranged from a maximum of 82.92% to a minimum of 75.98%. The obtained results for cutting efficiency was found to be in range with Sonawane et al. (2011) for developed banana slicer machine. The damage percentage of mango pieces range from a maximum of 20.21% to a minimum of 17.11%. The result for damage percentage of mango pieces was found to be in accordance with Gaikwad (2015).The observed data was subjected to Analysis of Variance (ANOVA).

Table 3 presents the ANOVA analysis for cutting capacity, cutting efficiency, and damage percentage. According to Lan et al., (2011), a model is considered more significant if it has a smaller p-value and a higher F-value. A p-value of 0.0001 indicates that the model is significant. The software recommended quadratic model for analysis of all responses. The cutting capacity of the machine was significantly affected by the speed of the cutting shaft and feeding rate of mangoes. The combine effect of speed of cutting shaft and feeding rate also was found to be significant at 5% level of significance. The both quadratic model terms (A^2 and B2) were found to be significant. The cutting efficiency of machine significantly affected by the speed of cutting shaft where the feeding rate of mangoes was observed non-significant. The combine effect and quadratic terms were also found to be significant. The damage percentage of mango pieces is significantly affected by all the factors individually and combine with quadratic model terms (A^2 and B2).

The R^2 value reflects how well the model explains the variation in the experimental data. For the three responses, the R^2 values were observed to be 0.9952, 0.9889, and 0.9932. This means that 99.52%, 98.89%, and 99.32% of the variation in cutting capacity, cutting efficiency, and damage percentage, respectively, could be attributed to the experimental variables, with the remaining variation attributed to noise.

Regression analysis was performed using the software to predict the machine responses. The coded values used for model prediction are expressed by the following equations:

$$\text{Cutting capacity} = 109.52 + 0.237 \times A + 1.202 \times B + + 0.11 \times AB - 1.544 \times A^2 + 0.345 \times B^2 \quad (5)$$

$$\text{Cutting efficiency} = 82.595 + 0.518 \times A + 0.018 \times B - - 0.37 \times AB - 3.268 \times A^2 - 2.403 \times B^2 \quad (6)$$

$$\text{Damage percentage} = 17.141 + 0.45 \times A + 0.349 \times B + + 0.236 \times AB + 1.57 \times A^2 + 0.502 \times B^2 \quad (7)$$

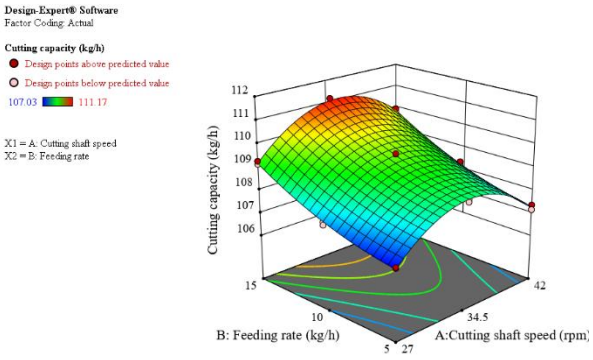
where
A and B are coded value for cutting shaft speed and feeding rate, respectively.

In equation 5, 6 and 7, positive sign of coefficient indicate increase in the responses with increment of level variable A and B. Whereas, negative sign of coefficient indicate decrease in the response.

3.2. Effect of machine parameters on responses: cutting capacity, cutting efficiency and damage percentage

Figure 3 illustrates the effect of cutting shaft speed on (a) cutting capacity, (b) cutting efficiency, and (c) damage percentage. Figure 3(a) revealed a significant interactive effect of the machine variables on the cutting capacity. The curved surface indicated the presence of quadratic effects, while the elliptical contour pattern confirmed interaction between the variables. The maximum cutting capacity of the machine was obtain for 34.5 rpm cutting shaft speed and 15 kg/h feeding rate. At both lower and higher speed of cutting shaft the capacity of the machine was found to be decreased. At lower speeds, more time was needed to push mango pieces through the cutting blade, which reduced cutting capacity. Conversely, at higher speed, the shaft failed to effectively engage the mango pieces, leading to a reduced cutting capacity. The similar findings were reported by Gaikwad (2015) and Karate et al. (2022) regarding cutting capacity. The cutting capacity of machine increases with increase in the feeding rate. An increase in feeding rate supplied a larger quantity of

mangoes to the cutting zone, thereby increasing the amount of material available for cutting and consequently enhancing the cutting capacity. The similar trend were observed by Dissanayake, 2009 for manually operated mango dicing machine.



Figur 3(a). Effect of machine parameters on cutting capacity

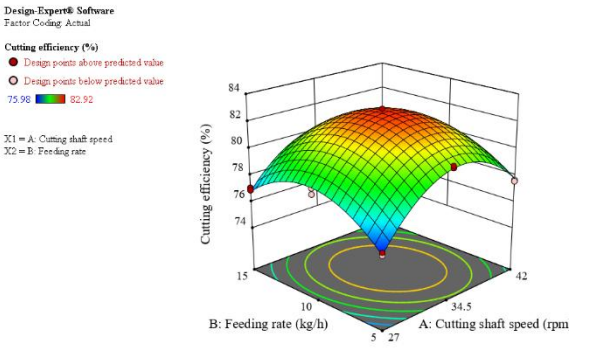


Figure 3(b). Effect of machine parameters on cutting efficiency

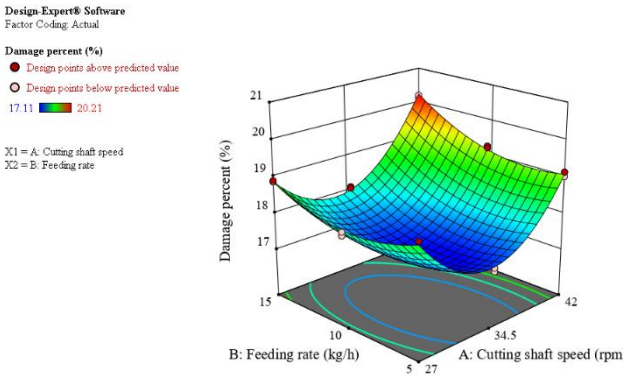


Figure 3(c). Effect of machine parameters on damage percentage

The effect of machine parameters on cutting efficiency, as shown in Figure 3(b). The cutting efficiency initially increased with shaft speed up to 34.5 rpm, but then decreased as the speed increased further. At lower speeds, fewer pieces were damaged, while at higher speeds, increased damage resulted in decreased cutting efficiency. At the optimal speed, the holding shaft's rotational velocity provides sufficient normal force and dwell time to press the mango halves firmly and squarely against the stationary blades, enabling a clean shear through the tissue. At sub-optimal speeds, efficiency drops due to two distinct failure modes. At low speed (27 rpm), inadequate force leads to incomplete cuts and tearing, while at high speeds (42 rpm), excessive velocity causes misalignment and slippage, resulting in mangled or partially cut pieces that are classified as damaged (Gaikwad, 2015). The cutting efficiency of machine increases with increase in feeding rate up to 10 kg/h, beyond this feeding rate the cutting efficiency observed to be decreased. This observed due to improved utilization of the cutting mechanism and increased material availability at the cutting zone. Beyond 10 kg/h level, efficiency decreased because the cutting unit became overloaded, reducing the residence time available for effective cutting and causing incomplete or improper cutting of mangoes. The reduction in efficiency at higher feeding rates may also be attributed to increased cutting forces and material congestion within the cutting chamber (Şeker et al., 2004).

The damage percentage caused by machine was found to be initially decreased with increasing shaft speed up to 34.5 rpm, but then raised as the speed continued to increase (Figure 3 (c)). Beyond 34.5 rpm, higher speed caused increased crushing of the mango pieces, leading to greater damage. Damage in this context primarily refers to physical bruising, crushing, and irregular fracturing of the mango flesh, which occurs when the cutting mechanism fails to execute a clean shear. At low speeds, damage arises from excessive compressive and frictional forces as the fruit is slowly crushed against the blade. At high speeds, damage increases due to impact loading and inertial misalignment; the fruit is subjected to high-velocity impacts and torsional stresses when improperly engaged by the holding shaft, leading to cell rupture and ragged edges (Salve et al., 2020). Whereas at the lower and higher feeding rate damage percentage was observed to be little bit higher as compare to 10 kg/h feeding rate. The damage percentage was lower at 10 kg/h because this feeding rate provided an optimal balance between material flow and cutting energy distribution. At lower feeding rates (5 kg/h), the sparse fruit supply caused each mango to absorb excessive impact energy due to lack of cushioning from neighbouring fruits. At higher feeding rates (15 kg/h), fruit congestion led to crushing, multiple improper cuts, and increased friction against machine components. Thus, both deviations from 10 kg/h increased

mechanical damage to the mangoes (Saravacos & Kostaropoulos, 2016).

3.3. Optimization of operational parameter on responses

To optimize the responses of raw mango cutting machine for maximum cutting capacity, maximum cutting efficiency, and minimum damage percentage, an analysis was conducted using Design Expert software. The optimization process involved setting goals for each variable based on the model and graphs obtained. First, the maximum and minimum limits for each variable were defined as goals in the criteria section. The software then provided a set of constrained variables and responses, as detailed in Table 4. The overlay contour plot formed by interaction of contour lines of the responses is shown in Fig. 4. The plot showing region of optimum range of variables with desirable quality traits at which machine should operate.

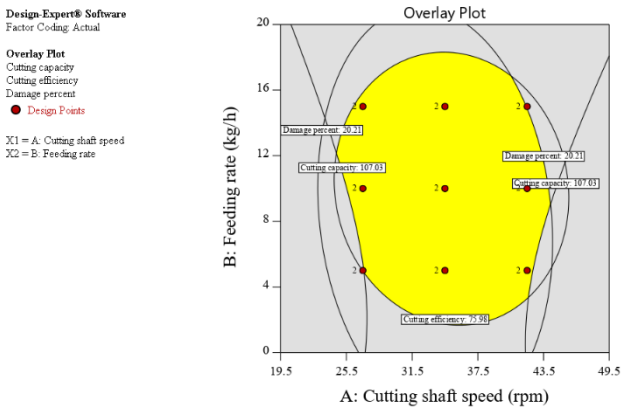


Figure 4. Overlay contour plot showing optimum region of machine variables

Table 4. Constrained set for responses for optimization of design parameter

Name	Unit	Goal	Lower Limit	Upper Limit
A: Cutting shaft speed	rpm	In range	27	42
B: Feeding rate	kg/h	In range	5	15
Response 1: Cutting capacity	kg/h	Maximize	107.03	111.17
Response 2: Cutting efficiency	%	Maximize	75.98	82.92
Response 3: Damage percentage	%	Minimize	17.11	20.21

The perturbation plot for cutting capacity (Fig. 5 (a)) revealed that the steeper slope of parameter B (feeding rate) suggests that it has a stronger positive influence on cutting capacity compared to parameter A (cutting shaft speed). The cutting capacity of machine is more sensitive to change of feeding rate than the change of cutting shaft speed. The perturbation plot for cutting efficiency (Fig. 5 (b)) indicated that the curves of A (cutting shaft speed) and B (feeding rate) are very close to each other, suggesting that both factors influence cutting efficiency in a similar manner. The slightly steeper curvature of parameter A indicates that cutting efficiency is marginally more sensitive to changes in cutting shaft speed than factor feeding rate of mangoes. The perturbation plot for damage percent (Fig. 5 (c)) revealed that parameter A (cutting shaft speed) has a steeper curvature than parameter B (feeding rate), indicating that damage percentage is more sensitive to changes in cutting shaft speed than feeding rate of mangoes. Small deviations in cutting shaft speed produce larger changes in damage percentage.

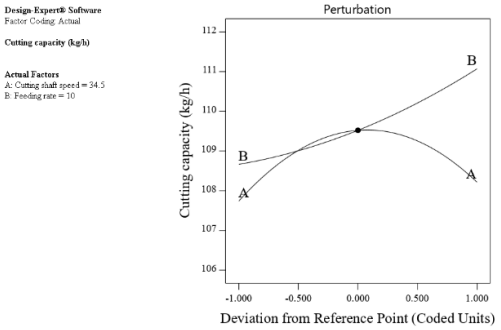


Figure 5(a). Perturbation plot for Cutting capacity for machine parameters, A: Cutting shaft speed (rpm) and B: Feeding rate (kg/h)

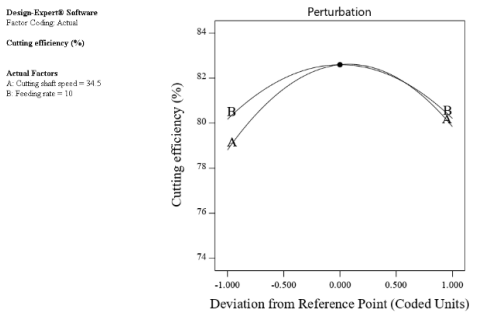


Figure 5(b). Perturbation plot for Cutting efficiency for machine parameters, A: Cutting shaft speed (rpm) and B: Feeding rate (kg/h)

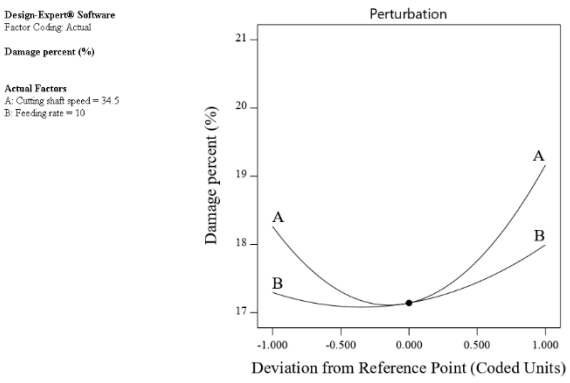


Figure 5 (c). Perturbation plot for Damage percentage for machine parameters, A: Cutting shaft speed (rpm) and B: Feeding rate (kg/h)

The best possible solution suggested by the Design Expert software, based on the optimized levels of the dependent parameters, are shown in Table 5. The software proposed optimal solution, with the desirability of 0.846. A desirability close to unity indicates minimal error values. The selected solution yielded responses of a cutting capacity of 109.96 kg/h, cutting efficiency of 82.32%, and a damage percentage of 17.31%. The optimized machine parameters suggested by software was at a cutting shaft speed of 34.43 rpm and feeding rate of 11.68 kg/h. Which was considered nearly equal to cutting shaft speed of 34.5 rpm and feeding rate of 12 kg/h.

These optimized responses were validated through an additional experiment conducted for triplicates at the specified cutting shaft speed of 34.5 rpm and feeding rate of 12 kg/h. The mean of observed responses for cutting capacity, cutting efficiency and damage percentage were 110.00 kg/h, 81.98%, and 17.26%, respectively. The pairwise t-test was performed to compare the predicted and observed mean values and result obtained is shown in Table 6. The p values for all responses were observed non-significant i.e. there is no statistically significant difference between the predicted and observed values. Therefore, the optimized operational parameters are considered valid for practical use. The cut pieces of raw mangoes obtained from machine shown in Fig. 6. The average dimensions of cubes of raw mangoes get from machine were observed 35.5 mm length, 27.2 mm width and 1.7 mm thickness.

The total manufacturing cost of the machine was estimated to be Rs. 48,400 (approximately USD 580–600), with material costs (Rs. 34,400) and fabrication costs (Rs. 14,000). At the optimal operating speed of 34.5 rpm with cutting capacity of 110 kg/h. If used for 4 to 6 hours daily during the mango season, it can process 0.44 to 0.66 tons per day, significantly reducing labor dependency and manual cutting time. Compared to traditional manual cutting (15 to 40 kg/h), the machine offers a 3 to 7 times increase in in throughput. It can recover its initial investment within a single processing season through saved labour costs and increased production scale with improving hygiene and cut consistency.



Figure 6. Cut pieces of raw mangoes obtained from machine (source: author's own photograph)

Table 3. ANOVA analysis for responses: cutting capacity, cutting efficiency and damage percentage

Source	Cutting capacity					Cutting efficiency					Damage percentage				
	Sum of Squares	df	Mean Square	F-value	p-value	Sum of Squares	df	Mean Square	F-value	p-value	Sum of Squares	df	Mean Square	F-value	p-value
Model	28.14	5	5.63	500.47	< 0.0001*	70.16	5	14.03	213.53	< 0.0001*	15.21	5	3.04	350.80	< 0.0001*
A	0.676	1	0.676	60.19	< 0.0001*	3.22	1	3.22	49.06	< 0.0001*	2.43	1	2.43	280.24	< 0.0001*
B	17.35	1	17.35	1542.9	< 0.0001	0.004	1	0.004	0.061	0.8085#	1.46	1	1.46	168.72	< 0.0001*
AB	0.096	1	0.096	8.61	0.0125**	1.10	1	1.10	16.67	0.0015*	0.446	1	0.446	51.49	< 0.0001*
A^2	9.54	1	9.54	848.08	< 0.0001*	42.73	1	42.73	650.25	< 0.0001*	9.86	1	9.86	1137.05	< 0.0001*
B^2	0.478	1	0.478	42.54	< 0.0001*	23.10	1	23.10	351.61	< 0.0001*	1.01	1	1.01	116.48	< 0.0001*
Residual	0.135	12	0.011			0.788	12	0.065			0.104	12	0.008		
Lack of Fit	0.041	3	0.013	1.34	0.3204#	0.429	3	0.143	3.59	0.0592#	0.076	3	0.025	8.48	0.0055
Pure Error	0.093	9	0.010			0.358	9	0.039			0.027	9	0.003		
Cor Total	28.28	17				70.94	17				15.31	17			

* and ** indicate 1% and 5% level of significance, # indicate non-significant terms. A: Cutting shaft speed (rpm), B: Feeding rate (kg/h)

Table 5. Optimized solutions suggested for responses

Sr. No.	Cutting shaft speed (rpm)	Feeding rate (kg/h)	Cutting capacity (kg/h)	Cutting efficiency (%)	Damage percent (%)	Desira-bility	
1	34.432	11.687	109.964	82.324	17.312	0.846	**Selected**

Table 6. Validation of responses with predicted and experimental observations using t-test

Sr. no.	Responses	Predicted value	Experimental Value Mean* SD (±)	t value	p value
1	Cutting capacity (kg/h)	109.96	110.00±0.59	-0.12648	0.9109
2	Cutting efficiency (%)	82.32	81.98±0.50	1.1703	0.3625
3	Damage percentage (%)	17.31	17.26±0.90	0.08978	0.9366

4. Conclusion

The mechanical operation of the raw mango cutting machine enhances cutting efficiency while reducing labour costs and operational time. Therefore, raw mango cutting machine was developed and its performance was evaluated. As responses of machine influenced by operational parameters i.e. speed of cutting shaft and feeding rate of mangoes, its optimization was done through Design Expert software. The optimal responses observed were a cutting capacity of 110 kg/h, cutting efficiency of 81.98%, and a damage percentage of 17.26%, all achieved at a cutting shaft speed of 34.5 rpm and feeding rate of 12 kg/h. The average dimensions of cubes of raw mangoes were observed as 35.5 mm length, 27.2 mm width and 1.7 mm thickness. The cost of developed machine was estimated to be Rs. 48,400, which can produce 0.44 to 0.66 tons per day raw mango cubes for 4 to 6 hour machine working hour.

References

Anonymous (2019). *Mango Processing.* Anna University. https://shodhganga.inflibnet.ac.in/bitstream/10603/181361/11/11_conclusion.pdf (accessed on 15.02.2019)

APEDA. (2025). *Mango.* Agricultural & Processed Food Products Export Development Authority (APEDA). Ministry of Commerce and Industry, Govt. of India. https://apeda.gov.in/Mango (accessed on 21.12.2025).

BIS. (1999). *Mango Pickle - Specification* (IS 4670:1999). Bureau of Indian Standards. New Delhi.

Chen, G., Chen, J., Srinivasakannan, C., & Peng, J. (2012). Application of response surface methodology for optimization of the synthesis of synthetic rutile from titania slag. *Applied Surface Science, 258* (7), 3068–3073. https://doi.org/10.1016/j.apsusc.2011.11.039

Dissanayake, T. (2009). *Development of a manually operated mango dicing machine.* [Unpublished master's thesis], Maharana Pratap University of Agriculture And Technology, Udaipur. Repository. https://krishikosh.egranth.ac.in/server/api/core/bitstreams/c7e86273-6604-4585-ab6f-58323f882517/content

Gaikwad, M. (2015). Development of slicing and cubing machine for raw mango. [Unpublished master's thesis], Anand Agricultural University, Gujarat. Repository. http://krishikosh.egranth.ac.in/handle/1/97087

Jha, S. N., Jaiswal, P., Narsaiah, K., Kaur, P. P., Singh, A. K., & Kumar, R. (2013). Textural properties of mango cultivars during ripening. *Journal of food science and technology, 50*(6), 1047-1057. https://doi.org/10.1007/s13197-011-0431-z

Karate, M., Kamble, K., & Kad, V. (2022). Design, development and performance evaluation of power operated raw mango cutting machine. *The Pharma Innovation Journal, 11*(12), 1694-1700.

Karate, M., Kamble, K., & Khobragade, U. (2023). Physical and engineering properties of raw mango fruit relevant to raw mango cutting machine. *Multilogic In Science, 13*(47), 959 – 963.

Lan, Y., Peng, P., Shi, B. (2011). Optimization of preparation conditions for PDMS-silica composite prevaporation membranes using response surface methodology. *Separation Science and Technology, 46*(14), 2211–2222. https://doi.org/10.1080/01496395.2011.594476

Mandhar, S.C., & Kumaran, G.S. (2000). Machinery for raw mango processing. *Acta Horticulturae, 509,* 523-530. https://doi.org/10.17660/ActaHortic.2000.509.60

Masibo, M., & He, Q. (2009). Mango bioactive compounds and related nutraceutical properties – a review. *Food Reviews International, 25*(4), 346–370. https://www.tandfonline.com/doi/abs/10.1080/87559120903153524

Meena, R., Patil, S., Yadav, N., Sagore, B., Prachi, P., & Meena, B. … Anushi. (2023). Studies on Preparation of Mango Pickle from Different Genotypes of Akola Maharashtra Region. *International Journal of Plant & Soil Science, 35*(23), 474-483. https://doi.org/10.9734/ijpss/2023/v35i234264

Nath, A., & Chattopadhyay, P. K. (2007). Optimization of oven toasting for improving quality of ready-to-eat raw mango pickle. *Journal of Food Quality, 80*(4), 1282-1292. https://doi.org/10.1016/j.jfoodeng.2006.09.023

Patil, S.B., & Chendake, A.D. (2017). Development of multipurpose punching and cutting machines. *International Journal of Agricultural Science and Research (IJASR), 7*(2), 177-188.

Salve, V. A., Kad, V. P., Kamble, K. J., & Kadam, P. B. (2020). Evaluation of Manually Operated Raw Mango Cutting Machine. *Journal of Krishi Vigyan, 8*(2), 129-132. DOI:10.5958/2349-4433.2020.00027.6

Saravacos, G., & Kostaropoulos, A. E. (2016). *Size Reduction – Effect of Feed Rate on Product Quality. In Handbook of Food Processing Equipment* (2nd ed.). Springer. https://doi.org/10.1007/978-3-319-25020-5

Şeker, U., Kurt, A., & Ciftci, I. (2004). The effect of feed rate on the cutting forces when machining with linear motion. *Journal of Materials Processing Technology, 146*(3), 403-407. https://doi.org/10.1016/j.jmatprotec.2003.12.001

Shahid, U., Hussain, S., Nadeem, M., Jabbar, S., Qureshi, T. M., Nasir, M. U., Zahra, S. M., & Rashid, F. (2015). Quality assessment of the mango-mandarin (kinnow) squash during storage. *Science Letters, 3*(3), 115-121.

Sirisomboon, P., Boonmung, S., Pornchaloempong, P., & Pithuncharurnlap, M. (2008). A preliminary study on classification of mango maturity by compression test. *International Journal of Food Properties, 11*(1), 206–212. http://dx.doi.org/10.1080/10942910701435430

Sonawane, S. P., Sharma G. P., Pandya A. C. (2011). Design and development of power operated banana slicer for small scale food processing industries. *Research in Agricultural Engineering, 57*(4), 144-152.

Vasugi, C., Sekar, K., Dinesh, M. R., & Suresh, E. R. (2008). Evaluation of unique mango accessions for whole-fruit pickle. *Journal of Horticultural Sciences, 3*(2), 156-160. https://www.redalyc.org/articulo.oa?id=577064430012