www.ThePharmaJournal.com
The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 1694-1700
© 2022 TPI
www.thepharmajournal.com
Received: 01-10-2022
Accepted: 06-11-2022

Mayur Karate
Ph.D. Scholar, Department of Process and Food Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Dr. Kailas Kamble
Associate Professor, Department of Process and Food Engineering, Dr. A. S. College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Dr. Vikram Kad
Associate Professor, Department of Process and Food Engineering, Dr. A.S. College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Corresponding Author:
Mayur Karate
Ph.D. Scholar, Department of Process and Food Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Design, development and performance evaluation of power operated raw mango cutting machine

Mayur Karate, Dr. Kailas Kamble and Dr. Vikram Kad

Abstract
Raw mangoes in India are mostly used for making pickles and chutneys. Mechanical operation of slicing and cube cutting of raw mango is advantageous because of more precise slicing and cube cutting than manual cutting. It reduces fruit damage and improves efficiency and accuracy. A power operated raw mango cutting machine designed and developed for small scale processing industry based on physical and engineering properties of raw mangos. The machine is consist of main frame, primary cutting blade, feeding hopper, holding shaft, cutting blades, upper trough plate, bottom trough plate and power transmission unit. The performance evaluation of raw mango cutting machine was conducted for the four different speeds of holding shaft i.e., 27, 32, 37 and 42 rpm. The results observed best at speed of 32 rpm having cutting capacity 111.8 kg/h, cutting efficiency 82.92% and damage percentage 17.11%.

Keywords: Raw mango, cutting blades, cutting shaft, power transmission, cutting capacity, cutting efficiency and damage percentage

Introduction
Mango is a rich source of carotenoids and provides high contents of ascorbic acid, phenolic compounds and is known as 'King of the Fruit' in India (Bhatnagar and Subramanyam, 1973) and consumed and cultivated worldwide more than 100 countries (APEDA, 2022). Mango is one of the most cherished fruits, not only in flavor and taste but also for its nutritional value. It is reported that mango is a good source of vitamin A and C and rich in carbohydrates, minerals potassium and phosphorus (Shahid *et al.*, 2015). The major mango-growing states in India are Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Gujarat, Karnataka and Bihar. Uttar Pradesh achieve first rank in mango production with a share of 23.47 % and highest productivity. India also major exporter of mangoes in world, during year 2020-21 country exported 21,033.58 MT of fresh mangoes of worth of Rs. 271.84 crores/ 36.23 USD Millions (APEDA, 2022).

Raw mangoes in India are mostly used for making pickles and chutneys. Pickles are prepared commercially and in almost every Indian house and is widely popular within the country. In country many households scale pickle manufacturers have expanded into medium and large-scale units. Mango pickles occupy an important place in our traditional and export market and uniformity of its quality is of vital importance not only for maintaining its existing market but also for expanding the export market. It occupies an important place among the processed food in India (Gaikwad, 2015).

Raw mango used for pickle is cut by traditional cutters, which is time and labour consuming, not precise and made up of mild steel. Mangoes cut by mild steel cutter cause blackening of pieces on cut portion of the piece (Salve *et al.*, 2020). The traditional cutting method required continuous sitting position of the labour with holding frame by one leg which cause stress on leg and alternatively reduces the cutting rate (Patil and Chendake, 2017). The shelf life of pickles made up of manually cut slices or cubes is reported 180 to 210 days, whereas that of mechanically cut slices or cubes 300 to 365 days (Mango Processing, 2019).

Handling of mango is done manually and in unhygienic ways. Most of the raw mango pickle industries perform basic operations like peeling, cutting, slicing, grating, and dicing. All these operations are tedious and labor intensive, as it involves manual work. Hence, it is essential to mechanize these operations by developing efficient machine which can reduce the processing time as well as cost of operation and make the process more hygienic (Mango Processing, 2019). Mechanical operation of slicing and cube cutting of raw mango is advantageous as it involves more precise slicing and cube cutting than the manual cutting. It reduces fruit damage and improves the efficiency and accuracy. Therefore, the objective of this research paper is to overcome above limitations of the operation of raw mango cutting by developing machine for raw mango cutting and evaluating performance for efficient operation.

2. Materials and Methods

2.1 Design of machine

Preliminary conceptual design of machine was drawn consist of part 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 conceptual machine shown in Figure 1. The developed machine fabricated using material like MS angle, MS sheet, MS square bar, SS plate, pulley, pedestal bearing and belt.

The frame of the machine is used to support the all component of the cutting machine, power transmission unit and speed reduction unit. The frame having the require strength to bear all weight of component and resist the vibration of the motor. The primary cutting blade is provided to cut the raw mango in half by pressing manually. It is a blade with handle having length 310 mm. Feeding hopper is made of S. S. sheet (18 gauge). From feeding hopper, the mango is feed into the cutting machine. The design of the feeding machine such way that only required quantity mango can pass through it. The feeding hopper pass the mango towards the cutting blade. A star wheel with six rectangular rods (100×25×25 mm) welded in one line at the interval of 10 mm distance between each and eight such lines on the perimeter at 10 mm apart are welded to hold the half-cut mango pieces and press against the cutting blade during movement. Such two-star wheels are arranged in the machine for cutting the raw mangoes in first and second stage shown in Figure 2.

The cutting blades are provided with the circular blade having diameter 300 mm shown in Figure 3. The blades on the shaft are fixed. The distance between the two blades is the dimension of the cut piece of raw mango. The blade shaft is fixed with respect to the cutting shaft in such a way that the cutting blades pass haft into the holding shaft to prevent the falling of mango without cutting. The upper trough plate is provided below the holding and blade shaft to receive the mango slices fall from the cutting blades. The trough plate is tilted from the horizontal at the angle of 35º for full recovery of mango pieces. The bottom trough plate is used to collect the cut pieces of mango discharge from the cutting unit. It collects the cut pieces of mango from secondary cutting unit. It is located at the bottom of the machine. In raw mango cutting machine the power to the machine given by the 1 hp electric motor. It transmits the power to both cutting shafts. The power transmission is carried out by the belt drive to the pulley attached on the shafts.

2.2 Operation procedure

The cutting of raw mango is divided into three steps as half cutting of mangoes, slice cutting and cube cutting. The feeding of the mango is done after the half cutting by feeding hopper. The half cutting of raw mango done by manual cutting. The regular cutting blade provided at the top of the machine which is fixed at one end and movable at another end provided with handle. The raw mango cut manually by half cutting blade one by one in half portion and separation of the stone is carried out at this primary level. As the half-cut pieces of the raw mango feed into the feed hopper, the cut pieces are carried by holding shaft. The shape of the wheel in such a way that the feed mango piece forced on cutting blade. Due to the sharp edges of the blade the half pieces of the mango cut into the vertical slices of the mango. The cut slices of the mango are drop on the upper trough plate. Due rotating motion of the holding shaft the continuously cutting of mango slices is done as half cut mango feed into the hopper. The slices of the raw mango which is carried by the upper trough plate is feed to the cube cutting mechanism. The cut slices of the raw mango carried by second holding shaft and cut into cubes by forcing slices on cutting blades. The cut cubes of the raw mango collected by the bottom trough plate which provided at the bottom of the machine.

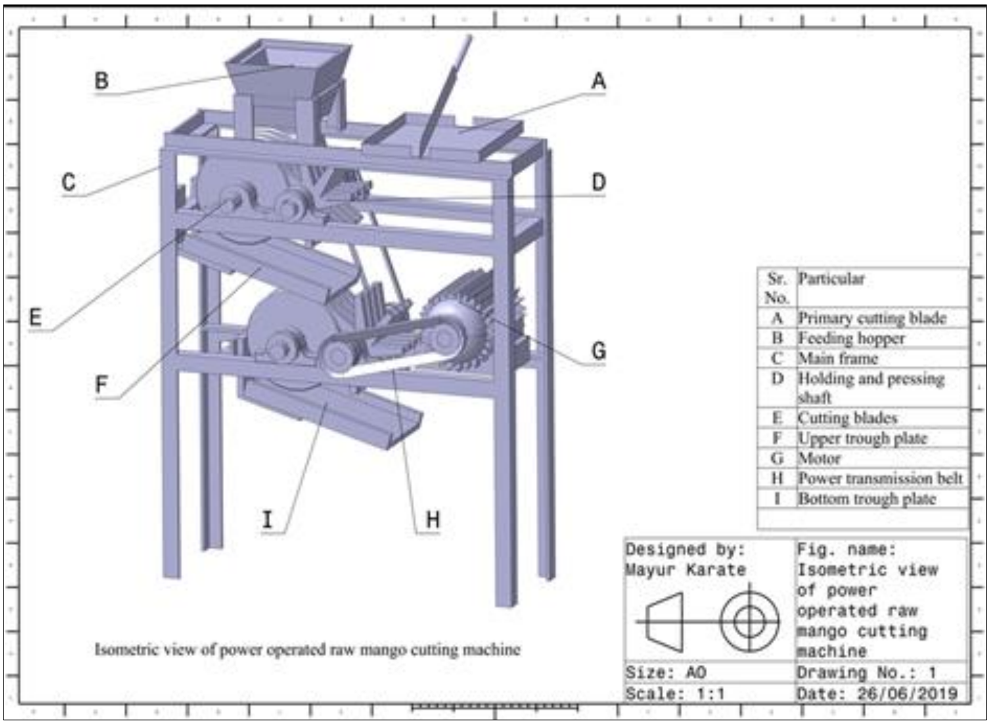

Fig 1: CAD view of power operated raw mango cutting machine

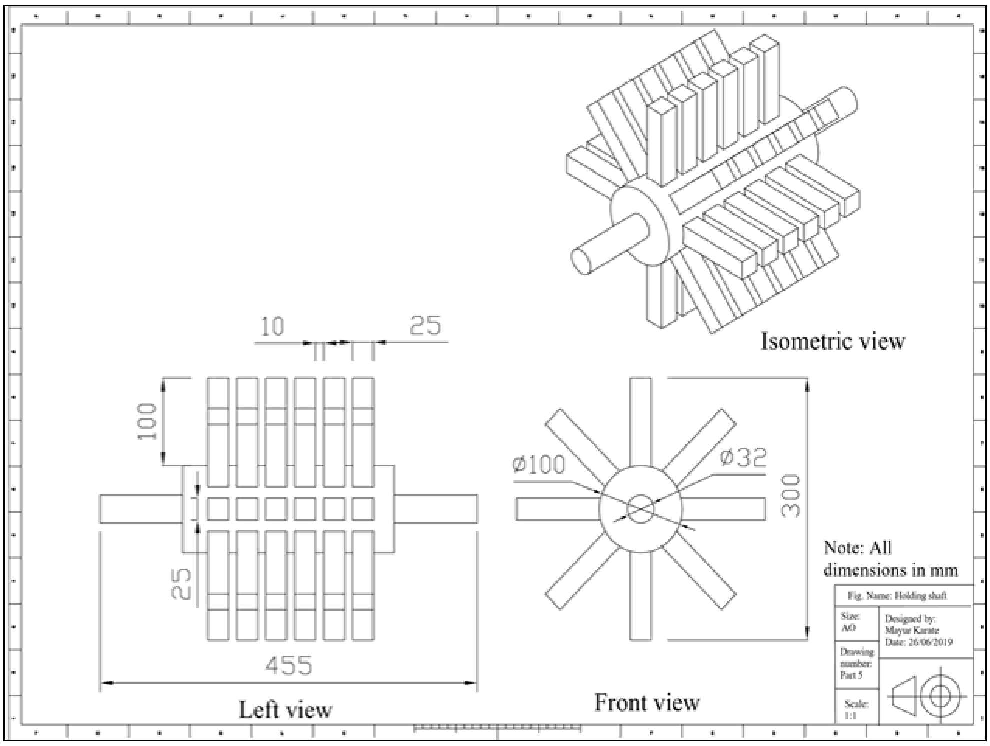

Fig 2: Detail view of holding shaft

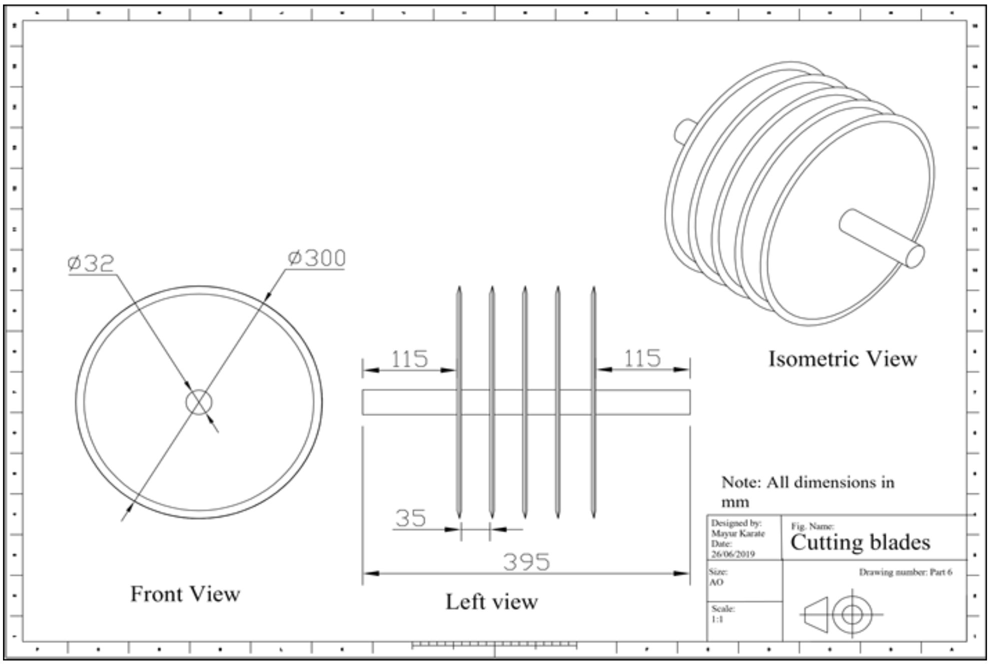

Fig 3: Detail view of cutting blades

2.3 Speed reduction calculation

The available motor speed at motor shaft is 1420 rpm, it too high speed than require speed. Therefore, the speed reduction mechanism is fitted to the machine to get require speed at cutting shaft for proper working of the machine. The motor speed is reduced into two steps i.e., speed reduction by first pulley and speed reduction by second pulley.

2.3.1 Speed reduction by first pulley

The pulley having diameter of 63.5 mm is fitted at motor shaft and first pulley having diameter 457.2 mm is fitted to another shaft. Then the first speed reduction is given as,

By equation (1).

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \tag{1}$$

Where,

N_1=rpm at motor pulley (1420 rpm)

N_2= rpm at first pulley

D_1= diameter of motor pulley (mm)

D_2 = diameter of first pulley (mm)

For appropriate speed reduction the diameter of first pulley is selected as 457.2 mm.

Therefore, speed at first pulley is

$$\frac{1420}{N_2} = \frac{457.2}{63.5}$$

$$N_2 = \frac{1420 \times 63.5}{457.2}$$

N2 = 197.22 rpm

2.3.2 Speed reduction by second pulley
The power transfer to second pulley from first pulley shaft having another small pulley of diameter of 3 inch. Therefore, speed reduction to second pulley is given by equation (2).

$$\frac{N_2}{N_3} = \frac{D_3}{D_2} \quad (2)$$

Where
N2=rpm at first pulley (197.22 rpm)
N3= rpm at second pulley
D2= diameter of first pulley (mm)
D3= diameter of second pulley (mm)

For appropriate speed reduction the diameter of second pulley is selected as 457.2 mm.
Therefore, speed at second pulley is

$$\frac{197.22}{N_3} = \frac{457.2}{76.2}$$

$$N_3 = \frac{197.22 \times 76.2}{457.2}$$

N3 = 32.87 rpm

Therefore, the speed at second pulley is 32.87 rpm. This speed is directly given to the cutting shaft for cutting of the raw mangoes.

2.4 Performance Evaluation of Machine
The performance of the raw mango cutting machine is evaluated in terms of cutting capacity and cutting efficiency. The performance evaluation of machine was measured at different speed of the machine i.e., 27, 32, 37 and 42 rpm. The speed was optimized on the basis of trials on the machine. To vary the speed for 27, 32, 37 and 42 rpm diameter of pulley of second speed reduction on shaft 63.5, 76.2, 88.9 and 101.6 mm were used.

2.4.1 Cutting capacity
The machine capacity for cutting of the mango have estimated on the basis of total quantity of cut pieces collected at outlet of machine and time required for cutting. The cutting capacity calculated by using the following equation (Mandhar and Kumaran, 2000).

$$\text{Cutting capacity (kg/h)} = \frac{\text{Quantity of mangoes (kg)}}{\text{Time taken for cutting (hr)}} \quad (3)$$

2.4.2 Cutting efficiency
The mango cutter efficiency was estimated on the basis of total number of cut mangoes collected at outlet of machine and measure the damage of the pieces. The cutting efficiency calculated by using the following equation (Gaikwad, 2015).

$$\text{Cutting efficiency (\%) } (\alpha) = \frac{Nt - Nd}{Nt} \times 100 \quad (4)$$

Where
α = cutting efficiency (%)
Nt = No. of total mango pieces
Nd = No. of damage mango pieces

2.4.3 Damage percentage
The damage percentage cause to the mango pieces during mango cutting by cutting machine was determined by visual observation. The damage cause to mango pieces due to friction and crushing mango pieces on blade. The number of damage mango pieces were collected and noted. The percentage of mango pieces damage calculated over total number of pieces using following formula (Gaikwad, 2015).

$$Dp = \frac{Nd}{Nt} \times 100 \quad (5)$$

Where
Dp = damage percentage
Nd = number of damage mango pieces
Nt = total number of mango pieces

2.5 Comparison of Developed Machine with Manual Cutting and Other Machines
The developed raw mango cutting machine compare with the manual raw mango cutting operation and other developed machines for raw mango cutting operation. Patil and chendke (2017) studied the comparison of traditional raw mango cutting operation with developed multipurpose punching and cutting machines. Salve *et al.*, (2020) compare the manually operated raw mango cutting operation with traditional raw mango cutting operation. Gaikwad (2015) compare study of performance of raw mango slicer and cube cutter with manual slicing and cubing operation.

3. Result and Discussion
The performance of the developed power operated raw mango cutting machine shown in Figure 4 was evaluated and detail data related to the tests conducted on performance of the machine is shown in Table 1.

Fig 4: Developed power operated raw mango cutting machine

3.1 Performance Evaluation of Developed Raw Mango Cutting Machine

3.1.1 Effect of speed on cutting capacity

The average capacity of the power operated raw mango cutting machine was found 97.99, 111.88, 99.98 and 105.28 kg/h with speed of holding shaft 27, 32, 37 and 42 rpm, respectively. The highest capacity of the machine was observed at the speed of 32 rpm i.e., 111.8 kg/h therefore the appropriate operation speed of machine chosen as 32 rpm as shown in Figure 5. At the speed of 27 rpm time required to cut the mangoes was more therefore the capacity of the was reduced. At the speed of 37 and 42 rpm the feed half pieces of the mangoes did not catch by the holding shaft due to high speed therefore the time required to cut the mangoes are more for this speed causing reduced cutting capacity. The result values of the machine statistically tested by one way ANOVA and the test was found significant for the cutting capacity as shown in Table 2.

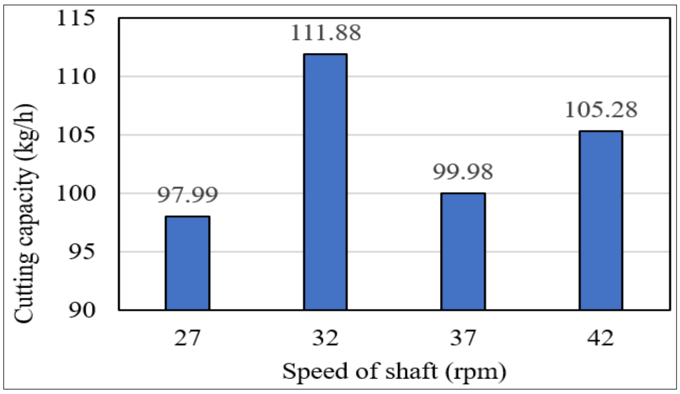

Fig 5: Effect of speed of shaft on capacity of machine

3.1.2 Effect of speed on cutting efficiency

The average cutting efficiency of the machine observed to be 81.84, 82.94, 80.81 and 79.71 per cent with speed of holding shaft 27, 32, 37 and 42 rpm, respectively. From Figure 6 it was observed that the highest cutting efficiency of the machine was observed to be 82.94 per cent on speed of shaft 32 rpm therefore the ideal speed of machine for operation considered as 32 rpm. As the damaged cut pieces observed more for the speed of 27, 37 and 42 rpm therefore cutting efficiency of the machine reduced. The data of the cutting efficiency statistically analyzed by one way ANOVA and test was found significant for the experiment as shown in Table 3.

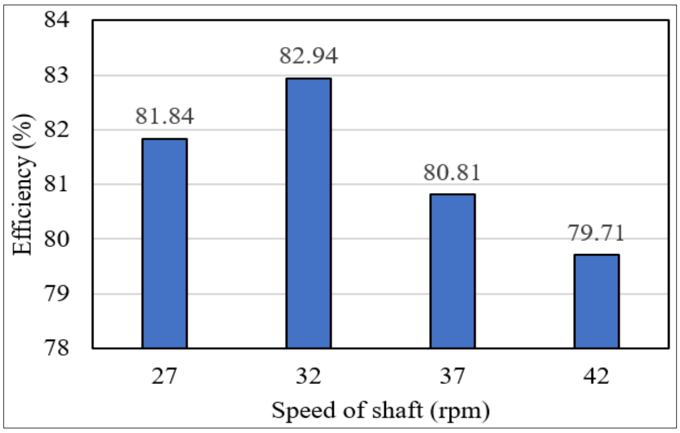

Fig 6: Effect of speed of shaft on cutting efficiency of machine

3.1.3 Effect of speed on damage percentage

The damage percentage of mango pieces cause by cutting operation was observed to be 18.14, 17.12, 19.17 and 20.27 per cent with the speed to holding shaft 27, 32, 37 and 42 rpm, respectively. The lowest damage percentage of the machine was observed 17.12 per cent at 32 rpm as shown in Figure 7 therefore the ideal speed of operation for machine considered as 32 rpm. At speed of 27 rpm due to low-speed mango pieces not properly forced by the holding shaft causing damage to the pieces. At speed of 37 and 42 rpm due to high speed of shaft mango pieces not properly placed over the cutting blades by holding shaft causing more damage to the pieces. The data of the damage percentage statistically analyzed by one way ANOVA and test was found significant for the experiment as shown in Table 4.

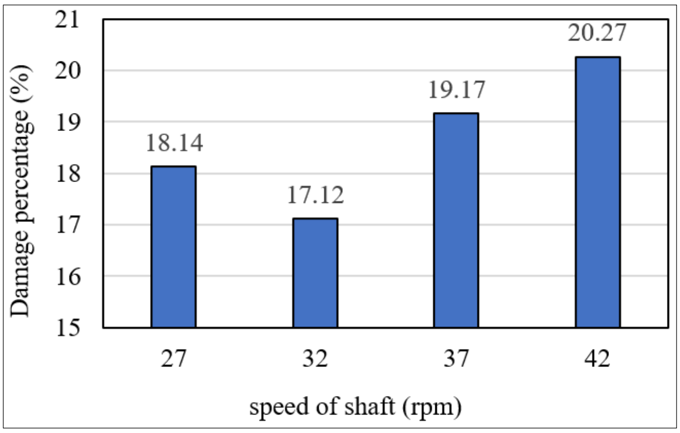

Fig 7: Effect of speed of shaft on damage percentage of machine

3.2 Comparison of Developed Machine with Manual Cutting and Other Machines

The performance of developed raw mango cutting machine was studied and compare with the traditional i.e., manual raw mango cutting operation and other raw mango cutting machines. Patil and Chendake (2017) studied the comparison of traditional raw mango cutting operation with developed multipurpose punching and cutting machine. The traditional cutting rate of raw mango cutting was observed 15 kg/h and developed multipurpose punching and cutting machine observed 21.22 kg/h. Salve *et al.*, (2020) developed manually operated raw mango cutting machine and studied comparison with traditional cutting machine. The cutting capacity of developed machine was observed 40 – 60 kg/hr which is 54 % labour saving than the traditional raw mango cutting method. Gaikwad (2015) studied the manual raw mango cutting operation for slicing and cubing operation. The capacity of the raw mango slicing and cubing operation by manual method reported 41.62 kg/h and 33 kg/h respectively. From the above reported existing study of traditional raw mango cutting and manual operating raw mango cutting machines it is observed that the developed raw mango cutting machine give higher cutting capacity of raw mango per hour.

The quality of the obtain cut pieces of raw mangoes was observed better than the traditional cutting blade. The blackening the cut pieces of raw mangoes observed in traditional method due to use of mild steel blade (Salve *et al.*, 2020), in developed machine the stainless-steel blade was used therefore the blackening of the cut pieces was not observed.

Table 1: Details of the tests of power operated raw mango cutting machine

Test no.	Sample size (kg)	Speed (rpm)	Replication	Time operation (min. and sec.)	No. of pieces	No. of undamaged pieces	No. of damage pieces	Capacity (kg/h)	Efficiency (%)	Damage percentage (%)
1	25	27	1	15' 18"	1098	898	200	98.03	81.78	18.22
			2	15' 20"	1083	888	195	97.82	81.99	18.01
			3	15' 17"	1081	884	197	98.14	81.77	18.23
			Avg.	15' 18"	1087.3	890	197.33	98.00	81.85	18.15
			SD (±)	1.52	9.29	7.21	2.51	0.16	0.12	0.12
2	25	32	1	13' 20"	1091	896	195	112.5	82.13	17.87
			2	13' 25"	1095	920	176	111.07	84.02	16.07
			3	13' 23"	1093	903	190	112.07	82.62	17.38
			Avg.	13' 22"	1093	906.33	187	111.88	82.92	17.11
			SD (±)	2.51	2	12.34	9.84	0.73	0.98	0.93
3	25	37	1	15'	1090	880	210	100	80.74	19.26
			2	15' 5"	1092	883	209	99.44	80.86	19.14
			3	14' 55"	1097	887	210	100.5	80.85	19.15
			Avg.	15'	1093	883.33	209.66	99.98	80.82	19.18
			SD (±)	5	3.60	3.51	0.57	0.53	0.07	0.07
4	25	42	1	14' 17"	1071	853	218	105.01	79.65	20.35
			2	14' 23"	1078	862	216	104.2	79.96	20.04
			3	14' 4"	1075	855	220	106.63	79.54	20.46
			Avg.	14' 14"	1074.6	856.66	218	105.28	79.72	20.28
			SD (±)	9.71	3.51	4.72	2	1.24	0.22	0.22

Table 2: ANOVA Analysis for the data of cutting capacity

Source	Degree of freedom	Sum of Squares	Mean Square	F	Prob.	Result
Treat	4	347.24	86.81	182.61	2.67E-09	**
Error	10	4.75	0.47			
Total	14	351.99				

** indicate that test is significant.

Table 3: ANOVA analysis for the data of cutting efficiency

Source	Degree of freedom	Sum of Squares	Mean Square	F	Prob.	Result
Treat	4	17.01	4.25	20.66	8E-05	**
Error	10	2.05	0.20			
Total	14	19.07				

** indicate that test is significant.

Table 4: ANOVA Analysis for the data of damage percentage

Source	Degree of freedom	Sum of Squares	Mean Square	F	Prob.	Result
Treat	4	16.73	4.18	22.40	5.6 E-05	**
Error	10	1.86	0.18			
Total	14	18.59				

** indicate that test is significant.

4. Conclusions

Most of the small-scale mango pickle industry perform operation of raw mango cutting manually which is time consuming and unhygienic. It is highly needed to develop the cutting machine for the raw mango which is affordable for small scale level. The power operated raw mango cutting machine was design and developed for the need. The machine tested and from the results obtained the highest cutting capacity of machine was 111.8 kg/h, cutting efficiency 82.92 per cent and lowest damage percentage of pieces observed for the speed of 32 rpm. Therefore, the operational speed of the machine recommended 32 rpm. The performance of the developed machine compared with traditional cutting method and manually operated raw mango cutting machine and it is observed that machine gave higher cutting capacity and less damage to the cut pieces of raw mangoes. The developed machine successfully performs the operation of cutting of raw mangoes with reducing the drudgery of the labor.

References

1. APEDA; c2022. https://apeda.gov.in/apedawebsite/SubHead_Products/Mango.htm,
2. Bhatnagar HC, Subramanyam H. Some aspects of preservation and export of mango and its products. Indian Food Packer. 1973;27(4):33-52.
3. Gaikwad M. Development of slicing and cubing machine for raw mango, A thesis submitted to Food Processing Technology, Anand Agricultural University, Gujarat. 2015.
4. Mandhar SC, Kumaran GS. Machinery for raw mango processing. Acta Horticulturae; c2000. p. 523-530.
5. Mango Processing. Anna University, Chennai, shodhganga.inflibnet.ac.in. 2019.
6. Patil SB, Chendake AD. Development of multipurpose punching and cutting machines, Department of Farm Machinery and Power, International Journal of Agricultural Science and Research (IJASR).

2017;(7)2:177-188.
7. Salve VA, Kad VP, Kamble KJ, Kadam PB. Evaluation of Manually Operated Raw Mango Cutting Machine. An International Refereed, J Krishi Vigyan. 2020;8(2):129-132.
8. Shahid U, Hussain S, Nadeem M, Jabbar S, Qureshi TM, Nasir MU, et al. Quality assessment of the mango-mandarin (kinnow) squash during storage, Open access journal, Institute of Food Science and Nutrition, University of Sargodha, Sargodha, Pakistan. 2015;(3)2:115-121.