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Ajay D Makwana
CAET FMP Department JAU, Junagadh, Gujarat, India

Ram Vaibhav
SRF, CSSRI RRS Bharuch, Gujarat, India

Dr. Saumya Shukla
CAET FMP Department JAU, Junagadh, Gujarat, India

Dr. VK Tiwari
HOD FMP CAET, JAU Junagadh, Gujarat, India

Corresponding Author:
Ajay D Makwana
CAET FMP Department JAU, Junagadh, Gujarat, India

Design and development of a device for harvesting of thorny fruits

Ajay D Makwana, Ram Vaibhav, Dr. Saumya Shukla and Dr. VK Tiwari

Abstract
Cactus pear fruit is fully thorny fruit which is very difficult to harvest. Therefore, this study was taken to solve the harvesting problem of this thorny fruit. First the engineering properties of Cactus pear fruit namely length, width, thickness, equivalent diameter, weight, firmness, sphericity, volume and density were observed/determined and considering these properties a harvesting device was developed and its performance evaluated in terms of harvesting capacity, losses, cost and efficiency. Use of the developed device Cactus pear fruit was harvested 10.05 kg/h with 6.14% harvesting loss, ₹ 4.98 per kg harvesting cost and with 93.86% harvesting efficiency i.e. 32.76% more capacity, 48.61% less loss, 24.54% less cost and 48.61% more efficiency compared to existing method.

Keywords: Developed device, cactus pear fruit, capacity, loss, cost, efficiency

Introduction
India is the second largest producer of fruits with 12 per cent share of total fruit production in the world. The area under horticulture crops which was 12.77 million hectares during 1991-1992 has increased to 23.69 million hectares during 2012-13. The total production during this period has increased by nearly 2.8 times and corresponding productivity has increased 1.5 times.

Cactus has been commercially exploited as fruit, vegetable, forage, energy, medicinal and dye yielding crop in the arid and semi-arid areas of the world. The other countries where cactus is grown as a cultivated crop and commercially exploited include Brazil, Argentina, South Africa, Israel, USA, Italy and many other Latin American countries. The cultivation of cactus as a commercial crop is known in Indian sub-continent. Only the wild cactus is found growing in wasteland, as a hedge around agricultural fields to protect crops from wild life. Due to its highest water use efficiency per unit dry matter production, the plant has ample scope for introduction and cultivation in rainfed and dry areas of India where 67% of the poor rural population is settled. Cactus has special significance in drought prone areas of the country where if planted will help in augmenting food and fodder requirement and thus halting cattle migration to other areas. In addition to its remarkable value as cattle and human food, it has a potential for soil and water conservation when planted on slopes in hilly terraces in rainfed areas of the country. Cactus is used as a fruit and vegetable for human consumption, forage for livestock and as a red dye. Several other uses of cactus are in control of diabetes, ethanol production and as live fence. Cactus pear fruit used as juice, beverages, jam, natural colour, gels, in pharmaceutical industries and for increasing haemoglobin in blood.

Cactus pear fruit is thorny and which is grown in thorny plant which is very difficult to harvest and also consume much labour and time and thus harvesting becomes costly. Limited information/references/literatures are available related to the harvesting of this thorny fruit and engineering properties. Therefore, this study was taken to solve the harvesting problem of this thorny fruit. First the engineering properties of Cactus pear fruits was determined and considering these properties a harvesting device was developed and its performance evaluated in terms of harvesting capacity, losses, cost and efficiency.

Materials and Methods
This study was conducted at Junagadh Agricultural University. In this study developed a device for a thorny fruit was designed basis of engineering properties of fruit and test its performance.

Engineering Properties of Cactus Pear Fruit

The following engineering properties of the most common variety of Cactus pear grown in the Saurashtra (Gujarat) region were determined as follows:

Size

The size of ripe Cactus pear was determined in terms of length (l), width (b) and thickness (t) by use of venire calliper. Size of each fruit in terms of equivalent diameter (De) was also determined by using following formula:

$$D_e = (lbt)^{1/3} \quad \ldots\ldots (1)$$

Where,
l = Largest dimension (mm)
b = Intermediate dimension (mm)
t = Smallest dimension (mm)

Shape

The shape of Cactus pear fruit was determined by the Standard chart of fruit shape. The Standard chart is shown in Plate 1.

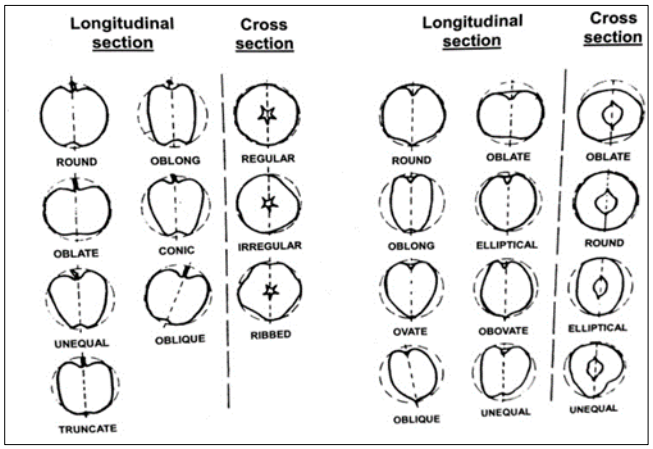

Plate 1: Chart for standard shapes

Firmness

Firmness of ripe fruit was measured by using the firmness tester instrument.

Volume, True density, Specific gravity

Platform scale method was used to determine the volume, true density and specific gravity of fruit.

$$\text{Volume } (cm^3) = \frac{\text{Weight of displaced fluid (g)}}{\text{Desity of fluid (g/cm3)}} \quad \ldots\ldots (2)$$

$$\text{True density } (g/cm^3) = \frac{\text{Weight of sample in air (g)}}{\text{Volume of displace fluid (cm3)}} \quad \ldots\ldots (3)$$

$$\text{Specific gravity} = \frac{\text{Weight of fruit in air(g)} \times \text{specificgravityof fluid}}{\text{Weight of displaced fluid (g)}} \ldots (4)$$

Design

The developed harvesting device consisted of the following main parts.

Handle

Length of handle was 200 cm i.e. decided based on physiological characteristic of Cactus plant as shown in Plate 2.

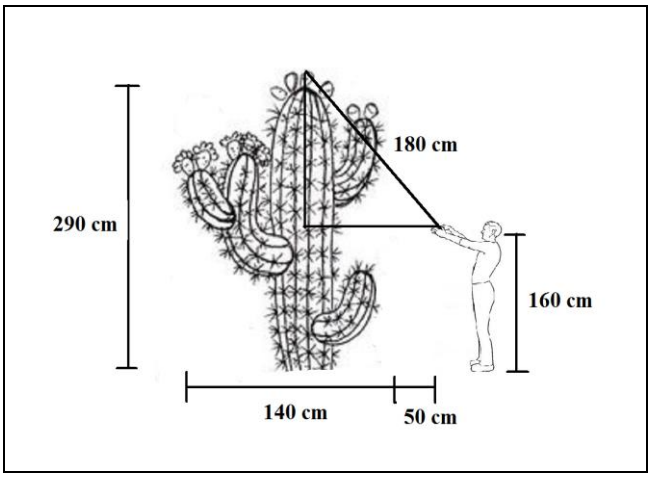

Plate 2: Physiological characteristic of Cactus plant

Cutting unit

For pick, detach and hold the Cactus pear in cutting unit was designed and developed. Cutting box consisted of 2 square jaws having 8 cm length and 4 cm width and cutting edges were made slightly sharp for easy holding and without broken fruit. In cutting unit one part was mounted and hooked with handle while another part was movable that was operated by string. A view of the design and the developed cutting unit is shown in Plate 3 and 4 respectively.

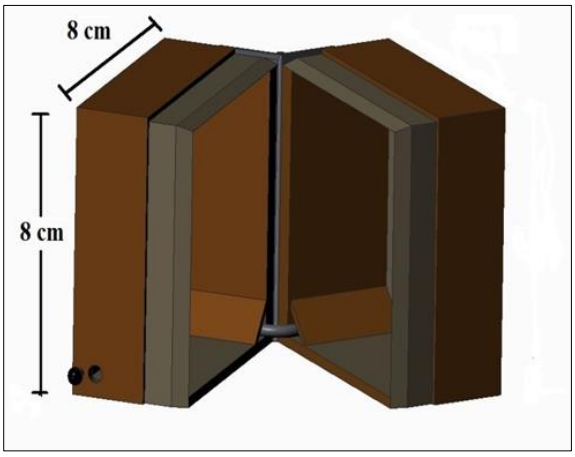

Plate 3: View of design cutting unit

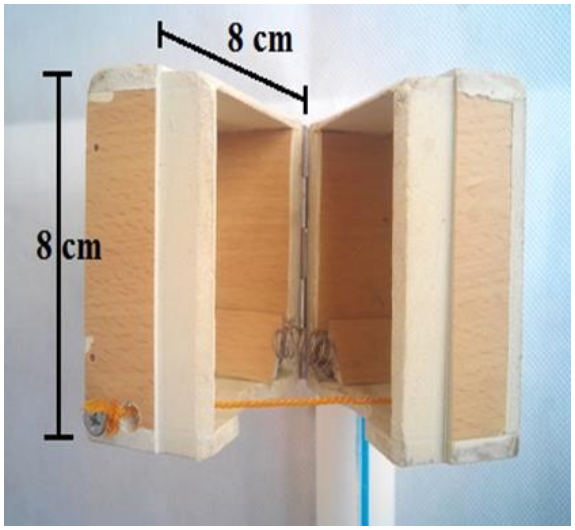

Plate 4: View of developed cutting unit

Views of device are shown in Plate 5.

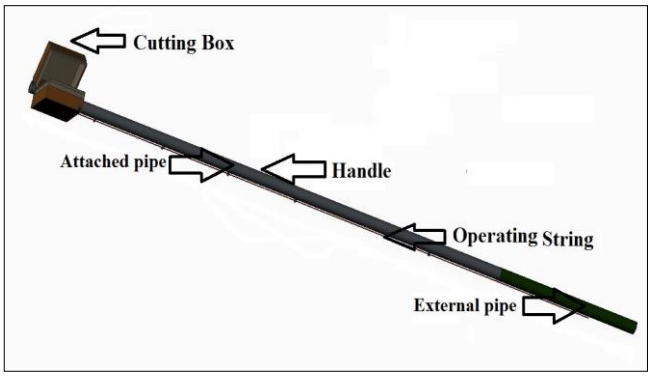

Plate 5: View of the design device

Performances

The performance of the developed device was evaluated in terms of harvesting capacity, losses, cost and efficiency and compared with existing method.

Harvesting capacity

Total amount of harvested fruits per unit time was calculated as follows:

$$\text{Harvesting capacity (kg/h)} = \frac{\text{Weight of total harvested fruit}}{\text{Total time of harvesting}} \ldots (5)$$

Harvesting losses

Under harvesting losses mechanical damage, unripe harvested and dropped out fruits were also considered.

Mechanical damage

$$\text{Mechanical damage (\%)} = \frac{\text{Weight of damage fruit}}{\text{Total weight of fruits in the sample}} \times 100 \ldots (6)$$

Unripe fruit loss

$$\text{Unripe fruit loss (\%)} = \frac{\text{Weight of unripe fruits}}{\text{Total weight of fruits in the sample}} \times 100 \ldots (7)$$

Dropped out fruit los

$$\text{Dropped out fruits loss (\%)} = \frac{\text{Weight of dropped out fruits}}{\text{Total weight (harvested + dropped out)}} \times 100 \ldots (8)$$

Cost of harvesting

The cost of harvesting was determined by knowing the total harvested amount of fruits with respect to total hours and shown in ₹ per kg. The fixed and variable costs of the device were determined by the straight line method.

Harvesting Efficiency

Harvesting efficiency (%) = 100 – [Total loss (%) + Un-harvested (%)].....(9)

Result and Discussion

Engineering Properties of Ripen Cactus Pear

Table 1: Engineering Properties of Ripen Cactus Pear.

Sr. No.	Engineering property		Minimum Value	Maximum Value	Average Value
1	Size	Length, mm	31.75	51.52	42.15
		Width, mm	24.03	36.50	31.40
		Thickness, mm	21.83	36.41	29.93
		Equivalent diameter, mm	27.23	39.27	34.04
2	Sphericity		0.67	0.90	0.81
3	Fruit weight, g		10.33	33.77	22.20
4	Firmness, kg/cm^2		6.88	15.25	11.01
5	Volume of ripe fruit, (cm^3)		12.20	28.70	19.52
6	Density of ripe fruit, (g/cm^3)		0.97	1.06	1.01
7	Specific gravity of ripe fruit.		0.97	1.06	1.01
8	Shape		Oblong		
9	Colour		Red		

Specifications of the Developed Device

Specifications of the developed device are shown in Table 2.

Table 2: Specifications of the developed device

Sr. No.	Particulars	Specifications
1	**Name of the device**	**Manually operated harvesting device for thorny fruit**
2	**Power source**	**Manually operated, by a single person**
3	**Overall dimensions**	
	Length in fully opened condition (cm)	200
	Total weight (kg)	1.0
4	**Cutting Box**	
	Length (mm)	80
	Width (mm)	80
	Thickness (mm)	4.30
	Cutting edge thickness (mm)	2.90
	Material	Plastic
	Shape of cutting box	Square
	No. of jaw	2

	Size of each jaw	8 × 8 × 4 cm
5	**Operating String**	
	Material	Plastic rope
	Thickness (mm)	2
6	**Handle**	
	Handle material	PVC Pipe
	Round pipe size	Diameter-3.4 cm Length-200 cm

Results of Working Performance

Harvesting Capacity

The harvesting of Cactus pear fruits were carried out by two different methods. The harvesting capacity of traditional and the developed device methods were found to be 7.57 & 10.05 kg/h respectively. The results of both the methods were shown graphically in Fig. 1. The harvesting capacity of the developed device was found 32.76% more as compared to the existing method. This was due to the increased reach of the human labour by the device. By the developed device the fruits could be harvested from a plant up to the height of 290 cm with comfort and safely without any injury. The results were analyzed statistically and presented in Table 3. The difference in harvesting capacities of both the methods was found statistically highly significant that can be seen in Table 3.

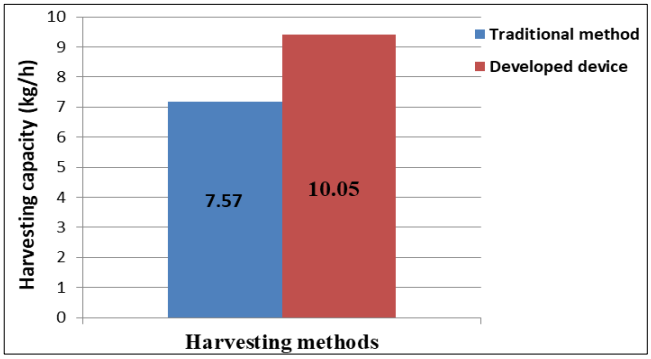

Fig 1: Harvesting capacity (kg/h)

Table 3: statistically analysis for the harvesting capacity

Sr. No.	Particulars	Method of harvesting	
		Traditional	Developed
1	Capacity (kg/h)	7.57	10.05
2	df	19	
3	t Stat	6.83	
4	t Critical two-tail	2.09	

Harvesting Losses

The average harvesting losses by the Traditional and the Developed device methods were found to be 4.75 & 6.14% respectively. These harvesting losses included the mechanical damage and dropout losses. The mechanical damages were found 1.19 & 1.80% and the dropout losses 3.56 & 4.34% for the Existing and the Developed methods respectively. The results are shown graphically in Fig. 2.

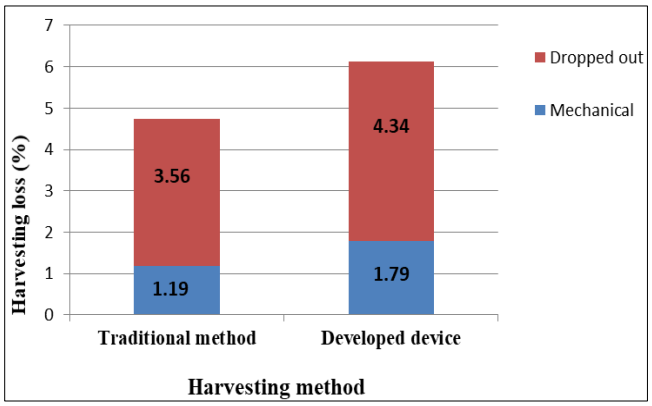

Fig 2: Different types of harvesting loss percentage

From the above Fig.2 it is clear that the dropped out losses were found more as compared to mechanical losses in both the methods. The total harvesting losses in the harvested fruits by the developed device are 1.39% more as compare to the traditional methods but traditional method harvested only up to 50% height of plant and the developed device harvested fully plant. If un-harvested fruits consider as loss so total loss could be 54.75% by traditional method while 6.14% loss by the developed device. The results were analyzed statistically and presented in Table 3. The difference in harvesting losses of both the methods was found statistically significant that can be seen in Table 4.

Table 4: Statistically analysis for the harvesting losses

Sr. No.	Particulars	Method of harvesting			
		Traditional		Developed	
		Mechanical	Dropped out	Mechanical	Dropped out
1	Losses (%)	1.19	3.56	1.80	4.34
3	Total losses (%)	4.75		6.14	
4	df	19			
5	t Stat	2.16			
6	t Critical two-tail	2.09			

Harvesting Cost

Harvesting of Cactus pear fruits was carried out by both the methods and the total harvesting cost was determined by the straight line method. The harvesting cost by traditional and the developed device methods were found to be ₹6.60 and 4.98 per kg respectively. The traditional method was found the more costly as compared to the developed device methods. The results of harvesting cost for both methods are shown in the Fig. 3.

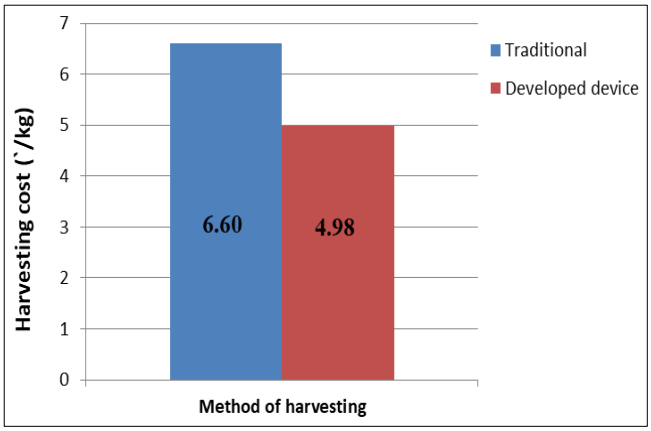

Fig 3: Harvesting cost of Cactus pear

By using the developed device one person can harvest roughly 55 kg per 6 hr of a day while by existing method one can harvest only 40 kg in the same time. Thus one person can earn not only ₹ 1050/- (based on market price of Cactus pear fruits ₹70 per kg) extra but he can harvest 100% by the developed device. Another way one person can save not only about one and half hour but can reduce un-harvesting losses by the developed device.

Harvesting Efficiency

Harvesting efficiency found to be 45.25% by traditional method while 93.86% by the developed device. Thus harvesting efficiency was 48.61% more by the developed device. The results are shown in graphically Fig. 4.

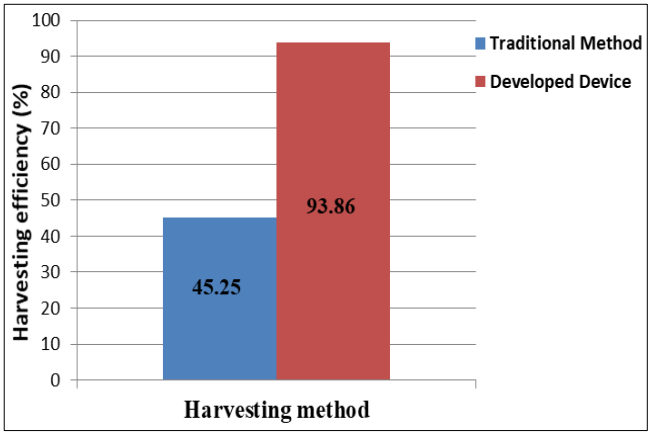

Fig 4: Harvesting efficiency of Cactus pear

Comparative Performance of Harvesting Methods

Traditional method could harvest 7.57 kg/h with 4.75% harvesting loss, ₹ 6.60 per kg harvesting cost and 48.61% harvesting efficiency as compared to the developed device could harvest 10.05 kg/h with 6.14% harvesting loss, ₹ 4.98 per kg harvesting cost and 93.86% harvesting efficiency thus 32.76% more capacity, 1.39% more loss, 24.54% less cost and 48.61% more efficiency by the developed device. The traditional method was found to be more risky to hand injuries and harvested only human reach and the developed device was found to be easier in use, more comfortable, less labour dependent, without hand injury and harvested top of plant around 290 cm. The results are shown graphically in Fig. 6. The results were presented in Table 5.

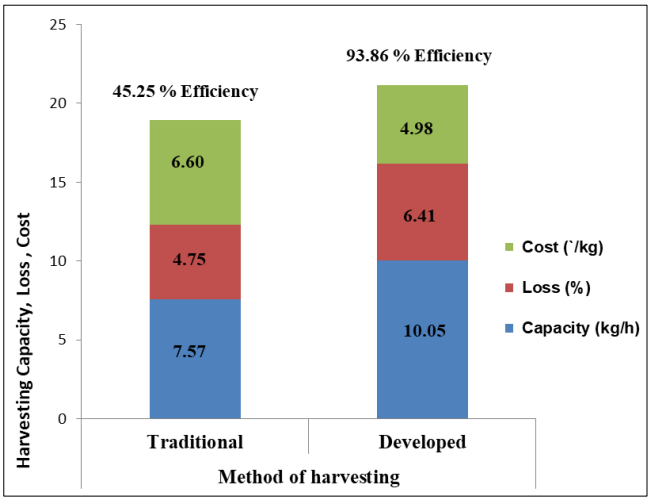

Fig 6: Comparative performance of harvesting methods

Table 6: Comparative performance of harvesting methods for Cactus pear

Sr. No.	Particulars	Method of harvesting	
		Traditional	Developed
1	Harvesting Capacity (kg/h)	7.57	10.05
2	Harvesting Loss (%)	4.75	6.14
3	Harvesting Cost (₹/kg)	6.60	4.98

Conclusions

1. Engineering properties for Cactus pear fruits for length, width, thickness, equivalent diameter, sphericity, weight, firmness, volume and density observed/determined were 42.15 mm, 31.40 mm, 29.93 mm, 34.04 mm, 0.81, 22.20 g, 11.01 kg/ cm^2, 19.52 cm^3, and 1.01 g/cm^3 respectively.
2. The harvesting capacity by the developed device was found 10.05 kg/h i.e. 32.76% more as compared to existing method.
3. The harvesting loss by the developed device was found 6.14% i.e. 48.61% less as compared to existing method.
4. The harvesting cost by the developed device was found ` 4.98 i.e. 24.54% less as compared to existing method.
5. The harvesting efficiency by the developed device was found 93.86% i.e. 48.61% more as compared to existing method.
6. In general the developed device was found better than the existing method as it harvested more with less losses and in less time. The developed device was also found easier in use, more comfortable & less labour dependent and without hand injury by the developed device as compared to traditional method.

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