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Potential Study of Existing Methods of Dragon Fruit Pulp Extraction

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Abstract

The present study investigates the performance of two existing manual methods Hand-Peeling and Scooping for pulp extraction from dragon fruit (Hylocereus spp.), aiming to identify their limitations and establish the need for a mechanized solution. The research was conducted at the Faculty of Agricultural Engineering, D. Y. Patil Agriculture and Technical University, Talsande, Kolhapur. Key performance parameters evaluated include time required for peeling, number of fruits peeled per hour, pulp extraction capacity (PEC), and pulp extraction efficiency (PEE). Experimental trials were performed on fruits harvested at 0, 2, and 4 days post-harvest to study the effect of storage on processing efficiency.

Results revealed that the Hand-Peeling Method was significantly more efficient, requiring an average of 48.37 seconds per fruit and achieving 74.69 fruits/hour with a pulp extraction efficiency of 95.21%. In contrast, the Scooping Method required 107.31 seconds per fruit, processed only 33.61 fruits/hour, and had a lower pulp extraction efficiency of 90.32%. Storage duration adversely affected performance in both methods, with reduced output and pulp yield observed after 4 days. Moreover, manual methods showed high labor demands, hygiene concerns, and inconsistent performance, rendering them unsuitable for commercial-scale operations.

These findings clearly indicate the limitations of manual techniques and highlight the necessity of developing a power-operated dragon fruit pulp extraction machine. Such mechanization would enhance productivity, reduce labor dependency, and improve hygiene, enabling efficient large-scale dragon fruit processing.

Keywords: Dragon fruit, pulp extraction, hand peeling, scooping method, pulp yield, extraction efficiency, post-harvest, processing, mechanization, storage effect

1. Introduction

Dragon fruit (*Hylocereus* spp.) is the tropical fruit known as pitaya or pitahaya or strawberry pear or night blooming cereus belongs to the Cactaceae family and is prevalent in two separate genera namely, 'Hylocereus' and 'Selenicereus'. The most common commercially cultivated varieties are from the Hylocereus genus covering around 16 different species (Le Bellec *et al*., 2006; Innes and Glass, 1992) [12, 10]. It is also called as strawberry pear, thangloy (Vietnamese), pitayaroja (Spanish), and la pitahaya rouge (French).

The dragon fruit can be categorized into four different species based on skin and pulp color, i.e., *Hylocereus undatus* (red skin, white pulp, Fig. 1.1 a), *Hylocereus polyrhizus* (red skin and red pulp, Fig. 1.1 b), *Hylocereus costaricensis* (red skin and purple pulp, Fig. 1.1 c) and

Hylocereus megalanthus (yellow peel and white pulp, Fig. 1.1 d) (Nerd *et al*. 2002) [17].

Three major countries *viz*., Vietnam, China and Indonesia contribute more than 93% of dragon fruit production of the world (Table 1.1). The share of Vietnam alone is more than half (51.1%) of the world production over an area of 55, 419 ha with average productivity of 22–35 t/ha/year. The volume of dragon fruit produced in Vietnam is more than 1 Mt of worth US$ 895.70 million.

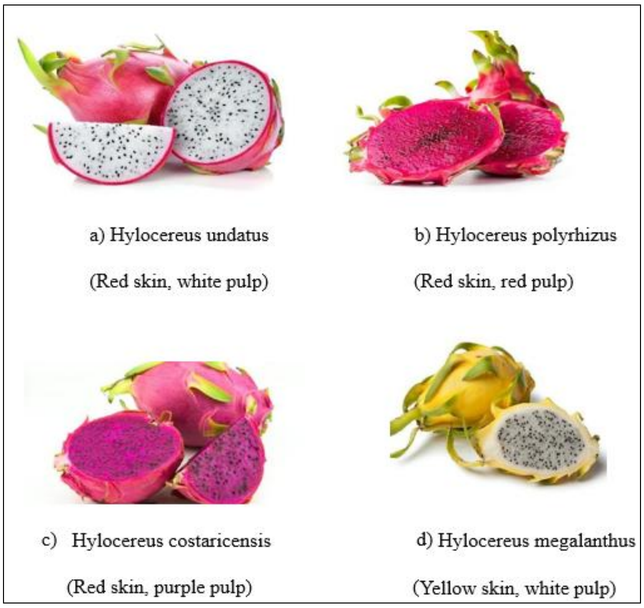

Fig. 1.1: Different species of dragon fruits

Table 1: Major dragon fruit producing countries (area, production and productivity, 2017 – 2018)

Country	Production Area (ha)	Production (MT)	Productivity ($MTha^{-1}$)
Vietnam	55,419	10,74,242	22-35
China	40,000	7,00,000	17.5
Indonesia	8,491	2,21,832	23.6
Thailand	3,482	26,000	7.5
Taiwan	2490.6	49,108	19.7
Malaysia	680	7,820	11.5
Philippines	485	6062.5	10-15
Cambodia	440	4,840	11.0
India	400	4,200	8.0-10.5
USA	324	5,832	18.0
Australia	40	740	18.5
South Africa	12	100	8.3
Total	1,12,264	21,00,777	-

Source: Wakchaure *et al.*, 2020 [24]

Global demand for dragon fruit is on a steady rise, as recent estimates indicate. According to the world dragonfruit.net.vn website, the demand across different international markets is significantly influenced by marketing information highlighting its nutraceutical properties and health benefits, alongside factors like price and sweetness level.

In India, dragon fruit was introduced during the late 1990s. Thereafter, area under its cultivation was gradually increased from 4 to 400 ha in different states during 2005–2017 (Digital and printed information available in public domain data collected by ICAR– NIASM). Initially cultivation of dragon fruit was started by the farmers from Karnataka, Maharashtra, Gujarat, Kerala, Tamil Nadu, Odisha, West Bengal, Andhra Pradesh, Telangana and Andaman & Nicobar Islands. Nowadays, its cultivation has extended to Rajasthan, Punjab, Haryana, Madhya Pradesh, Uttar Pradesh and Northeastern States. According to recent estimates (Table 1.2 and 1.3), India's dragon fruit production increased drastically to more than 12,000 tons over an area of 3,000–4,000 ha in 2020 (Estimated area, production and productivity, 2020).

Table 2: Year Wise estimated area (ha) under dragon fruit cultivation in India

Year	Area (ha) under cultivation
1990	Introduced in India (0.5)
2005	4.0
2010	12.0
2012	15.0
2014	35.0
2017	400.0
2020	3085.0

Source: Wakchaure *et al*., 2020 [24]

Gujarat, Karnataka, and Maharashtra are the top contributors, accounting for approximately 70% of India's dragon fruit production (Table 1.3). The arid regions of Kutch in Gujarat, Northern Karnataka, and Western Maharashtra are the primary areas for dragon fruit cultivation in the country. The southern and western states have been significant contributors to dragon fruit production, having cultivated the fruit over the past 5 to 8 years. For instance, in Karnataka, more than 600 farmers have started growing dragon fruit in the last five years after observing its success. The area dedicated to dragon fruit in Karnataka expanded from about 8 to 10 hectares in 2012 to roughly 500 hectares in 2020, with expectations to reach around 5000 hectares in the next five years. Currently, over 200 farmers in Gujarat's Kutch are cultivating dragon fruit on approximately 800 hectares of land (Wakchaure *et al*., 2020) [24].

However, selecting such crops and fruits for introduction necessitates a critical assessment of factors related to adaptation, shelf life, consumer acceptability, and market opportunities for the socio-economic development of the debt-ridden farming community in barren, flood, and drought-prone regions. Dragon fruit is one such potential crop that can be easily cultivated in large parts of degraded land and drought-prone areas of the country. It has gained worldwide recognition, initially as an ornamental plant and subsequently as a fruit crop, becoming a preferred choice for salads due to its colorful bracts, dark red flesh, and edible tiny black seeds embedded in white flesh. Value-added products such as juice, jam, jelly, candy, syrup, and wine can be derived from dragon fruit pulp. It is one of the fastest-returning perennial fruit crops, offering quick returns on investment with production commencing in the second year and reaching full production in the fifth year of plantation. Given these attributes, this fruit is also gaining popularity among Indian farmers, entrepreneurs, and consumers in both rural and urban areas. In the past 3–5 years, some Indian growers have initiated steps to adopt cultivation technologies for the commercial production of dragon fruit. Since the crop is relatively new to the diverse agro-climatic conditions of India, the primary challenge is to optimize region-specific protocols for cultivation, harvesting, and post-harvest management practices to achieve maximum yield and quality performance.

Table 3: Major dragon fruit producing states (Estimated area, production and productivity, 2020)

Major States	Total Area (ha)	New area (ha) 80%, A1*	Productivity of A1 (MT/ha), P1	Production in A1 (MT), Y1	Old Area (ha), A2	Productivity (MT/ha) of A2*, P2	Production in A2 (MT), Y2	Total production (MT) (Y1+Y2)
Andhra Pradesh	140.4	112.3	1.5	168.5	28.1	10.2	286.5	455.0
Telangana	80.9	64.8	1.8	116.6	16.2	10.0	161.9	278.4
Tamil Nadu	121.4	97.1	2.2	213.7	24.3	12.0	291.4	505.1
West Bengal	303.5	242.8	2.1	509.9	60.7	11.0	667.7	1177.7
Maharashtra	323.8	259.0	3.1	802.9	64.8	13.5	874.1	1677.1
Karnataka	485.6	388.5	3.0	1,165.5	97.1	12.4	1,204.4	2,369.9
Gujrat	1,214.1	971.3	2.2	2,136.8	242.8	8.0	1,942.5	4,079.3
Rajasthan	38.4	30.8	1.5	46.1	7.7	8.0	61.5	107.6
Meghalaya	174.0	139.2	2.8	389.8	34.8	11.4	396.8	786.6
Other	202.3	161.9	1.5	242.8	40.5	10.7	433.9	676.7
Total/ average	3,084.6	2,467.7	2.2	5,792.6	616.9	10.7	6,320.7	12,113.4

Note: A1* newly cultivable area after 2018–19 and A2* well established cultivable area more than 4 years olds plantation
Source: Wakchaure *et al.*, 2020 [24]

A major advantage of cultivating dragon fruit is that once planted, it can grow for about 20 years, with one hectare accommodating roughly 800 plants. Notably, it is a perennial crop that offers quick returns, with production starting the year after planting and reaching full production within five years. As dragon fruit is highly perishable, careful attention is required from cultivation through to harvesting, handling, storage, processing, and transportation until it reaches the market. Since a large portion of the fruit is consumed fresh, establishing an effective marketing channel for long-distance transportation is a considerable challenge. Therefore, postharvest research and development efforts need to be intensified to support the industry. From a processing standpoint, dragon fruit is used to create value-added products such as juice, jam, jelly, powder, and wine. Given its nutritional benefits and commercial significance, the role of dragon fruit in the processing industry is substantial.

Raw Dragon fruits are astringed, while ripe fruits are mild sweet. Dragon fruit is a medium size fruit, generally with a diameter range from 71.90 mm to 81.70 mm for red dragon fruit & for white dragon fruit 76.90 mm to 85.50 mm with round to oblong shaped appearance. For red Dragon fruit weight 204.01 g to 338.81 g. It is mainly used as dessert fruits besides many processed products are prepared from Dragon fruit namely jam, jelly, yogurt and soft drinks. Mature fruits are used for making mixed fruits jams and provide a valuable source of raw materials for manufacture of industrial glucose, protein and natural fruits jellies. Moreover, dragon fruits are canned as slices.

Being non-climacteric in nature, dragon fruit provides the best quality for consumption when it is harvested ripe as the quality diminishes during storage. Chein *et al.*, 2007 studied at optimum maturity, it has ample amount of small black seed with a bright red/yellow skin and white/coloured pulp depending on the type of cultivar. Dragon fruit consists of three major components, pulp (47.40–73.76%), peel (36.-70–37.60%), and seeds (2.70–14.67%). Esquivel, P.; 2007 [4] and Lim, H. K. *et al.*, 2007 [14] studied that the colour of fruit pulp may vary from white to various hues of red and purple. Peel of red or yellow colour is observed in dragon fruit (Mizrahi, Y.and Nerd, 1999) [16]. Also, the red colour of peel is deeper in red dragon fruit than white fruit. Seeds are tiny, soft in texture, edible and black coloured (Lichtenzveig *et al.*, 2000) [13]. Dragon fruit is native to Mexico, Central America and South America; but now widely cultivated as fruit crops in Southeast Asian countries (Haber 1983; Mizrahi *et al*. 1997) [27, 15].

Fruit pulp is an edible part of dragon fruit. It is generally used in fruit salad and is a natural source of antioxidants. The pulp of dragon fruit is mildly sweet, low in calories and contain high amount of vitamin C and antioxidant. It has gained more attention due to its health benefits including prevention of memory losses, prevention of cancer, control of blood glucose level in diabetic patients, prevention of oxidation, aiding in healing of wounds etc. In addition, it has the ability to promote the growth of probiotics in the intestinal tract (Zainoldin and Baba 2009) [26].

Dragon fruits are reported to contain sugar, acids, protein, amino acid, phenolics *viz*, galic acid, catechin, chlorogenic acid, leucodelphinidin, and leucodelargonidin and Leucopelargonidin, carotenoids, ascorbic acids, and minerals like potassium, calcium and iron (Chia, S. L. and Chong, G. H., 2015) [2]. Fruits contain moisture in the range of 88-92% for red dragon and 90-93% for white dragon fruit. TSS in the range of 10-12 for red dragon and 10-11% in white dragon fruit. pH (for red dragon fruit 5.53 and for white dragon fruit 4.24– 100 g), Acidity (for red dragon fruit 0.74 and for white dragon fruit 0.64– 100g), Total sugar (for red dragon fruit 8.83 and for white dragon fruit 8.01-100 g), Reducing sugar (for red dragon fruit 4.62 and for white dragon fruit 4.11-100 g) and minerals nutrient *viz*.

Quality is defined as the absence of defects or degree of excellence and it includes appearance, colour, shape, injuries, flavour, taste, aroma, nutritional value and being safe for the consumer. Due to a higher market exigency as for high quality products, the juice and pulp industries have been looking for fruits with better internal and external features, including fruit length and width; fruit weight; pulp, seed and peel percentages per fruit; number of seeds per fruit; seed size and peel diameter; soluble solids (ºBrix); Titratable acidity (%); vitamin C content (mg/100g of fresh fruit); pulp pH and soluble solids/ Titratable acidity ratio. Many studies have been reported on physical properties of fruits such as Apple, Apricot, Banana, Olive, Pomegranate and grape by the researches. The literature on physico-chemical properties of Dragon fruit is scarce that is required for design.

The information about the minimal processing of dragon fruit on pilot scale is very limited. The mechanization will help to reduce the production cost, human drudgery and in achieving a better quality of end products. Processing of by-products, i.e. peel and seed merely will not enhance the profitability, yet additionally provide new products for food, cosmetic, and pharmaceutical industry. Given these challenges, there is a clear need for a analysis of the hand-peeling method and scooping method for dragon fruit processing.

2. Review of Literature

In the potential study of dragon fruit pulp extraction methods, it is essential to comprehend the multidisciplinary aspects that include fruit characteristics, post-harvest physiology and existing processing technologies. This literature review offers critical insights into the biological and technological parameters that affect the efficient extraction of pulp from dragon fruit, a fruit of increasing commercial and nutritional significance in tropical and subtropical regions.

2.1 Existing Methods for Dragon Fruit Pulp Extraction

Hoa *et al*. (2006) [8] and Le Bellec *et al*. (2006) [12] stated the pulp extraction of dragon fruit (Hylocereus spp.) is primarily performed using manual methods, especially in small-scale and cottage-level industries. The traditional technique involves cutting the fruit in half using a knife and then manually scooping out the pulp with a spoon or hand. While simple and cost-effective, this process is labour-intensive, time-consuming, and highly dependent on human hygiene practices. The variability in pulp yield, risk of contamination, and physical fatigue associated with repetitive handling limit its suitability for large-scale operations.

Zainal *et al*. (2012) [25] and (Paull, 2008) [20] highlighted the limitations of manual extraction, particularly regarding time efficiency, operator fatigue, and inconsistent pulp recovery. Manual methods often result in significant pulp losses adhering to the peel or due to improper scooping techniques, yields a recovery efficiency of around 75–80%, depending on the operator’s skill and fruit ripeness. Hygiene concerns are especially prominent, as bare-hand contact with the fruit pulp may introduce microbial contaminants, reduce shelf life and violate food safety norms.

To address these issues, semi-mechanized techniques such as mechanical slicers, rotary drum pulpers, and manually fed screw-type extractors have been explored. Phan *et al*. (2020) [21] suggested however most of these are either adapted from systems used for other fruits (e.g., papaya or guava) or are not optimized for dragon fruit's soft pulp and delicate seed structure. These machines still require considerable manual intervention during feeding, positioning, or cleaning, thus limiting the scope for automation and sanitary handling.

Hmar *et al*. (2017) [7] conducted a comparative analysis between traditional and semi-mechanized systems and showed that while semi-mechanized machines improve throughput and reduce labour, they often cause damage to seed or result in pulp-seed mixtures requiring further separation. Moreover, the peel sometimes gets mixed with the pulp due to inefficient separation mechanisms, lowering pulp purity. These findings underscore the need for a dedicated machine design tailored to dragon fruit’s physicochemical and structural properties.

In summary, while existing methods offer basic functionality, they fall short on parameters like hygienic handling, efficiency, continuous operation, and precision in pulp separation. The development of a specialized, food-grade, and motorized dragon fruit pulp extraction machine like the one proposed in this study aims to bridge these gaps by improving yield, maintaining pulp quality, and enhancing post-harvest processing efficiency.

3. Materials and Methods

This chapter contains material and equipments used, methodology followed for evaluating the existing methods of pulp extraction from dragon fruit, The experimental work was carried out at Faculty of Agricultural Engineering, D. Y. Patil Agriculture and Technical University, Talsande, Kolhapur (MS), India.

The properties of agricultural produces vary widely based upon the conditions to which they are exposed. Hence, relevant properties were determined to specify their characteristics before being used in experiments. Besides, information on some of the properties was also needed in the design and operation of dragon fruit pulp extraction machine. Hence, the first set of experiments was intended for study of existing methods of peeling dragon fruit. Also checked performance for parameter for this, *viz*. pulp extraction efficiency (PEE) & pulp extraction capacity (PEC). The experiment planned under this investigation are described below.

3.1 Number of Fruits Peeled per Hour

For both methods, a consistent set of 10 dragon fruits were selected for each trial. Each fruit was peeled using either the Hand-Peeling Method or the Scooping Method. The time taken to peel each fruit was recorded using a digital timer. The total number of fruits peeled per hour was calculated by dividing the total peeling time by the number of fruits peeled in a specific period. The average number of fruits peeled per hour was calculated for each method.

3.2 Pulp Yield Measurement

After peeling, the pulp, peel, and total weight of the fruit were measured separately using a weighing balance. Pulp-to-fruit ratio and peel-to-fruit ratio were also calculated to evaluate the amount of usable pulp and wasted peel.

3.3 Evaluation of Existing Methods for Pulp Extraction from Dragon Fruit

The pulp extraction from dragon fruit is done by peeling off the outer cover of the dragon fruit by hands or by using a scoop to extract the pulp from the cut fruit. Peeling is manual process (using hands) used to separate the peel from the fruit (Fig. 3.1) and scooping is a process of removing pulp using a spoon-like tool (Fig. 3.2). Fresh and ripen dragon fruits were used for both the hand-peeling and the scooping for studying the pulp extraction efficiency (PEE) & pulp extraction capacity (PEC). The fruits were used after immediate harvesting 0 days, 2 days, and 4 days after harvesting to assess the effect of after harvest period on the pulp extraction performance.

For both methods, a consistent set of 10 dragon fruits (harvested after 0, 2 & 4 days each)were selected for each trial using hand-peeling and the scooping.The time required to extract the pulp from each fruit was recorded using a digital timer.The average weight of pulp received per hour was calculated for each method for each harvest period of fruits.

Fig. 1.3: Hand Peeling Method

Fig. 1.4: Scoping Method

After peeling, the pulp, peel, and total weight of the fruit were measured separately using a weighing balance. The pulping efficiency was determined from the percentage of pulp extracted relative to the initial weight of the fruit.

4. Results and Discussion

The results of research work conducted for the development of dragon fruit pulp extraction machine and its performance evaluation using different independent parameters was studied and optimized. After getting an optimized independent parameters a long run test was conducted and recorded the performance. The results obtained are discussed as under.

4.1 Evaluation of existing methods for pulp extraction from Dragon fruit

The pulp extraction of dragon fruit was studied using two existing methods namely the Hand-Peeling Method and the Scooping Method. These methods were evaluated based on several performance parameters *viz*. time required for extracting pulp, amount of pulp extracted per hour, and the total weight of fruit, peel, and pulp. The amount of pulp left on the peel was measured to assess pulp extraction loss, pulp extraction capacity (PEC) and pulp extraction efficiency(PEE) were determined to compare the effectiveness of both techniques. The pulp-to-fruit ratio and peel-to-fruit ratio were also calculated to study the performance of pulp extraction. These findings provide valuable insights into optimizing the pulp extracting process for improved efficiency and reduced loss in dragon fruit processing.

4.2 Time required for peeling of dragon fruit by Hand-Peeling Method and the Scooping Method

From Table No. 4 & 5 the results indicate a significant difference in the time required for peeling dragon fruit using the Hand-Peeling Method and the Scooping Method. The Hand-Peeling Method had an average time of 48.37 seconds, with individual peeling times ranging from 44.58 to 53.48 seconds, showing relatively low variation. This suggests that hand peeling is a more consistent and faster method for removing the peel.

On the other hand, the Scooping Method had a much higher average time of 107.31 seconds, with peeling times ranging from 97.58 to 113.15 seconds. This method took more than twice the time compared to hand peeling, indicating that it is less efficient and more time-consuming. The increased time in the scooping method may be due to the complexity of separating the pulp from the peel manually, whereas hand peeling allows for quicker and more direct removal. These findings highlight the efficiency of the hand-peeling method in terms of time and ease of operation. Manual operation is tedious, time-consuming, and operated by hand to facilitate the removal of the peel from the cassava tuber.

4.3 No. of Fruits peeled /hr. for peeling of dragon fruit by Hand-Peeling Method and the Scooping Method

From Table No. 4 & 5 the results highlight a clear difference in the efficiency of the Hand-Peeling Method and the Scooping Method in terms of the number of dragon fruits peeled per hour. For the Hand-Peeling Method, the average number of fruits peeled per hour was 74.693, with individual values ranging from 67.31 to 80.75 fruits per hour. This indicates a higher efficiency and relatively consistent performance across trials. The higher number suggests that this method allows for quicker and easier peeling, making it a time-saving approach for processing dragon fruit. Zainal *et al*. (2012) [25] and (Paull, 2008) [20] studied that Manual methods often result in significant pulp losses adhering to the peel or due to improper scooping techniques, yields a recovery efficiency of around 75–80%, depending on the operator's skill and fruit ripeness in custard apple.

In contrast, the Scooping Method showed an average peeling rate of 33.61 fruits per hour, with values ranging between 31.81 and 36.89 fruits per hour. This method is significantly slower, achieving less than half the efficiency of hand peeling. The lower rate may be due to the complexity and additional effort required to scoop out the pulp, making it a more labor-intensive and time-consuming process. Overall, the Hand-Peeling Method proves to be the more efficient technique, making it preferable for large-scale dragon fruit processing, where speed and consistency are crucial.

4.4 Pulp extraction capacity of hand-peeling method and scooping method

From Table No. 7 the results highlight a clear difference in the pulp extraction capacity of the Hand-Peeling Method and the Scooping Method in terms of the number of dragon fruits peeled per hour. For the Hand-Peeling Method, the average number of fruits peeled per hour was 76, with individual values ranging from 72 to 80 fruits per hour. Whereas In contrast, the Scooping Method showed an average pulp extraction capacity of 35 fruits per hour, with values ranging between 32 and 36 fruits per hour. This indicates a higher pulp extraction capacity and relatively consistent performance across trials. The higher number suggests that this method allows for quicker and easier peeling, making it a time-saving approach for processing dragon fruit.

Scooping method is significantly slower, achieving less than half the pulp extraction capacity of hand peeling. The lower rate may be due to the complexity and additional effort required to scoop out the pulp, making it a more labor-intensive and time-consuming process. Overall, the Hand-Peeling Method proves to be the more efficient technique, making it preferable for large-scale dragon fruit processing, where speed and consistency are crucial. Manual operation is tedious, time-consuming, and operated by hand to facilitate the removal of the peel from the cassava tuber. The output of the skilled person for manual peeling is about 25 kg/h with a 25-30% loss of weight in the peels (Gumanit and Pugahan, 2015) [5].

Table 4: Evaluation of Hand peeling method for peeling of dragon fruit

Sr. No.	Time Required (sec)	No. of Fruits peeled /hr.	Total Weight of Fruit (gm)	Peel Weight of Fruit (gm)	Pulp Weight of Fruit (gm)	Amount of Pulp on peel	Total Weight of Pulp	Efficiency of pulping	Pulp to Fruit Ratio	Peel to Fruit ratio
1	45.26	79.54043305	370.58	171.66	190.02	8.9	198.92	95.5258	53.678	46.32
2	48.12	74.81296758	395.41	156.48	230.53	8.4	238.93	96.4843	60.4259	39.57
3	44.58	80.75370121	349.45	166.25	175.31	7.89	183.2	95.6932	52.4252	47.57
4	52.69	68.32416018	380.15	147.94	221.37	10.84	232.21	95.3318	61.0838	38.92
5	49.74	72.37635706	395.87	171.24	214.38	10.25	224.63	95.4369	56.7434	43.26
6	53.48	67.31488407	364.51	179.36	172.3	12.85	185.15	93.0596	50.7942	49.21
7	47.25	76.19047619	383.47	158.79	214.83	9.85	224.68	95.6159	58.5913	41.41
8	45.48	79.15567282	398.58	174.14	213.56	10.88	224.44	95.1523	56.3099	43.69
9	46.88	76.79180887	365.47	166.35	186.58	12.54	199.12	93.7022	54.4833	45.52
10	50.23	71.67031654	405.83	168.98	224.98	11.87	236.85	94.9883	58.3619	41.64
Avg	48.37	74.693	380.93	166.11	204.38	10.42	214.8	95.099	56.2896	43.71

Table 5: Evaluation of Scooping method for peeling of dragon fruit

Sr. No.	Time Required (sec)	No. of Fruits peeled /hr.	Total Weight of Fruit (gm)	Peel Weight of Fruit (gm)	Pulp Weight of Fruit (gm)	Amount of Pulp on peel	Total Weight of Pulp	Efficiency of pulping	Pulp to Fruit Ratio	Peel to Fruit ratio
1	97.58	36.8928059	375.51	161.71	191.2	22.6	213.8	89.4293	56.9359	43.06
2	108.41	33.2072687	382.14	164.18	198.72	19.24	217.96	91.1726	57.0367	42.96
3	113.15	31.81617322	361.25	172.15	173.92	15.18	189.1	91.9725	52.346	47.65
4	103.89	34.65203581	389.32	152.18	222.47	14.67	237.14	93.8137	60.9113	39.09
5	108.75	33.10344828	391.41	177.32	193.9	20.19	214.09	90.5693	54.6971	45.3
6	106.41	33.83140682	377.45	172.46	187.05	17.94	204.99	91.2483	54.3092	45.69
7	112.24	32.07412687	390.82	165.28	207.27	18.27	225.54	91.8994	57.7094	42.29
8	101.15	35.59070687	387.11	178.19	186.73	22.19	208.92	89.3787	53.9692	46.03
9	110.47	32.58803295	372.16	158.34	196.9	16.92	213.82	92.0868	57.4538	42.55
10	111.14	32.39157819	401.17	174.61	212.73	13.83	226.56	93.8956	56.4748	43.53
Avg	107.31	33.61	382.83	167.64	197.08	18.1	215.18	91.5666	56.18	43.81

Table 6: Storage Period affects on peeling of dragon fruit

Methods	Duration (hr)	Storage period & No. of Fruits peeled in hr & pulp extraction capacity (kg/hr)		
		0 Days	After 2 Days of harvesting	After 4 Days of harvesting
Hand Peeling Method	1	84 (31.03 kg/hr)	76 (28.07 kg/hr)	64 (23.64 kg/hr)
Scooping Method	1	36 (13.29 kg/hr)	32 (11.82 kg/hr)	24 (8.86 kg/hr)

Table 7: Evaluation of existing method for pulp extraction from dragon fruit

A) Hand peeling method										
Replication	**Duration (hr)**	**No of Fruits peeled/hr**	**Total Weight of Fruit (kg/hr)**	**Peel Weight received (kg/hr)**	**Pulp Weight received (kg/hr)**	**Pulp lost (kg/hr)**	**Total Weight of Pulp (kg/hr)**	**Pulp Extraction Efficiency**	**Pulp to Fruit Ratio**	**Peel to Fruit ratio**
1	1	76	30.08	13.06	16.34	0.673	17.01	96.04	56.57	43.42
2	1	72	29.21	13.89	14.52	0.791	15.31	94.83	52.42	47.57
3	1	80	27.95	11.64	15.46	0.854	16.31	94.76	58.36	41.64
Average	1	76	29.08	12.86	15.44	0.773	16.21	95.21	55.76	44.21
B) Scooping method										
Replication	**Duration**	**No of Fruits peeled/hr**	**Total Weight of Fruit (kg/hr)**	**Peel Weight received (kg/hr)**	**Pulp Weight received (kg/hr)**	**Pulp lost (kg/hr)**	**Total Weight of Pulp (kg/hr)**	**Pulp Extraction Efficiency**	**Pulp to Fruit Ratio**	**Peel to Fruit ratio**
1	1	36	13.30	6.09	6.42	0.78	7.20	89.47	54.18	45.81
2	1	32	12.83	5.58	6.67	0.57	7.24	92.08	56.47	43.53
3	1	36	13.51	5.82	6.88	0.81	7.69	89.42	56.93	43.06
Average	1	34.66	13.21	5.83	6.66	0.72	7.38	90.32	55.86	44.13

4.5 Pulp extraction efficiency of hand-peeling method and scooping method

From Table No. 7 the results indicate a difference in pulp extraction efficiency between the Hand-Peeling Method and the Scooping Method when peeling dragon fruit. For the Hand- Peeling Method, the average pulp extraction efficiency was 95.21%, with individual values ranging from 94.76% to 96.04%. Whereas this high pulp extraction efficiency suggests that minimal pulp is left on the peel, making this method more effective in extracting the maximum amount of usable pulp. The consistent results across trials further indicate that the Hand-Peeling Method provides a reliable and efficient approach for pulp extraction. In contrast, the Scooping Method had a lower average pulp extraction efficiency of 90.32%, with values ranging between 89.42% and 92.08%. The mean peeling efficiency in cassava fruit is 75.46%, with a mean flesh loss of 8.801% in 10 kg feed. The scooping technique, being more time-consuming and manual, likely results in incomplete pulp separation, reducing overall efficiency. Overall, the Hand-Peeling Method outperforms the Scooping Method in terms of both capacity and efficiency, making it the more suitable choice for large-scale dragon fruit processing where maximizing yield and minimizing wastage are key factors. Bakane *et al.*, 2014 studied that Cylinder inlet diameter of 213 mm and an outlet diameter of 177 mm exhibited the best performance, with a machine efficiency of 82.50% and a minimum pulp loss of 2.09% for Mango.

4.6 Effect of storage on pulp extraction performance

The effect of storage period on the pulp extraction capacity of dragon fruit using two different methods: hand peeling and scooping method was also studied (Table 6). The data clearly shows that as the storage period increases from 0 to 4 days after harvesting, both the number of fruits peeled per hour and the pulp extraction capacity decrease significantly for both methods. On the day of harvest (0 days), the hand peeling method allows peeling of 84 fruits per hour with a pulp extraction capacity of 31.03 kg/hr, whereas the scooping method handles 36 fruits per hour yielding 13.29 kg/hr. However, after 4 days of storage, these values reduce to 64 fruits (23.64 kg/hr) for hand peeling and just 24 fruits (8.86 kg/hr) for scooping method. It is evident that the storage period significantly decreases the pulp extraction capacity of dragon fruit (Mizrahi & Nerd, 1999; Hoa *et al*., 2006) [16, 8]. As the storage duration increases, fruit texture softens, reducing ease of peeling and pulp yield (Singh *et al*., 2010) [23]. This confirms that immediate post-harvest processing is ideal to maintain efficiency (Sharma & Dhawan, 2018) [22].

Overall, the hand peeling method remains more efficient than the scooping method across all storage durations, but early post-harvest processing is essential to achieve maximum pulp yield and efficiency. The analysis of the Hand-Peeling Method and Scooping Method for dragon fruit processing highlights several limitations, including high labor requirements, low efficiency, pulp wastage and compromised food hygiene. The Hand-Peeling Method, while relatively faster, still demands significant manual effort and results in inconsistent output. Both the methods making it highly impractical for large-scale operations. Given these challenges, there is a clear need for a power-operated dragon fruit pulp extraction machine. Such a machine would not only improve efficiency and reduce labor dependency but also enhance hygiene standards and processing capacity, making it a viable solution for commercial-scale operations. Manual methods like hand peeling and scooping suffer from labor-intensive operations, low throughput, and hygiene concerns (Phan *et al*., 2015; Patel *et al*., 2020) [21, 18]. These challenges underline the necessity for mechanized solutions tailored for soft fruit like dragon fruit (Jain & Verma, 2016) [11].

5. Conclusion

With limited practices of for dragon fruit processing, the focus is on improving efficiency and reducing waste. This study comprehensively evaluated the traditional manual methods for dragon fruit peeling and developed an automated pulp extraction machine optimized through rigorous experimental analysis. The integration of physicochemical characterization, statistical modelling, and techno-economic assessment provides a holistic view of the process improvements achievable through automation. The manual peeling techniques Hand-Peeling and Scooping were critically examined. This initiative underscores the importance of research in improving dragon fruit handling and processing methods.

The analysis of the Hand-Peeling Method and Scooping Method for dragon fruit processing highlights several limitations, including high labor requirements, low efficiency, and compromised food hygiene. The Hand-Peeling Method, while relatively faster, still demands significant manual effort and results in inconsistent output. Its efficiency declines with storage time, as the peeling duration increases from 41.93 seconds on the day of harvest to 47.58 seconds after two days and 55.91 seconds after four days. The Scooping Method is even less efficient, requiring significantly more time 97.56 seconds on harvest day, rising to 104.63 seconds after two days and 111.23 seconds after four days making it highly impractical for large-scale operations. Additionally, both methods contribute to pulp wastage, are labor-intensive, and pose food safety concerns due to direct hand contact with the fruit. Given these challenges, there is a clear need for a power-operated dragon fruit pulp extraction machine. Such a machine would not only improve efficiency and reduce labor dependency but also enhance hygiene standards and processing capacity, making it a viable solution for commercial-scale operations.

1. *Hand-Peeling* demonstrated an average peeling time of 48.37 seconds with a throughput of approximately 74.69 fruits per hour and pulping efficiency around 95.10%.
2. *Scooping* was considerably slower, averaging 107.31 seconds per fruit and 33.61 fruits per hour with a slightly lower efficiency of 91.57%.
3. Both methods showed increased processing times with extended storage periods, highlighting limitations in scalability, labor intensity, and food hygiene.

6. References

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