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A review on fruit pulp extraction machines: Design, performance, and technological advancements

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Abstract

Fruit processing plays a crucial role in reducing post-harvest losses, extending shelf life, and enhancing the value of agricultural produce. Among various processing operations, pulp extraction is a key step in the production of juices, purees, nectars, jams, and other fruit-based products. However, conventional manual extraction methods are labor-intensive, time-consuming, and often result in low pulp recovery and inconsistent product quality. This review examines the design, development, operating principles, and performance of fruit pulp extraction machines with emphasis on their extraction mechanisms, efficiency, capacity, and suitability for different fruit types. The major extraction systems reviewed include screw conveyor-based, brush and sieve-based, and centrifugal mechanisms. The performance characteristics of various machines developed for processing mango, custard apple, mangosteen, watermelon, citrus fruits, blackberry, palmyrah, pineapple, and other fruits are critically analyzed. Reported studies indicate that machine design parameters such as sieve size, rotational speed, feed rate, extraction chamber configuration, and conveying mechanisms significantly influence pulp yield, extraction efficiency, throughput capacity, and extraction losses. Brush-based systems are effective for fruits containing large seeds and delicate pulp, while auger-based systems provide continuous operation and high extraction performance for soft and fibrous fruits. Commercial and industrial pulping machines have demonstrated high extraction efficiencies, increased processing capacities, and reduced labor requirements. The review highlights recent advancements in fruit pulp extraction technology and identifies opportunities for improving machine performance, product quality, and energy efficiency. Adoption of efficient pulp extraction systems can contribute significantly to minimizing post-harvest losses, promoting value addition, and supporting sustainable fruit processing industries..

Keywords: Fruit pulp extraction, Post-harvest losses, Extraction efficiency, Fruit processing machinery, Pulp yield

Introduction

Fruits and vegetables constitute an essential component of the human diet because they provide vital nutrients, dietary fiber, vitamins, minerals and bioactive compounds that contribute to overall health and well-being. Regular consumption of fruits has been associated with a reduced risk of chronic diseases, including cardiovascular disorders, diabetes, and certain forms of cancer ^[1]. Despite their nutritional importance, fruits are highly perishable due to their high moisture content and metabolic activity, making them susceptible to rapid deterioration after harvest. Significant post-harvest losses occur during harvesting, handling, storage, transportation, and marketing because of microbial spoilage, mechanical damage, and inadequate processing facilities. In developing countries, post-harvest losses of fruits have been reported to range from 20% to 50%, resulting in considerable economic losses and reduced food availability ^[2&1]. Recent studies have also emphasized that improper post-harvest management remains a major cause of fruit wastage worldwide ^[3]. Fruit processing offers an effective approach to reducing post-harvest losses while extending shelf life and increasing the value of agricultural produce. Among various processing operations, pulp extraction is one of the most important steps in the production of fruit juices, purees, nectars, jams, concentrates, and other value-added products. The process involves separating the edible pulp from peels, seeds, fibers, and other inedible portions of the fruit ^[4]. Efficient pulp extraction directly influences product quality, yield, processing efficiency, and overall profitability of the fruit processing industry.

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Conventional pulp extraction methods, such as manual peeling and hand pressing, are labor-intensive, unhygienic, time-consuming, and often result in lower pulp recovery due to incomplete separation of edible portions from waste materials. Furthermore, manual processing may not meet industrial requirements for hygiene, consistency and large-scale production. To overcome these limitations, researchers and manufacturers have developed various mechanical and automated fruit pulp extraction machines. These systems employ different extraction mechanisms, including crushing units, rotating brushes, perforated sieves, beaters, screw conveyors, and pulping chambers to improve extraction performance and reduce processing losses. Several studies have evaluated the performance of fruit pulp extraction machines under different operating conditions. Researchers have reported that machine design parameters such as sieve size, rotational speed, feed rate, and extraction mechanism significantly affect pulp yield, extraction efficiency and quality characteristics of the extracted pulp. Advances in automation and machine design have enabled higher throughput, improved pulp recovery, reduced labor requirements and enhanced product quality. However, achieving maximum pulp recovery with minimum extraction losses continues to be a major challenge, particularly for fruits with varying physical and rheological properties.

Therefore, the development and evaluation of efficient fruit pulp extraction machinery remains important research area in the food processing sector. The present study focuses on the design, development and performance evaluation of a fruit pulp extraction machine aimed at maximizing pulp recovery, improving extraction efficiency, minimizing losses and providing a cost-effective solution for fruit processing operations. The observations of this study are expected to reducing post-harvest losses, enhancing value addition and promoting sustainable utilization of fruit resources.

Limitations of Manual Fruit Pulping

Manual fruit pulping is a simple and low-cost method; however, it has several limitations that restrict its application in commercial fruit processing. The process is labor-intensive, time-consuming, and often results in inconsistent pulp quality due to variations in operator skill and handling practices. Manual extraction generally provides lower pulp recovery and higher product losses because complete separation of pulp from seeds and peels is difficult to achieve. In addition, extensive human handling increases the risk of microbial contamination and compromises product hygiene. The method is also unsuitable for large-scale operations because of its limited processing capacity and poor scalability. Furthermore, repetitive pulping activities may cause worker fatigue and physical strain, reducing overall productivity. These limitations have increased the demand for efficient mechanical fruit pulp extraction systems that offer higher yield, improved quality, and enhanced processing efficiency [5].

Types of Fruit Pulp Extraction Mechanisms

1. Screw conveyor-based systems

Screw conveyor-based systems are widely used for large-scale fruit pulp extraction, particularly for fibrous and bulky fruits such as mangoes and papayas. In these systems, the

rotating screw mechanism transports the fruit material forward while applying mechanical pressure, facilitating the separation of pulp from seeds and peel. Due to their robust mechanical action, screw-driven extractors are highly effective in processing dense and high-fiber fruits, producing a relatively high pulp yield with minimal manual intervention. These systems are preferred in industrial applications because they can handle high pulp-content fruits and support continuous operation, which is essential for large-scale [6].

2. Brush and Sieve Mechanisms

The brush and sieve system is commonly used in fruit pulp extractors, particularly for fruits such as mango and pomegranate, where mild processing is required. It operates through a combination of rotating or stationary brushes along with a sieve to separate and filter pulp from seeds and skins. The brushes assist in breaking open the fruit and pushing the pulp through the sieve without damaging the seeds. This action helps produce a smooth and uniform pulp texture. The sieve further removes unwanted materials such as broken seeds and skin particles, thereby enhancing the quality of the extracted pulp [6].

3. Centrifugal Systems

Centrifugal systems are highly efficient for processing fruits with high juice or pulp content, such as tomatoes and citrus fruits. This method utilizes high-speed rotation to generate centrifugal forces that separate the pulp from seeds and skins with minimal effort. It is particularly suitable for fruits that need to be processed quickly in large quantities. Compared to mechanical pressing methods, centrifugal extractors are designed for soft fruits and offer high throughput with low pulp loss. These machines often include variable speed controls, allowing operators to adjust the operating conditions according to the type of fruit being processed [6].

Development and Performance of Fruit Pulp Extraction Machines

Brush-based extraction systems are widely employed for fruits containing large seeds or delicate pulp, as they facilitate pulp-seed separation while minimizing seed damage. These systems typically utilize rotating brushes in combination with perforated sieves to force pulp through the screen while retaining seeds and fibrous residues.

A horizontal cylindrical separator with a rotating brush, as developed by Ridho *et al.*, (2018) [7], provided efficient pulp-seed separation in a mangosteen pulper machine, achieving a processing capacity of 157.3 kg h⁻¹ without causing seed damage. Similarly, A custard apple de-seeding machine consisting of a brush roller and cylindrical sieve for pulp-seed separation, developed by Bakane *et al.*, (2014) [8], was evaluated to study its performance under different operating conditions. The performance of the machine was influenced by roller speed, feed rate, and sieve geometry. Among the tested configurations, the cylindrical sieve with an inlet diameter of 213 mm, an outlet diameter of 177 mm, and a sieve opening of 20 × 4 mm exhibited the best performance, achieving a machine efficiency of 82.5% with a minimum pulp loss of 2.09%. The study further reported that machine capacity and efficiency increased with increasing roller speed and feed rate, highlighting the

importance of optimizing operating parameters for efficient pulp extraction.

A low-cost stainless steel (SS-304) mango pulper, developed by Akram *et al.*, (2021) ^[9], was designed to minimize post-harvest fruit losses among rural farmers. The machine consisted of a hopper, extraction chamber, perforated sieve, shaft, Teflon-mounted brushes, bearings, and a mainframe. It was evaluated at feed rates ranging from 2.0 to 3.0 kg/min and extraction speeds of 500–1400 rpm. The maximum extraction efficiency, pulp yield, and extraction loss achieved were 96.03%, 77.03%, and 9.3%, respectively. The optimum operating conditions were identified as an extraction speed of 900 rpm and a feed rate of 2.5 kg/min, although satisfactory performance was also obtained at a feed rate of 3.0 kg/min.

2. Auger-Based Pulp and Juice Extractors

Auger-based extraction systems employ screw conveyors to crush, compress, and transport fruit material, enabling continuous extraction of pulp or juice. Such systems are particularly effective for soft and fibrous fruits due to their ability to apply uniform mechanical pressure.

A small-scale watermelon juice extraction machine, designed and evaluated by Adekanye *et al.*, (2017) ^[10]. The system operated on a combination of compressive and shearing actions generated by an auger within a cylindrical chamber and comprised a feeding hopper, juice sieve, and pulp outlet. Powered by a 1 hp electric motor with a gear reduction mechanism (46.67 rpm), the machine achieved a maximum juice yield of 86%, an extraction efficiency of 92.6%, and a processing capacity of 49.04 kg/h, demonstrating its effectiveness for small-scale juice processing applications.

A portable stainless-steel multipurpose juice extractor for pineapple, orange, and watermelon, developed by Aremu and Ogunlade (2016) ^[11], was evaluated using sieve openings ranging from 0.5 to 2.0 mm with both peeled and unpeeled fruits. The results indicated that the 2 mm sieve produced the highest juice yield and extraction efficiency, while sieve size had a significant influence on extraction performance. The study demonstrated that the locally fabricated extractor was suitable for efficient small-scale fruit juice and pulp extraction. In another study, Bhalekar *et al.*, (2019) ^[12] developed a pneumatic-operated juice extractor for orange and pineapple consisting of feeding hoppers, a chopping unit, and a screw (auger) conveyor enclosed within a cylindrical barrel. The system performed

chopping, crushing, and pressing sequentially, with the extracted juice separated through perforations at the base of the barrel. The machine generated a force of 100.158 N, which was sufficient for juice extraction, whereas the required extraction forces were 32.298 N for orange and 36.98 N for pineapple, indicating efficient mechanical operation for fruit pulp extraction.

A manually operated fruit juice extractor for small-scale applications, designed and fabricated by Eyeowa *et al.*, (2017) ^[13], was constructed using locally sourced materials. The machine operated through a screw mechanism that crushed and compressed fruits while separating the juice through a perforated screen. Performance evaluation using watermelon, orange, and pineapple resulted in extraction efficiencies of 71.3%, 65.8%, and 63.8%, respectively, with corresponding processing capacities of 19.51, 15.97, and 18.10 kg h⁻¹. The study demonstrated that manual screw-based juice extractors are cost-effective and suitable for small-scale fruit processing, providing acceptable juice yield at low operating cost. Similarly, Gbabo Agidi *et al.*, (2013) ^[14] designed, constructed, and evaluated a bush mango juice and seed extractor incorporating a beating chamber and a decreasing-pitch screw conveyor (auger). The machine operated at 250 rpm for the beaters and 98 rpm for the auger, achieving an extraction efficiency of 66% and a juice recovery of 69%. Fabricated from locally available materials, the low-cost machine was recommended for small-scale bush mango juice processing.

A multipurpose fruit juice extraction machine incorporating a serrated auger for fruit crushing and juice extraction, developed by Jongbo (2021) ^[15], achieved extraction capacities of 88.4 and 84.5 kg h⁻¹ for pineapple and sweet orange, respectively, with corresponding extraction efficiencies of 91.13% and 85.96%. The study highlighted the potential of auger-based extraction systems for efficient small-scale fruit processing and post-harvest loss reduction. A small-scale mango juice extractor based on a screw conveyor mechanism, developed and evaluated by Olaniyan and Obajemihi (2014) ^[16], consisted of a hopper, extraction chamber, perforated cylindrical drum, juice and waste outlets, and a motorized drive system. The screw conveyor compressed the macerated mango pulp against the abrasive perforated surface to facilitate juice separation. The extractor achieved an average juice yield of 34.56%, an extraction efficiency of 55.14%, and an extraction loss of 10.15%, demonstrating its suitability for small-scale mango processing with potential for industrial-scale application.



Fig 1: a) Juice Extraction from Peeled Orange

b) Extracted Orange Juice (Ref: Burbade *et al.*, 2025)^[17]

These studies indicate that auger-based systems provide efficient and continuous fruit processing with high extraction performance.

3. Commercial and Industrial Pulp Extraction Machines

Commercial and industrial pulp extraction machines are designed to provide higher throughput, improved extraction efficiency, and consistent product quality for large-scale fruit processing operations. These systems generally incorporate mechanized feeding, pulping, screening, and separation units that enable continuous or semi-continuous operation while reducing labor requirements and processing losses. The development of such machines has played a significant role in enhancing value addition and reducing post-harvest losses in the fruit processing industry.

A locally fabricated motorized citrus juice extractor for small- and medium-scale processing enterprises, developed by Martins *et al.*, (2018) ^[18], was constructed using stainless steel, aluminum alloy, and mild steel components to ensure durability, corrosion resistance, and food safety. Performance evaluation revealed that extraction efficiency and juice yield were strongly influenced by the operating speed of the prime mover. At an operating speed of 600 rpm, the machine achieved an extraction efficiency of 84.54%, a juice extraction capacity of 39.31 L h⁻¹, and a processing capacity of 38.89 kg h⁻¹. The authors concluded that the locally fabricated machine provided a cost-effective alternative to imported equipment while maintaining satisfactory extraction performance.

A semi-automated citrus juice extractor incorporating a hopper, cutting unit, shearing mechanism, extraction

chamber, sieve, and residue collector, developed and evaluated by Nnamdi *et al.*, (2023) ^[19], achieved optimum performance at an operating speed of 15 rpm and a feed rate of 2.5 kg/min. Under these conditions, the machine attained an extraction efficiency of 64%, a juice yield of 60%, and an extraction loss of 35%, demonstrating its suitability for small- to medium-scale citrus processing. Similarly, Olabisi and Adelegan (2015) ^[20] designed, constructed, and evaluated a citrus fruit juice extractor that achieved extraction efficiencies of 84%, 87%, and 89% for orange, tangerine, and lime, respectively, indicating its effective performance for citrus juice extraction.

A guava fruit pulper, designed and developed by Prafulla and Patil (2007) ^[21], utilized small sharpened blades mounted on a rotating shaft that operated against a stationary sieve driven by an electric motor. The study demonstrated that this mechanism enabled effective pulp extraction from guava fruits. In another study, Vengaiah *et al.*, (2023) ^[22] developed a mechanized fruit pulp extractor for Palmyrah (*Borassus flabellifer* L.) consisting of a compact housing equipped with stainless steel teeth mounted on a rotating shaft. The machine operated through combined beating and shearing actions to separate pulp from fruit tissues. Performance evaluation under different rotational speeds and batch capacities showed that the highest pulping efficiency (84.78%) and pulp recovery (33.9%) were achieved at 410 rpm with a 10 kg batch size, resulting in a processing capacity of 50 kg h⁻¹. The study demonstrated the potential of mechanized pulping systems to replace labor-intensive manual processing methods.



Fig 2: Palmyrah fruit pulp extractor with inside view (Vengaiah *et al.*., 2023)^[22]

Rahman *et al.*, (2022) ^[23] designed and fabricated a medium-sized blackberry (*Syzygium cumini*) pulp extractor for hygienic and commercial-scale juice production. The machine comprised a hopper, screen cylinder, wing shaft, prime mover, and power transmission system and operated on the principles of compression and shear. The extractor achieved a throughput capacity of 39.58 kg h⁻¹, pulp yield of 77.49%, extraction efficiency of 96.72%, and extraction loss of 6.38%. The high extraction efficiency obtained highlights the suitability of the machine for commercial fruit processing applications. Similarly, Lyaruu *et al.*, (2025) ^[24] developed a multipurpose fruit pulping machine capable of

processing oranges, watermelon, pineapple, and tangerine. The machine incorporated a feeding hopper, worm shaft, juice sieve, juice collector, waste outlet, transmission system, and supporting frame. During operation, the worm shaft conveyed, crushed, and pressed fruit material while facilitating juice separation through a sieve. The machine achieved extraction efficiencies of 91.2% for pineapple and 90.5% for watermelon, while juice yields ranged from 69.1% to 85.1%. Powered by a 3hp single-phase electric motor, the system was considered suitable for smallholder enterprises and local fruit-processing industries because of its versatility and high extraction performance.

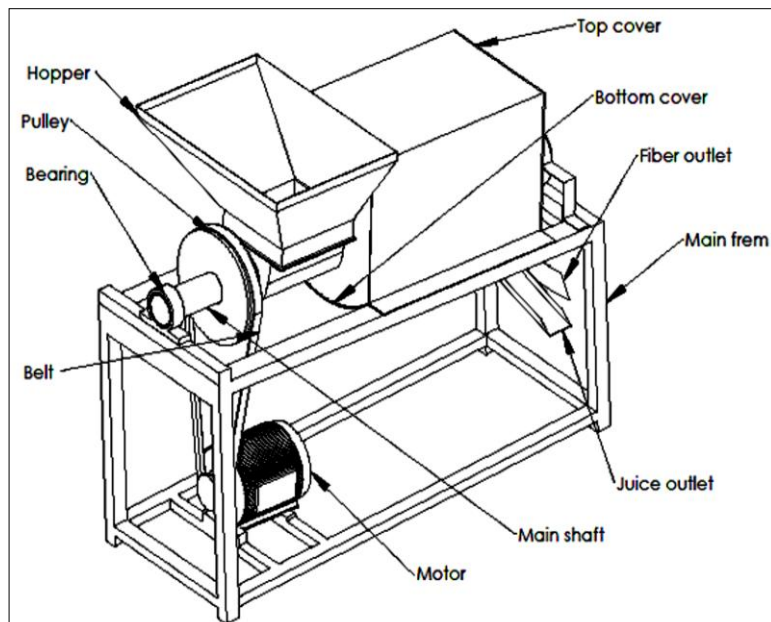


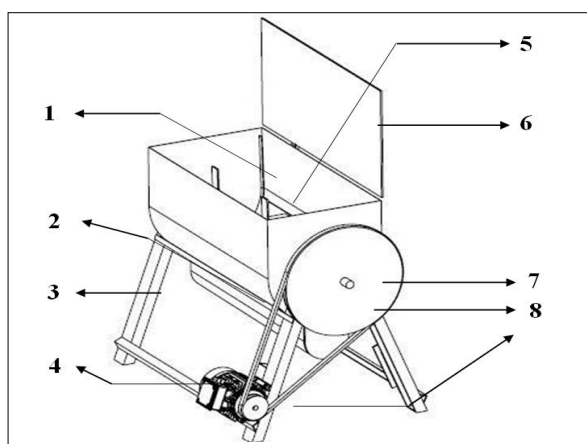
Fig 3: Fruit pulping Machine (Lyaruu *et al.*, 2025) ^[24]

Overall, commercial and industrial pulp extraction machines have significantly improved fruit processing efficiency by integrating mechanized extraction and separation systems. The reviewed studies indicate that these machines can achieve extraction efficiencies exceeding 80–95%, while

simultaneously increasing throughput and reducing labor requirements. Their adoption offers considerable potential for enhancing fruit utilization, improving product quality, and reducing post-harvest losses in both small-scale enterprises and commercial processing industries.

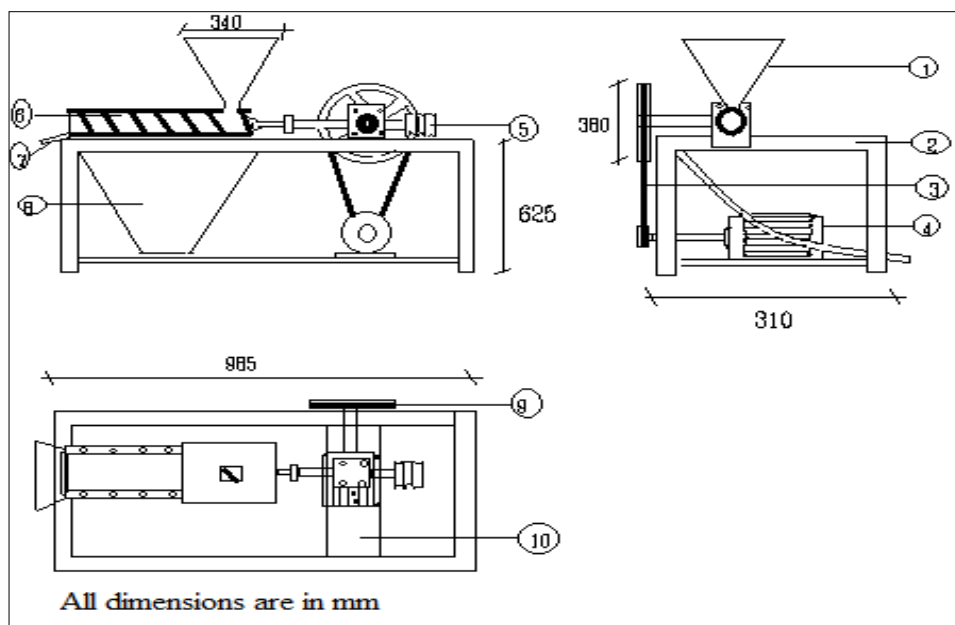


Fig 4: Photograph of the multi-fruit juice extractor. (Aviara *et al.*, 2013) ^[1]



1. Pulping chamber, 2. Discharge chute, 3. Frame, 4. Electric motor, 5. Beater 6. Closing lid, 7. Pulley, 8. Shaft

Fig 5: View of the palmyrah fruit pulper ^[22]



(1) Hopper, (2) Tool frame, (3) V-belt, (4) Electric motor, (5) Flywheel, (6) Extraction chamber, (7) Waste chute, (8) Juice Drain, (9) Pulley and (10) Flat bar

Fig 6: Multi-juice applicator in orthographic views (Aviara *et al.*, 2013) ^[1]

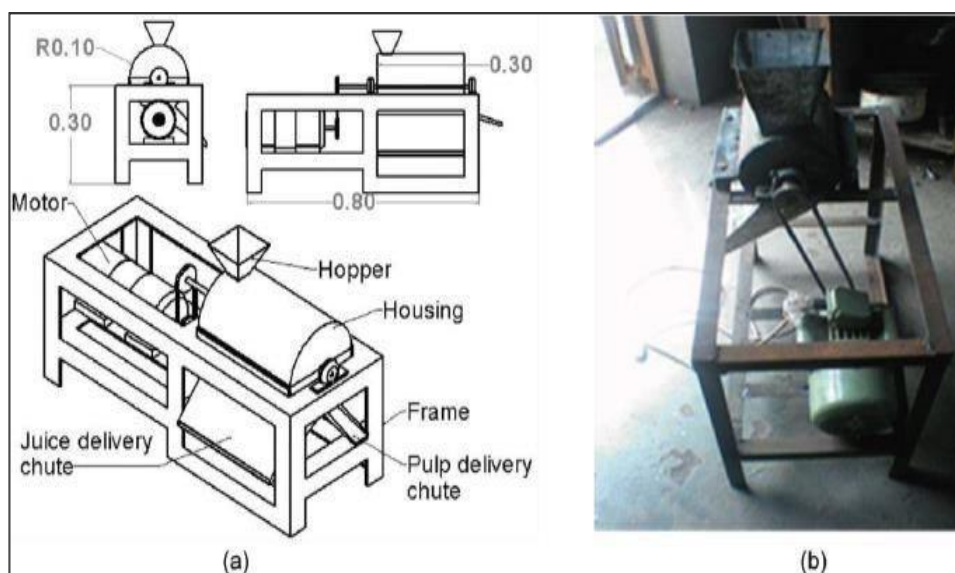


Fig 7: (a) Schematic and (b) pictorial view of the fruit juice machine (Jongbo *et al.*, 2021) ^[15]

Challenges and Recommendations

Challenges

Despite considerable progress in fruit pulp extraction technology, several challenges remain. Variations in fruit size, shape, moisture content, fiber content, and seed characteristics make it difficult to develop a single machine suitable for multiple fruits. Machine performance is highly dependent on operating parameters such as rotational speed, feed rate, sieve size, and extraction mechanism, which directly influence pulp yield, extraction efficiency, and processing capacity. High operating speeds may increase throughput but can reduce pulp quality and increase extraction losses. Wear of components such as brushes, augers, and sieves also increases maintenance costs. In addition, high initial investment, limited access to modern equipment, and inadequate evaluation of energy consumption and economic feasibility restrict the adoption

of pulp extraction machines, particularly in developing countries ^[6].

Recommendations

Future research should focus on developing multipurpose, energy-efficient, and cost-effective fruit pulp extraction machines capable of processing different fruit types. Optimization of design parameters, including sieve size, auger configuration, brush arrangement, rotational speed, and feed rate, is essential to improve extraction efficiency and pulp quality. Incorporating automation, variable-speed drives, and AI-based control systems can further enhance machine performance. More comprehensive studies on energy consumption, economic feasibility, durability, and standardized performance evaluation are also needed to support the commercialization and wider adoption of fruit pulp extraction technologies.

Table 1: Comparative Review of Fruit Pulp Extraction Machines, Working Mechanisms, and Performance Parameters

Author(s)	Year	Crop/Fruit	Principle Used / Mechanism	Major Findings	Reference No.
Adebayo et al.	2014	Pineapple	Motorized juice extractor	Extraction efficiency 87.5%; capacity 26.7 L/h.	[24]
Agidi et al.	2013	Bush mango	Beating and extraction chamber	Extraction efficiency 66%; juice recovery 69%. Successfully extracted juice without crushing seeds.	[25]
Aviara et al.	2013	Pineapple, Orange, Watermelon	Auger-based squeezing	Extraction efficiencies ranged from 83.6-97.1%.	[1]
Cruz et al.	2016	Ginger	Screw conveyor juice extractor	Capacity 0.5 kg/min; juice yield 80 ml/kg.	[27]
Dickson	2015	Wild fruits	Auger screw pulping	Pulp separated by friction and shear forces.	[28]
Hmar et al.	2017	Kendu fruit	Brush-type pulper	Throughput 50 kg/h; extraction efficiency 78.36%.	[29]
Olabisi & Adelegan	2015	Citrus fruits	Juice extractor	Extraction efficiencies: orange 84%, tangerine 87%, lime 89%.	[30]
Olaniyan & Obajemihi	2014	Mango	Screw press extractor	Extraction efficiency 55.14%; juice yield 34.56%.	[31]
Ridho et al.	2018	Mangosteen	Rotary brush-based pulp–seed separation	Horizontal cylinder with rotary brush was the most effective design; prototype achieved 157.3 kg/h input capacity and 93.5 kg/h output capacity, successfully separating pulp from seeds without seed contamination.	[7]
Patil et al.	2025	Various fruits	Review of traditional and advanced fruit pulping technologies	Reviewed the evolution of fruit pulping from traditional mechanical methods to smart technologies (enzyme-assisted pulping, ultrasound-assisted extraction, AI-based automation, and sustainable processing), highlighting improvements in efficiency, product quality, and resource conservation.	[25]
Lanjewar & Handa	2025	Mango, Pomegranate	Fruit pulp extraction machine	Reviewed machine design and performance, highlighting efficient pulp extraction, optimization of blade clearance and motor speed, and recommending IoT-based automation, energy-efficient design, and sustainable processing for future fruit pulp extractors.	[6]

Conclusion

Fruit pulp extraction machines play a crucial role in improving post-harvest utilization of horticultural crops. Mechanical extraction systems significantly enhance pulp recovery, processing efficiency, and product quality compared to manual methods. Among various systems, brush, screw, and centrifugal mechanisms offer distinct advantages depending on fruit characteristics. Future research should focus on developing energy-efficient, low-cost, and multipurpose machines suitable for small and medium-scale processing industries.

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