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Research paper

Design and Performance Evaluation of Fruit Pulp Extraction Machine

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Abstract

This research presents the design, development and performance evaluation of a fruit pulp extraction machine aimed at enhancing efficiency in the fruit processing industry. The study examines various efficiency metrics, including pulp yield, extraction rate, energy consumption, and machine capacity, through comparative analysis with different fruits such as mangoes and pomegranates. Results indicate significant effectiveness in pulp extraction, showcasing the machine's potential for both small-scale and commercial applications. However, challenges such as power constraints, maintenance requirements, and adaptability to various fruit types were identified, emphasizing the need for design improvements. The proposal included suggestions for improving energy efficiency and scalability through smart technology integration. Research directions for the future will involve studying technological innovations including IoT applications and bio-inspired designs to promote sustainable growth in fruit processing machinery. The study advances fruit pulp extraction technology development while focusing on minimizing post-harvest losses and boosting agro-industrial sector profitability.

***Keywords**: Fruit pulp extraction, pulp extraction machines, fruit processing efficiency, post-harvest loss reduction, mechanized extraction systems, commercial fruit processing*

1. Introduction

The fruit processing sector transforms raw fruit materials into value-added goods such as juices, concentrates, jams, and purees, pulps, etc., which makes it essential to the global food supply chain. The processed fruit product market growth combined with initiatives to lower postharvest losses propelled major sector expansion throughout both developed and developing areas. The fruit processing industry drives economic development by creating jobs and ensures consistent food availability throughout the year through fruit product manufacturing beyond usual harvest seasons. The initial step of producing various fruit products requires fruit pulp extraction as an essential processing stage. The process of pulp extraction processing enables the separation of the fruit's edible sections from its seeds, peel and other non-edible components. The extraction method ensures longer fruit preservation and improves product quality by maximizing the quantity of accessible fruit content. Food processors who optimize their pulp extraction procedures can cut production costs and improve profitability through waste reduction. Fruit pulp extraction has advanced from labor-heavy manual methods to streamlined mechanized systems. Small home-based and rural fruit processing units relied mainly on hand pressing and manual crushing methods combined with squeezing techniques [1]. These methods of extraction are plagued by a number of limitations since they have poor extraction efficiencies while demanding massive amounts of manpower in unhygienic working conditions. Literature indicates that the manual extraction process results in high pulp loss due to incomplete recovery processes and rough handling which also present contamination risks [2,3]. Mechanical pulp extraction systems were implemented to overcome problems in place, triggering a fruit processing revolution. The new systems not only maximized extraction effectiveness but also hygiene levels and facilitated scaling up production operations. According to research evidence, mechanical methods of extraction achieve faster processing time and reduced labor costs while increasing the output of pulp production [4,5]. Different pulp extracting machines operate using specific mechanisms intended to deal with the unique properties of each fruit. Screw conveyor extraction machines are basic machinery for fruit processing sector when it comes to Apple and pineapple pulp extraction. Mechanical devices first crush fruits and then move them through screw conveyor systems using mechanical pressure to break pulp away from seeds and peel. Experiments indicate that screw-based extraction systems provide high-grade pulp as well as strong mass production performance [6, 7]. Fruit pulp becomes separated from non-edible parts through fast spinning in centrifugal extraction machines. The high content of juice in citrus fruits like oranges makes it possible for machines to utilize them to the point of optimal efficiency. The fast rotation technique ensures adequate separation of fruit content without subjecting it to mechanical damage that preserves its flavor and nutritional values [8]. Mechanical pulp removal from a soft fruits like Mangoes needs brush and sieve mechanisms. The processing equipment employs rotating brushes to exert gentle pressure on fruits that then travel against a sieve which separates the pulp from seeds and skin [9]. Scientific investigation proves such mechanisms are a key factor in guarding fruit against the processing phases. Advances in technology have improved means of fruit pulp extraction but working limitations remain instrumental in designing machinery. High energy requirements by machinery become a big issue because they raise operational expenses and reduce equipment functionality in areas with irregular power supplies. Jongbo et al. [10] revealed that big pulp extracting machines cannot be fully adopted in the developing regions as a result of high-power consumption requirements. The existing machines encounter difficulty when extracting various fruit varieties. Machines specifically designed for certain fruits exhibit low flexibility when processing fruits with diverse texture and sizes. Equipment developed to extract pulp from soft fruits, like papaya perform badly for pulp extraction of harder fruits like guavas [11]. Processors have to purchase independent machines for every variety of fruit since flexible machinery is not available which adds to their investment costs. Research indicates that machinery producing and processing several types of fruit with slight adjustment enhances the operational efficiency and minimizes the expenditure.

Today's extraction equipment makes pulp but doesn't integrate multiple pre-treatment functions such as peeling and seed separation into their systems. Extraction methods for mixed-fruit pulp with intact seeds necessary for oil-extraction purposes are still under-researched. The significant limitations of today's fruit pulp extraction systems specify the need for higher research priority. Scientists are creating a multipurpose machine for the extraction of pulp of different fruits, which will integrate various preprocessing tasks to enhance efficiency as well as working with multiple fruit varieties. The new machine solves problems of processing by providing cheaper processing options while enhancing efficiency and minimizing waste for all sizes of fruit processing companies.

2. Material and Methods

The development of the Fruit Pulp Extraction Machine started with the setting of initial parameters to guide the production process. The building of the Fruit Pulp Extraction Machine involved an understanding of fruit types and size differences along with desired grain size of pulp and required processing speeds. Detailed assembly drawings for the machine materialized as a result of CAD software application. This approach allowed users to see parts as they gained accurate measurements necessary for achieving maximum machine operation. The choice of the electric motor revolved around meeting precise RPM and power requirements. The motor performance testing demonstrated adequate torque and speed for maintaining efficient machine function. A power transmission system succeeded in delivering motor power to the machine components. The peel removal mechanism was chosen because it could accommodate various skin thicknesses across different fruit types. The mechanism design prioritized both effective peel removal and the protection of fruit underneath. The engineers selected the coring system because of its capacity to effectively remove seeds of different sizes from a variety of fruit types. The design of the mechanism enabled the peeling system to function without error while maintaining efficient fruit pulp extraction. The engineers developed a system which controls the particle dimensions of extracted fruit pulp to deliver the intended grain size. Different fruit operation processing needs required this mechanism to demonstrate sufficient adaptability. The beater blade became the preferred cutting tool because its optimized cutting-edge angle improved both cutting efficiency and fruit pulp yield. Scientists evaluated multiple blade designs to find the configuration that offered the highest extraction yield and the lowest waste levels. The Fruit pulp extraction machine employs construction materials selected due to the fact that they are long-lasting durable and combine hygiene as well as simple maintenance ability. The structure of the machine allows for effective performance of work while it simplifies cleaning and maintenance to be carried out and provides compliance with hygiene standards. The Fruit Pulp Extraction Machine developed employs an extensive approach that provides it with effective and efficient operation across different types of fruits and enhances processing outcomes in small-scale business operations.

3. Design and Development of the Machines

3.1 Design of Feed Hopper

The hopper feed acts as the major entry point of fruits into the fruit pulp extracting machine where the processing starts. The design of the feeding system of the hopper influences the effectiveness of the machine in operations and its rate of production. The trapezoidal hopper design shape is made from a 1.5 mm thick stainless-steel plate. The design of the hopper guarantees the controlled motion of fruits into the extraction chamber to enhance the flow rates and the minimize blockage hazards. The trapezoid shape provides a consistent feed rate when fruits are prepared for extraction. The composite volume strategy of the hopper design involves a division into two rectangular frustums to guarantee efficient fruit distribution. The formula provided enables users to calculate the frustum volume V*h*.

$$V_h = \frac{h}{3}\left(B_1 + B_2 + \sqrt{B_1 + B_2}\right) \quad (1)$$

Where, Vh is the volume of the frustum, h is the height of the frustum, B1 is the area of the top square, and B2 is the area of the bottom square.

The pass hole of the hopper is 85mm wide and 55mm in height. The designed dimension provides sufficient space for the passage of fruit into the extraction system while avoiding clogging. Fruit pulp extraction is unbroken and operates at improved productivity levels when the opening is at a size preventing blockage. The design of the feed hopper is of utmost significance in fruit pulp extraction machines because it guides appropriate fruit treatment that leads to maximized extraction performance.

3.2 Pulp Extraction Chamber Design

The pulp extraction chamber becomes a crucial component in fruit pulp extraction machine designs because it mechanically separates fruit pulp from seeds and other solids. A power shaft and beater blades combine with an internal stationery sieved cylinder to form interconnected components within the mechanical chamber. The specialized functions performed by each part enable efficient pulp extraction and continuous operation necessary for large-scale fruit processing systems.

3.2.1 Power Shaft

The primary mechanical part of the system the power shaft transfers torque to the beater blades enabling both crushing and extraction. The stainless-steel shaft design combines enduring durability and corrosion resistance to fulfill essential food processing equipment standards

[12]. Through mechanical principles the shaft design maintains structural stability while resisting peak operational torque to enable smooth operation. Equation 2 identifies the power shaft diameter as a critical design parameter.

$$d^3 = \frac{16T_s}{0.27\pi\sigma_y} \quad (2)$$

where d is the shaft diameter, Ts is the maximum torque, $\sigma y$is the yield stress, and π is a constant

3.3 Beater Blades

The beater blades play a critical role in fruit pulp extraction by shredding fruit material which helps separate the pulp from seeds and skin efficiently. Food processing blades use stainless steel construction to achieve extended durability while resisting corrosion. The blades possess teeth with 30° thread angles which boost cutting efficiency while reducing resistance throughout the crushing operation. The power shaft maintains blade positions at 120° intervals to ensure even force distribution across each blade which reduces vibrations and improves machine stability and performance. The users can adjust the clearance between the blades and the sieved cylinder to any value within the range of 25 mm to 35 mm [13]. The machine's adjustable mechanism enables users to handle fruits of varying textures and hardness. Soft fruits like mango require close clearance settings for effective pulp extraction and minimum waste while pomegranate requires wider settings to avoid seed damage and maintain pulp quality [14]. The optimized configuration enhances extraction performance that increases yield output and maintains the integrity of the extracted pulp. The durable build of the beater blades enables the machine to operate reliably and sustain performance over repeated use. The design enables these blades to operate effectively during high-speed rotation and continuous mechanical pressure without suffering significant wear. The longevity of machine parts creates reduced maintenance needs and replacement intervals that contribute to lowered operating costs. The incorporation of precision-balanced blades provides energy efficiency as well as improved machine operation in the processing of fruit pulp in small-scale and commercial operations.

3.4 Inner Stationary Sieved Cylinder

The system consists of a fixed sieved cylinder that is an essential part for the extraction of pulp from seeds and other solid particles. The system adopts the usage of a thin-walled pressure vessel model so that the cylinder can withstand internal operational stresses [15]. This mathematical formula determines the longitudinal stress σ that occurs in the cylinder.

$$\sigma = \frac{pr_{ic}}{2t} \quad (3)$$

where p is the internal pressure, ric is the internal radius of the inner cylinder, and t is the thickness of the cylinder wall. The volume of the inner cylinder is determined by the following equation:

$$V_{ic} = \pi r_{ic}^2 l_{ic} \quad (4)$$

where Vic represents the cylinder volume, ric is the internal radius, and lic is the length of the cylinder.
A robust 304-grade food-grade stainless steel body constitutes the cylinder while its 2 mm diameter perforations ensure free pulp flow but prevent seeds and other large particles from passing through. By optimizing perforation sizes with high precision, the research team was able to achieve maximum pulp yield and minimize solid waste retention [16]. The stainless-steel power shaft and sieved cylinder ensure hygiene standards required for food safety which prevents corrosion and extends the lifespan of the machine when used in industrial applications [17].

3.5 Electric Motor & Power Transmission

Power transmission system design has a direct impact on the performance and efficiency of fruit pulp extraction machines. Key extraction elements like screw conveyors and beater blades depend on the electric motor and pulley-belt system to drive the power transmission system. Engineers determined the required driving power for the machine based on data from both operational requirements and design parameters.

3.5.1 Power Requirement

The power required to drive the fruit pulp extraction machine is calculated using an empirical equation adopted by Olaniyan et al. [18]

$$P = \frac{QL\rho_d gF}{3.6} \quad (5)$$

Where, P is the power required to drive the machine (W), Q is the machine capacity (m^3/h), L is the shaft length (m), is the density of the fruit (kg/m^3), g is the acceleration due to gravity (9.81 m/s^2), and F is the material factor.
The theoretical machine capacity Q is calculated by using following equation.

$$Q = 60X\frac{\pi}{4}(D^2 - d^2)pN\emptyset \quad (6)$$

where D is the diameter of the inner cylinder (m), d is the screw diameter (m), p is the screw pitch (m), N is the rotational speed of the shaft (rpm), and ϕ is the filling factor.
Considering power losses due to pulley friction and other transmission inefficiencies, a motor power rating of 1000 W is selected. The actual power of the electric moto required to drive the system is estimated by using the following equation:

$$P_m = {}^{P}/_{\eta} \quad (7)$$

Where, Pm is the power of the electric motor (W) and η is the motor efficiency, assumed to be 0.8. Thus, a 2 HP single-phase electric motor is selected to meet the operational requirements of the machine.

3.5.2 Pulley & Belt Drive

The pulley and belt drive system transmits the mechanical power from the electric motor to the screw conveyor and beater blades, ensuring the required speed and torque for efficient fruit pulp extraction. To ensure that slippage during power transmission is minimized, the maximum permissible pulley diameter ratio is limited to 4:1.
The centre-to-centre distance C and the length of the transmission belt L are calculated using the following equations:

$$C = \frac{D_1 - D_2}{2} - D_1 \quad (8)$$

This combination of electric motor and pulley-belt drive system ensures that the machine operates at optimal efficiency, providing the necessary power to extract fruit pulp effectively in both small-scale and industrial applications.

3.6 Bearings

The power shaft of the extraction unit in the fruit pulp machine receives support from two deep groove ball bearings with 20 mm inner diameters installed at both ends. Deep groove ball bearings are commonly used in farm and food processing equipment because they provide constant rotation while working properly under different conditions. The machine shows higher longevity since its bearings operate in solid casings that control vibration and wear. Deep groove ball bearings are used by manufacturers due to their inherent performance under varying load condition [19]. The bearings are coupled to the machine frame through M12 bolts and nuts for stability and alignment when rotating at high speeds. Power shaft life improves with bearings mounted on both ends since even support minimizes operating stress deflection.

3.7 Machine Frame

Mild steel L-section angle bars measuring 40 mm × 40 mm provide the machine frame with both strength and rigidity while remaining cost-effective. Due to its high tensile strength and fabrication ease mild steel serves as a common choice for machine frames which support both the pulp extraction unit and the electric motor [20,21]. The machine maintains stability during operation thanks to the structural backing provided by L-section angle bars which work effectively against dynamic loads from rotating elements. A rigid frame design cuts down on vibration which lowers mechanical stress on machine components while boosting the machine's operational efficiency. The frame design provides convenient access to different machine parts for maintenance and repair which boosts machine longevity and enhances operational ease [22].

4. CAD Model of the Fruit Pulp Extraction Machine

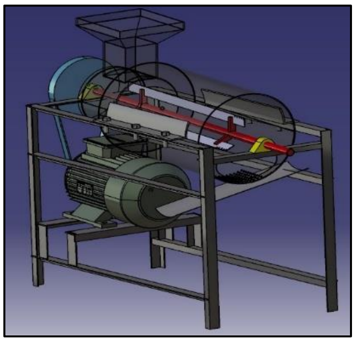

Fig. 1: CAD model showing integral components

The 3D fruit pulp extraction machine model displayed in Figure 1 demonstrates an integrated design which enhances the pulp extraction process. The machine functions through the coordinated operation of its essential components to achieve optimal performance. The Feed Hopper positioned at the top has a trapezoidal stainless-steel construction through which fruits enter the extraction system. The gradual narrowing design helps feed the fruits into the machine smoothly while preventing blockages. An electric motor powers the machine's operation through the centrally positioned power shaft. Stainless steel construction of the shaft enables it to drive the rotating beater blades within the stationary-sieved cylinder. The beater blades positioned at a 120-degree angle crush fruit pieces and push the pulp through the perforated sieved cylinder while separating out seeds and skins. The thin-walled design of the sieved cylinder enables efficient separation of pulp from solids. The extraction unit receives power from an electric motor located beneath it which transfers motion through a pulley and belt drive system to all rotating elements. A sturdy mild steel frame supports the machine which delivers structural stability while minimizing operational vibrations. The design combines compactness with functionality to maximize pulp yield while facilitating simple maintenance and operation.

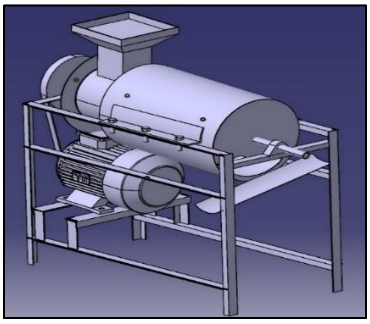

Fig.2. CAD model of the fruit pulp extraction machine

5. Principles of operation

The Fruit Pulp Extraction Machine demonstrated in the CAD model (Figure 2) utilized multiple mechanical processes working together to extract fruit pulp efficiently. The machine operates with a powerful feeding system alongside a power transmission mechanism and an extraction unit to achieve high output with minimal mechanical losses while maintaining smooth functionality. The initial stage involved placing fruit into the system through a feed hopper which was positioned at the top of the machine. The hopper design featuring a wide inlet and a narrowing outlet enabled controlled fruit feeding into the extraction unit. The trapezoidal design enabled the processing of high fruit volumes and avoided clogging which maintained extraction efficiency in pulp production [23, 24].
The system received power from a single-phase electric motor which transferred energy through a belt and pulley setup. A V-belt drive transmitted the motor's rated power of 2 HP to the main power shaft. The speed reduction achieved through the pulley ratio of 4:1 The speed reduction from 1450 rpm to 435 rpm enabled by the pulley system produced optimal conditions for the extraction process. The system's configuration reduced slippage while maintaining steady torque delivery throughout its operation [25]. Two deep groove ball bearings supported the power shaft at both ends and the machine frame secured them. The bearings minimized rotational friction and managed axial forces created during operation thereby enabling the system to function smoothly for extended durations. Stainless steel beater blades at 120° intervals were installed on the rotating shaft inside the extraction chamber. The 30° threaded beater blades crushed the fruit while propelling it forward through the chamber as they rotated. The extraction unit's 15° tilt enabled gravitational fruit material flow toward the outlet which ensured efficient movement and prevented chamber blockages [26]. Users can adjust the blade clearance relative to the stationary sieved cylinder between 25 mm and 35 mm based on fruit size in order to optimize the crushing process. The solid stainless steel stationary cylinder with sieve features was vital for separating fruit pulp from seeds and other solid elements. The 2 mm holes permitted pulp to flow through while larger unwanted particles stayed inside the chamber until they exited through the waste outlet [27]. Food-grade stainless steel construction enables efficient fruit processing while providing long-lasting durability and corrosion resistance. The system obtained structural support from a machine frame built with 40 mm × 40 mm mild steel L-section angle bars. The structural design combined the electric motor and extraction unit to maintain operational stability and rigidity. The design of the machine minimized operational vibrations to maintain performance and ensure high quality of extracted pulp. The use of M12 bolts and nuts to secure the bearings increased the machine's durability and improved its resistance to wear.

6. Results and discussion

The research team tested the fruit pulp extraction machine to examine its effectiveness at processing mangoes, pomegranates and guavas. The evaluation focused on vital performance indicators including pulp yield together with extraction rate, energy usage and machine capacity. The research team conducted a comparative performance analysis of different fruits and presented the results in Table 1.

6.1 Efficiency Metrics

Researchers evaluated pulp yield by measuring the fruit mass percentage converted to pulp and calculated extraction rate in kg/min energy consumption in kWh together with machine capacity in m^3/h. The equipment performed differently when processing various fruits due to variations in fruit surface textures and differences in pulp consistency and seed size. Mangoes received the highest pulp yield and extraction rate in performance results, but guavas produced very little output because their seeds are tough. Patel et al. 's research confirms these observed trends. According to Patel et al. Mangoes reach superior extraction efficiency through their fibrous and pulpy composition whereas fruits such as guavas experience reduced extraction efficiency due to their hard seeds and dense flesh structure.

6.2 Testing with Different Fruits

Researchers compared mango, pomegranate, and guava fruit processing under the same experimental conditions. Each fruit offered different operating difficulties to the machine when they were being processed by them such as seed separation and pulp consistency retention. Mango's high pulp yield and processing capacity are a result of their soft nature and huge seeds. Pomegranates' processing involving smaller seeds required effective removal of seeds that made processing time longer. The hard guava seeds resulted in lower processing throughput rates and increased retention time that adversely impacted system performance.

6.3 Data from Trials

Table 1 provides trial data summaries for every type of fruit with levels of throughput, retention time duration, pulp quality readings and seed separation efficiency rates. Mangoes were at maximum processing speed together with decreased retention time but guavas showed longer retention time and low seed separation efficiency as a result of having hard seeds. Gekonge et al. also documented the same results in their research. Based on Gekonge et al. [28], mechanical treatment provided greater efficiency in extraction in mangoes than in guavas due to differences in morphological characteristics among the fruits.

Table 1: Comparative Performance Metrics of the Fruit Pulp Extraction Machine for Different Fruits

Fruit Type	Pulp Yield (%)	Extraction Rate (kg/min)	Energy Consumption (kWh)	Machine Capacity (m^3/h)	Retention Time (min)	Pulp Quality	Seed Separation Efficiency (%)
Mango	75	0.65	1.25	1.43	2.5	Smooth	98
Pomegranate	70	0.58	1.25	1.35	3	Medium	85
Guava	68	0.52	1.25	1.22	3.8	Coarse	78

The constructed Fruit Pulp Extraction Machine was tested with various types of fruits to evaluate performance using measures such as peeling efficiency, coring efficiency, pulp yield, rate of extraction, and seed integrity. Table 2 provides a tabulation of results that indicate that the machine achieved 80% to 95% peeling efficiency upon testing with various fruits. Oranges and papayas achieved higher peeling efficiency due to their softer or thinner skins while pomegranates showed lower efficiency because of their complex outer structure. Different seed structures resulted in varied coring efficiency rates with both papaya and mango achieving the highest efficiency levels at 92% and 90% respectively. Pulp yield for all tested fruits varied between 78% and 89%, with papaya and orange producing the highest yields because of their soft pulp nature. The machine processed pomegranates at 40 kg/hr while processing papayas at 60 kg/hr which demonstrates that fruit hardness and fiber content impact processing speeds. The machine maintained seed quality especially well for pomegranates as 95% of seeds stayed intact which allowed them to proceed to oil extraction steps. The developed machine proves its capability to process several fruit types while maintaining high pulp recovery rates and efficient seed separation methods.

Table 2: Performance Comparison of the Fruit Pulp Extraction Machine for Different Fruits

Fruit Type	Peeling Efficiency (%)	Coring Efficiency (%)	Pulp Yield (%)	Extraction Rate (kg/hr)	Seed Integrity (% Unbroken)
Mango	92	90	85	50	88
Pomegranate	80	85	78	40	95
Orange	95	N/A	88	55	N/A
Papaya	93	92	89	60	90
Apple	90	88	83	45	85

6.4 Discussion

According to performance evaluation data the machine processed mangoes most efficiently producing maximum pulp yield with both the highest extraction rate and machine capacity. Mango processing benefits from smoother operation because their large single seed makes efficient seed separation possible. Pomegranate processing presented a moderate difficulty because their numerous small seeds necessitated extra time for disentanglement which led to reduced extraction rate and seed separation efficiency. Due to their hard seeds and fiber-rich pulp guavas produced the poorest results in all evaluated metrics with significant difficulties in seed separation and long retention time. The findings of this study match those reported by George et al. The work of George et al. [29] highlights how the mechanical pulp extraction systems heavily depend on the fruit texture and seed hardness for optimal performance. The power consumption remained unchanged at approximately 1.25 kWh for all tests regardless of the fruit variety used. Machine capacity differed because fruit texture and seed properties affected throughput alongside extraction efficiency. Research findings validate Harinath et al. [30]'s prior study which demonstrated that optimized motor specifications and mechanical load distribution result in consistent energy requirements during pulp extraction. Soft single-seed fruits such as mango achieved optimal results with the fruit pulp extraction machine but tougher fruits like guava would benefit from improved seed separation and sieve mechanisms. The research results show that the machine performs successfully in pulp extraction and supports previous findings about mechanical pulp extraction techniques. Future research should focus on developing advanced seed separation techniques alongside optimized processing parameters for hard-to-process fruit varieties to increase overall extraction effectiveness.

7. Challenges, recommendations, and future directions in fruit pulp extraction machines

7.1 Challenges and limitations

The fruit pulp extraction machine displayed several operational issues and constraints. The inconsistent electrical power supply posed a significant challenge for power management in these locations. The machine's performance decreased due to inconsistencies which produced both motor speed fluctuations and irregular extraction rates. Fruit pulp extraction machines faced increased operational difficulties in rural areas where energy resources were insufficient. Maintenance requirements for the machine introduced an additional challenge that needed resolution. Power shafts and bearings require regular inspections and lubrication from operators as they face beater blade wear when processing fibrous fruits like pomegranates. The extraction chamber tended to become clogged when processing fruits that contained a high amount of fiber. Elevated maintenance needs led to higher operational expenses and less machine availability which created a barrier to commercial success.

7.2 Recommendations for improvement

The team recognized several improvement recommendations to address identified challenges. The implementation of energy-efficient motors together with pulley system optimization will enhance energy efficiency. Integrating renewable energy resources like solar power can help resolve electricity unreliability problems in various locations. Research exploring methods to minimize frictional losses during power transmission will lead to better energy efficiency. To achieve scalability modifications to the machine structure which include adjustments to the frame and motor capacity should be made to serve both small and industrial processing tasks. The machine’s design flexibility enables processing larger quantities of fruit while remaining appropriate for household and small business operations. The machine's multi-fruit capability can be improved through design changes like adjustable beater blade clearance and a variable speed motor. The updated machine design will improve efficiency when processing various types of fruit. A flexible hopper system will process multiple fruit sizes and enhanced seed separation technology will improve performance for difficult fruits like pomegranates. The progress of future developments will heavily rely on implementing automation combined with smart technology solutions. IoT devices together with machine learning algorithms enable real-time monitoring and optimization of extraction processes to make processing adjustments based on the particular types of fruit being processed. Integrating predictive maintenance capabilities will lead to higher operational efficiency by reducing downtime levels.

8. Conclusion

The study provides in-depth analysis of fruit pulp extract machine design and subsequent performance assessment through the study of efficiency factors like pulp yield extraction rate energy consumption and machine capacity. The extraction machine is highly efficient in extracting pulp from mangoes as well as pomegranates thereby establishing its applicability to operate on any level. During their assessment process researchers encountered several operational issues with regards to energy limitations, maintenance requirements and compatibility issues with different fruits. Scalability and machine performance necessitate design improvement as problems revealed these requirements. The report recommended several improvements such as energy-saving design modifications that would facilitate scalable use across different scales of production along with integration of smart technology to improve system management. Researchers propose that modifications of critical machine components such as beater blade clearance and speedup motor speed should enhance multiple fruit processing capabilities. Future research directions need to blend Internet of Things technologies with automated systems with incorporation of sustainable design principles. Manufacturers should study bio-inspired designs and zero-waste systems to develop future generation fruit pulp extraction machines that provide efficiency and environmental sustainability. The study provides elementary information and guidance for the development of sophisticated pulp extraction technologies that enhance agro-industrial equipment processing efficiency.

References

[1] Sonar DJ (2018). Design and fabrication of mango pulp extraction machine. *International Journal for Research in Applied Science and Engineering Technology* 6(5): 849–852. https://doi.org/10.22214/ijraset.2018.5137
[2] Wang C, Pan W, Zou T, Li C, Han Q, Wang H, Yang J, Zou X (2024). A review of perception technologies for berry fruit-picking robots: Advantages, disadvantages, challenges, and prospects. *Agriculture* 14(8): 1346. https://doi.org/10.3390/agriculture14081346
[3] Girma Tura A (2020). Design and development of mango (Mangifera indica) fruit peeler machine. *International Journal of Food Science and Biotechnology* 5(3): 49. https://doi.org/10.11648/j.ijfsb.20200503.13
[4] Okusanya M, Agbongiaban F (2023). Development and performance evaluation of hand operated screw juicer for small scale application. *Turkish Journal of Agricultural Engineering Research* 4(1): 133–150. https://doi.org/10.46592/turkager.1220141
[5] Math RG, Ramesh G, Nagender A, Satyanarayana A (2015). Design and development of annatto (Bixa orellana L.) seed separator machine. *Journal of Food Science and Technology* 53(1): 703–711. https://doi.org/10.1007/s13197-015-2019-5
[6] Wu C, Ge F, Shang G, Wang G, Zhao M, Wu L, Guo H (2021). Design of screw type automatic apple juicer. *Journal of Physics: Conference Series* 1750(1): 012042. https://doi.org/10.1088/1742-6596/1750/1/012042
[7] Savalkar SD, Babar KP, Bornare DT (2018). Development of lab scale pineapple fruit juicer. *International Journal of Agricultural Engineering* 11(2): 320–323. https://doi.org/10.15740/has/ijae/11.2/320-323
[8] Martins OO, Bolaji BO, Adeyemi OH, Sanusi OM (2018). Design and construction of a motorized citrus juice extractor. *FUOYE Journal of Engineering and Technology* 3(2). https://doi.org/10.46792/fuoyejet.v3i2.209
[9] Amitabh A, Kumar V, Jain SK, Kashyap V, Sami R, Helal M, Aljuraide NI, Uguru H (2023). Development and performance evaluation of watermelon pulper based on mechanical action of crushing and shearing force. *Journal of Biobased Materials and Bioenergy* 17(3): 375–382. https://doi.org/10.1166/jbmb.2023.2283
[10] Jongbo A (2021). Multipurpose fruit juice machine for preventing fruit wastage in Nigeria villages. *Turkish Journal of Agricultural Engineering Research* 2(2): 321–329. https://doi.org/10.46592/turkager.2021.v02i02.006
[11] Kumar A, Mamatha P, Kuchi V, Madhumathi C (2017). Standardization of protocol for best blending ratio of papaya cv. Red Lady and guava cv. Allahabad Safeda fruit pulp for preparation of fruit bar. *International Journal of Biochemistry Research & Review* 17(3): 1–10. https://doi.org/10.9734/ijbcrr/2017/34077
[12] Patel AD DA (2015). Stainless steel for dairy and food industry: A review. *Journal of Material Science & Engineering* 4(5). https://doi.org/10.4172/2169-0022.1000191
[13] Khan HF, Usman M, Rashid MM, Ayub M, Qadir A (2023). Design and comparative analysis of beater knife mechanism for mango pulp extraction. *ARPN Journal of Engineering and Applied Sciences* 911–918. https://doi.org/10.59018/0423121
[14] Catania P, Comparetti A, De Pasquale C, Morello G, Vallone M (2020). Effects of the extraction technology on pomegranate juice quality. *Agronomy* 10(10): 1483. https://doi.org/10.3390/agronomy10101483
[15] Ibrahim A, Ryu Y, Saidpour M (2015). Stress analysis of thin-walled pressure vessels. *Modern Mechanical Engineering* 5(1): 1–9. https://doi.org/10.4236/mme.2015.51001
[16] Muhammad Lawal Abdullahi M, Abubakar Saleh Jadas A, Ibrahim Abdulmalik Yahaya I (2024). Design development and construction of solar powered fresh juice extracting machine. *International Journal of Innovative Research and Development*. https://doi.org/10.24940/ijird/2023/v12/i10/oct23003
[17] Rossi S, Leso SM, Calovi M (2024). Study of the corrosion behavior of stainless steel in food industry. *Materials* 17(7): 1617. https://doi.org/10.3390/ma17071617
[18] Olaniyan AM (2010). Development of a small-scale orange juice extractor. *Journal of Food Science and Technology* 47(1): 105–108. https://doi.org/10.1007/s13197-010-0002-8
[19] Li F, Li X, Shang D (2021). Dynamic modeling and vibration characteristics analysis of deep-groove ball bearing, considering sliding effect. *Mathematics* 9(19): 2408. https://doi.org/10.3390/math9192408
[20] Raji NA, Adedeji KA, Olaleye JO, Adele FA (2019). Design and fabrication of tiger nut juice extractor. *Journal of Applied Sciences and Environmental Management* 23(3): 563. https://doi.org/10.4314/jasem.v23i3.29
[21] Fadeyibi A, Faith Ajao O (2020). Design and performance evaluation of a multi-tuber peeling machine. *AgriEngineering* 2(1): 55–71. https://doi.org/10.3390/agriengineering2010004
[22] Omoregie MJ, Francis-Akilaki TI, Okojie TO (2018). Design and fabrication of a juice extractor. *Journal of Applied Sciences and Environmental Management* 22(2): 207. https://doi.org/10.4314/jasem.v22i2.9
[23] Dela Cruz LF, Magnaye VG, Manalo JV, Camello NC (2016). Development of ginger juice extractor. *EPH - International Journal of Science and Engineering* 2(3): 13–21. https://doi.org/10.53555/eijse.v2i3.158
[24] Amiebenomo SO (2025). Design and performance evaluation of a multi-fruit juice extraction machine. *American Journal of Innovation in Science and Engineering* 4(1): 75–85. https://doi.org/10.54536/ajise.v4i1.3742
[25] Lyaruu HML, Warwa GMW, Yuda BLY, Makange NRM (2025). Design and evaluation of grapes crusher de-stemmer machine for small to medium-scale grape producers. *Sumerianz Journal of Scientific Research* 81: 1–14. https://doi.org/10.47752/sjsr.8.1.1.14
[26] Khan H, Ahmad Shafi A (2020). Development and performance evaluation of an improved mechanized fruit pulp extracting unit. *Journal of Agricultural Sciences* 57(1): 199. https://doi.org/10.21162/PAKJAS/20.9129

[27] Akram ME, Khan MA, Khan MU, Amin U, Haris M, Mahmud MS, Zahid A, Pateiro M, Lorenzo JM (2021). Development, fabrication and performance evaluation of mango pulp extractor for cottage industry. *AgriEngineering* 3(4): 827–839. https://doi.org/10.3390/agriengineering3040052
[28] Gekonge DO (2021). Production, utilization and processing of Kenyan guavas: Development of nutrient-enriched guava nectars from local varieties. PhD diss., University of Nairobi.
[29] George N (2021). Date fruit fiber variability in composition, tissue distribution, and contribution to hardness of date fruits (Phoenix dactylifera L.). PhD diss.
[30] Harinath E, Biegler LT, Dumont GA (2011). Control and optimization strategies for thermo-mechanical pulping processes: Nonlinear model predictive control. *Journal of Process Control* 21(4): 519–528. https://doi.org/10.1016/j.jprocont.2011.01.009