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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(9): 502-512

www.thepharmajournal.com
Received: 16-06-2023
Accepted: 18-07-2023

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An overview of different peelers, pulpers, and juicers for fruits and vegetables: Research, development, and recommendations

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Abstract
Fruits and vegetables (F&V) are the second-highest agricultural commodities that are rich in vitamins, minerals, and antioxidants. These are useful for boosting immunity against different diseases. These are essential elements in the human diet but are highly perishable. On that account, a significant quantity of these worthy foods gets lost due to improper post-harvest operation and management. Virtually entire fruits and vegetables exhibit short harvesting intervals of roughly 1-2 months. Over this short period, fruits and vegetables are available in ample quantity. There is a high need for an effective means to conserve this fruit ingredient for a long-term span. Hence, preserving these fruits and vegetables in slices, juices, and other value-added products is the best way to protect fruit and vegetable's nutrients. The juice extraction commences with a tiresome manually squeezing method to motorized juice extraction machines worldwide. Various manually and motor-operated machinery is available in the market. The traditional way of hand pressing is modest and proficient, but it requires more time. A manually functioned machine is cheaper but shows limited output, while the motorized extractors are fully automated but may require high power consumption. Manually and motor-powered juice extractors reviewed in this work shall support the developers in designing cost-efficient and affordable machinery that gratifies the demand of juice processors. Several juice extractors accompanied by their corresponding functioning and performance were discussed in this work to promote more refined and superior juice extraction in the future. This review discusses different types of peelers, pulpers, and juicers, their working principle, and their application in F&V processing.

Keywords: Fruit and vegetable, peeler, pulper, juicer, design, efficiency

1. Introduction

Peeling is one of the major important processing in post-harvest technology of fruits and vegetables. It is the first process from harvest to processing which is an essential operation. The best quality of processed F&V depends on this operation. Improper peeling can produce low quality finished products due to high peeling loss and cost also will increase. Peeling methods are mainly divided into four types such as chemical, enzymatic, thermal, and mechanical. Mechanization of the peeling process can drive increased cultivation of F&V along with different value-added products with hygienic standards, processing efficiency, product quality, increased processing rate, and minimum loss**.** Manual tools such as knives and wood-made tools are used for peeling. The review has been arranged based on the technique and examples of the latest works of interest. The juice extraction commences with a tiresome manually squeezing method to motorized juice extraction machines worldwide. Various manually and motor-operated machinery is available in the market. The traditional way of hand pressing is modest and proficient, but it requires more time. A manually functioned machine is cheaper but shows limited output, while the motorized extractors are fully automated but may require high power consumption. Manually and motor-powered juice extractors reviewed in this work shall support the developers in designing cost-efficient and affordable machinery that gratifies the demand of juice processors. Several juice extractors accompanied by their corresponding functioning and performance were discussed in this work to promote more refined and superior juice extraction in the future (Patil *et al.*, 2021) [21].

Mechanical peeling interacts with the peel and removes the peel. Industrially used peelers are abrasive devices, knives, rollers, drums, and milling cutters (Shirmohammadi *et al.*, 2011) [26].

They provide fresh quality finished products which are non-toxic and eco-friendly. The method is associated with peeling and material loss due to the low flexibility of the machine, different shapes, sizes, and weight of the F&V, and change in the texture of flesh, peel, and rind. Thus, the raw materials are exposed to extra loads such as impact, shear, compression, and vibration result in the fruits' bruising. Where as manual abrasive peeling very close to the ideal peeling. Manual peeling consists of drudgery and long time of operation and labor. Mechanical, thermal (Freeze and steam) and chemical peeling methods are available conventional processes used for F&V. Any have, every method has its advantages and disadvantages depending on the methodology used. Mechanical peeling is more preferred due to its low environmental pollution, the more freshness of peeled product, less damage to the flesh, and the possibility of using the byproducts (Kumar *et al*., 2019) [13].

1.1 Characteristics of peelers

Based on the mechanism used for peeling, the mechanical peelers use a blade or knife, abrasive rollers, and rotary or milling cutters. The quantity and quality of peeling are high in case of mechanical peeling. The ideal peeling process possesses the following characteristics as-

i) Minimization of product loss
ii) Minimization of energy
iii) Use of fewer chemicals
iv) Minimization of pollution
v) Minimization of heat ring formation

Mechanical peeling is popular because of its fresh peeled products. The major conclusion will be taken into consideration is to find whether it can mechanize manual processes to minimize the weekly breakdown maintenance and worker fatigue.

2. Working principles of peelers

Different working principles are adopted for peeling purpose according to the category of fruits and vegetables. Mahawar *et al*. (2020) [17] developed peeler cum juicer for sweet orange and kinnow based on the principle of cutting and shearing. Rajesh *et al*. (2018) [23] designed and fabricated a garlic peeler in which garlic segments are peeled off due to shearing and slight compression. The jackfruit peeler cum corer in which the jackfruit rotates and the peeling is done in a helical manner due to the linear motion of the blade from bottom to top. The clearance between the blade and peeler arm was fixed on the basis of the thickness of the rind. Similarly cutting and coring operation is done by converting the rotary motion of pulley into linear motion with the help of screw mechanism. During these operations, the core removing tool which is attached to the screw shaft was pressed against the fruit. The thickness of corer and cutting blades of core removing tool was fixed based on cutting strength of jackfruit. Le *et al*., (2019) [14] developed a lychee peeling machine in which peeling part consists of two rollers with rubber coating and a pressing belt on top of the rollers. The lychee fruit's smooth movement along the axial direction of the rollers is ensured by the rotational motion of two opposing rollers and the translational movement of the belt. This coordinated motion and the force exerted by the belt prevent any jumping or significant damage to the fruit. As the belt advances, it gently presses the lychee against the rollers, facilitating the separation of the peel from the pulp through a combination of friction and shearing forces generated between the belt, fruit, and rollers.

A mango peeler machine was developed by (Girma Tura, 2020) [10] that removes the peel from matured mango. These are round shaped and inserted between shafts that consisting of a needle. From the left side of shaft, mango is to be fed and moves in clockwise direction, at the end peeled mango is collected. This peeler reduces the pulp loss and more productivity and safe.

Akram *et al*., (2021) [2] also developed a pulp extractor for mango useful in cottage industry. Mangoes are fed into the feed hopper and passed through extraction compartment in which the auger (screw conveyor) crush the fruit and forward to rotating sieve drum to separate the pulp. The residual waste is also collected from other end.

3. Types of peelers

3.1 Cassava Peeler

3.2 Manual peeling

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) [11]. Some broken cassava is referred to as mechanical damage and not losses in peeling. The mean peeling efficiency is 75.46%, with a mean flesh loss of 8.801% in 10 kg feed. The capacity of the machine that could peel was about 60 kg/h, where the cassava was loaded every 5 minutes compared to manual peeling for the skilled person of 25 kg/h. The grating and pressing capacity is 21.216 kg/h while the mean grating and pressing efficiency is 83.779%. For the overall machine, the mean duration time from peeling to dewatering per 10 kg batch basis is 22 min 15 sec. The mean recovery for three trials of testing for 10 kg feed is 6.4 kg with fine cassava grates as a final output of the machine. However, the designed machine will not peel all sizes of cassava.

Moreover, the machine is restricted up to medium sizes, specifically 254 mm length of cassava, to facilitate peeling. For further improvement of this research, the researchers recommend that the material used for design must be locally available, particularly on machine elements, for ease and affordability and an avoidance of the delay of fabrication. In the following line of study and further modification of the fabricated machine, a speed regulator can be installed to regulate the motor speed during peeling and improve the chute door mechanism for transferring the peeled cassava. For the grating unit, increase the teethed cylinder diameter to increase the surface area in contact for grating cassava tubers. It is suggested that the pressing unit be openable for easy cleaning. In addition, the rotation of the presser should be lowered to 40-50 rpm to attain better-pressed cassava grates. Further improvement and extensive literature review could still be made to this study to enhance more effective and acceptable performance.

3.1.2 Mechanical peeling

Gumanit and Pugahan, (2015) [11] developed a batch type cassava peeling, grating and pressure machine. The raw cassava are passed in a peeler with perforated material connected to its inner perimeter. The circular drum rotates from the bottom and allows the cassava tubers to move in a same motion against the perforated tool to occur peeling. Water is added both for cleaning and washing the root pieces and to discard the peel.

Odigboh, (1976) [19] designed and fabricated a cassava peeler that can peel mixed sizes of cassava. It consists of knives equipped in a cylinder and another cylinder with corrugations. Both are having 20 mm distance apart on a frame parallelly. The machine is fitted with a 1 hp electric motor (1425 rpm, single-phase) and the series of knives are driven by belt rotating to right at 200 rpm. Inside cylinder also moves in same direction at 88 rpm by gearing to the knife cylinder. It performs best with sized lots of cassava. When set up for a specific size range of roots, the peeling efficiency is over 95 % while for mixed sizes efficiency was 75 %. The peeling efficiency is not appreciably affected when peeling is done one day after harvest. The throughput capacity was 185 kg/h. The requirement of cutting approximately 100 mm length is time-consuming and, therefore, a disadvantage. The amount of subsequent hand trimming necessary is small when the machine is set up for a particular size of roots. Still, hand trimming is not eliminated, especially for small sizes of roots (40 mm and less).

Baba Hassan, (2012) [4] designed and fabricated a cassava peeler with an efficiency of 65.5 %. The linear tubers were loaded by hand and then conveyed by rail to the peeling drum. The machine will be welcomed by industries due to its simplicity, performance, and affordability.

3.2. Garlic peeler

Rajesh *et al*., (2018) [23] designed and developed a mechanical garlic peeler Garlic peeling is time-consuming, tedious and labor intensive. Traditional methods are used for peeling the garlic for many years. These methods bring forth unhygienic practices, laborious, and cause more damage to garlic segments. The angular and flat iron was used for the main frame and supporting the primary units. A food-grade rubber and mild steel pipe were used in the rubber roller to remove peel from garlic.

3.3. Mechanical peeler cum juicer for sweet orange and kinnow

A mechanical peeler cum juicer was designed and developed for both peeling and juice extraction of sweet orange and kinnow. Significant parts of the machine include two fruit holders, spur gear assembly, a revolving shaft with a length of 570 mm, and 25 mm of clearance, and a cutting knife containing 80 mm length. This was operated by a gear assembly, motor and a combination of pulleys. It was fitted with a feed hopper having a flat base in order to acheive the juice extraction from peeled fruits. The rotational speed of fruit (220, 260, 280, 300, and 360 rpm) was considered as an independent parameter for performance evaluation. Peeling efficiency (%), time (s), unpeeled area on fruit (%), and juice loss (%) were considered to be dependent parameters. The best performance was acquire at a 260 rpm (sweet orange) and 220 rpm (kinnow) speed with higher peeling efficiency and minimum juice loss was reported by Mahawar *et al*., (2020) [16].

3.4 Jackfruit peeler cum corer

Expecting the minimum processing time and bulb wastage with higher efficiency by using three sizes of jackfruit, the speed of the corer pulley (110, 130, and 150 rpm) and fruit holder (90, 120, and 150 rpm) was optimized. The peeling operation at optimized speed (90 rpm) showed minimum bulb wastage for small (7.85 %), medium (7.24 %), and large (6.20%) sized fruits with high peeling efficiency of 85.27, 83.51, and 80.64%, with a trend of increasing operational time of 38.24, 44.58, and 50.34 sec respectively. Similarly, coring operation at optimal speed (130 rpm) showed processing times of 16.98, 22.39, and 24.83 sec and high coring efficiency of 92.85, 90.32, and 82.03 %, with bulb wastage of 10.337, 7.81, and 6.09 % respectively. The average power consumption of optimal operational speeds for medium-sized jackfruit with load was found as 0.0149 ± 0.0029 kWh/fruit, whereas in without load condition was found to be 0.0104±0.0007 kWh/fruit. The average time for peeling, cutting-coring, and bulb separation in manual and mechanical process was 28.8 min and 13.3 min/fruit respectively. The maximum throughput in manual and mechanical process was 17.36 kg/h and 37.5 kg/h respectively. The cost of the machine was estimated as Rs. 46950/-. The operational cost by manual and mechanical process was Rs. 47.5/h and Rs. 52.97/h respectively. The benefit-cost ratio of the developed machine and manual process was 2.32:1 and 2.66:1 respectively (Shidenur H.T., 2016).

3.5. Litchi Peeler

Le *et al*., (2019) [14] developed a litchi peeler which works based on the principle of shearing and friction. The main components of this device are two rubber covered rollers and a pressing belt. This can reduce the juice and pulp loss, breakage, and flesh damage compared to a peeler using pure friction. The critical peeling force of lychee fruits was recorded as 10.5 N. Both rollers rotate in opposite direction at 159 rpm to separate the peel from the litchi fruits. The pressing belt which is parallel to the rollers provide exerting pressure of 13.5 N on the fruits. The roller diameter, length, and clearance between the rollers can greatly affect the efficiency of the peeler.

3.6. Mango Peeler

The peeling of the mango is traditionally done which is time-consuming. and there is the loss of pulp within the peel and seed. It results in low quality and less efficiency and consumes more time, chances of hand injuries. A peeler machine was designed and developed for mango to make the peeling process easy. This machine consists of the spur gears, frames, sample, blade and screw shafts, and blade (Girma Tura, 2020) [10].

The power is transmitted to the sample shaft through spur gears from the feeding section. Spur gears are having 34 and 86 teethand gear ratio of 2:5.

3.7. Onion Peeler

The main components of onion peeling machine are main frame, inlet and outlet openings, peeling drum, collection basin, power transmission system, and water and air supply systems. The machine was evaluated using large, medium and small onion bulb sizes. The evaluation process was conducted under peeling residence times (1, 2, and 3 min), drum rotational speeds (30, 40, and 50 rpm) and batch loads (18, 24, and 30 kg). The peeling efficiency of 74.9, 65.24, 80.08, and 85.45 % were obtained at 24 kg batch load (0.36 ton/h.), 2 min peeling residence time, and 40 rpm for small, medium, mixed and large sizes onion bulbs, respectively (El-Ghobashy *et al*., 2012) [6].

The objective of this study is to design and assess an onion peeling and trimming machine suitable for small and medium-scale production units, including restaurants, hotels, and small onion drying facilities. Peeling experiments were conducted on Giza 6 and Beheri onions, with average moisture contents of 79.6% and 81.1% (w.b.), respectively. The fabrication, development, and testing of the onion peeling machine were carried out. Various parameters were considered, including four open flat belt speeds (15, 20, 25, and 30 rpm), onion sizes (small, medium, and large), and two popular onion cultivars: Giza 6 (white) and Beheri (red). Results indicated that the peeling efficiency, peeling capacity, and total cost were higher for Giza 6 onions compared to Beheri onions when using the peeling machine. For Giza 6 onions, the highest peeling capacity of 140.61 kg/h was achieved at an open flat belt speed of 30 rpm with large-sized onions.

The key findings can be summarized as follows:

1. Peeling efficiency, peeling capacity, and total cost were higher for Giza 6 onions compared to Beheri onions when using the peeling machine.
2. To achieve optimal peeling and trimming quality, lower costs, and power requirements for Beheri and Giza 6 onions, the recommended speed is 15 rpm with medium-sized onions.
3. Sizes smaller than medium onions are more suitable for home use, pickling, etc., due to lower cost feasibility.
4. For enhanced economic viability, onion grading and sorting equipment should be implemented prior to the peeling machine.
5. Further experimentation is recommended to reduce machine size and incorporate electronic control units for improved peeling quality, keeping up with advancements in agricultural processing machines (Ghanem, 2020) [8].

3.8. Vegetable peeling and cutting machine

The vegetable peeling process is time-consuming and becomes inefficient during weekly breakdown maintenance. It is vital for both food processing industry and domestic point of view. The main component of machine are drum, abrasive peeling section, and cutting section. The design of the machine is based on the idea of combining all the processes in one, which helps to reduce the manpower and satisfies the needs of industries and households. The machine is simple to operate, safe, and easy to repair. The technology is affordable and less expensive when compared to existing peeling machines. It has a low operating cost.

3.9 Pneumatic Pineapple peeler

Harvested pineapple may go to waste before they are consumed due to a lack of appropriate technology and infrastructure. A pneumatic pineapple peeler was developed for slicing the pineapple to create a cylindrical pulp. It has a cylindrical blade used to strip the pineapple flesh. It can remove the leaves, core of the pineapple and peel the outer surface. In 7 hours, roughly 2100 pineapples could be peeled (Madhankumar *et al*., 2021) [15].

3.10. Power-operated plantain peeler

Plantains are usually processed into chips, and the peel is used to prepare pickles. The nendran type plantain is preferred chiefly for making chips. The commercial chip manufacturing process involves peeling, slicing to small wafers, frying, and packaging. At present, the peeling of plantain is done by traditional methods using stainless steel knives. This conventional method poses a danger to the operator’s finger by inflicting injury, less capacity, time-consuming, and labor-intensive. So, a power-operated plantain peeler was fabricated. The plantains with a moisture content of 80 ± 2 % was used. The peel and pulp were weighed to determine the pulp-to-peel ratio. This peeler consists of feeding unit, peeling unit, pushing unit, collection unit, power transmission assembly, frame assembly. The feeding unit consists of 4 cylindrical guides of different diameters placed 90º apart and fixed to a flat plate of 266.7×266.7 mm. Four MS hollow cylinders with diameters of 44, 47, 47, and 55 mm, a height of 200 mm, and a thickness of 2 mm were used to fabricate a cylindrical guide. The peeling unit separates the peel from the pulp. Four high carbon steel blades of width 25 mm are bent to form circular type openings of diameters 25, 32.5, 32.5and 40 mm for respective cylindrical guides through which plantain passes. Pushing rod consists of a piston rod, screw shaft, and pulley. The lowering and lifting of the piston are achieved by a screw shaft mechanism. Screw shaft with outer square threads meshed with cast-iron pulley with inner threads. It converts the rotary motion of the pulley into the linear motion of the screw shaft. A 1.0 hp single phase reversible electric motor of 1425 rpm was fitted as the power source. The speed of the plantain peeler was optimized using a gearbox. The speed reduction gear was connected with the motor to reduce the motor speed in the ratio of 5:1 rpm. The belt and pulley were used to transmit power from one shaft to another. 5 V-grooved pulleys (3 pulleys of 150 mm diameter, 200 mm, and 50 mm) made up of cast iron were used for power transmission. The outlet chute was made of SS sheet with a 45º inclination towards the horizontal to facilitate easy discharge. A collecting tray of 270 x 270 x 50 mm was made from an SS sheet of 1 mm.

The average peel thickness of plantain was measured as 2.36 mm. The pulp-to-peel ratio of the nendran variety varies between 1.75 and 1.77, with an average value of 1.76. The maximum and minimum diameters with peel were 40.3and 23.29 mm, respectively. The corresponding values for without peel were 33.55 and 24.67 mm, respectively. The maximum load required to cut a cross-sectional slice of peel and pulp was 47 N and 27 N, respectively. The machine's overall capacity for the 42 mm diameter feeding cylinder varied from 5.98 to 7.15 kg/h with an average value of 6.62 kg/h.

Similarly, the machine's overall capacity for 47mm and 54mm diameter feeding cylinders varied from 12.44 to 14.09 kg/h and 15.07 to 17.45, respectively. The average overall capacities for 42 mm, 47 mm, and 54 mm diameter feeding cylinders were estimated to be 6.62, 13.23, and 16.81 kg/h, respectively. A maximum capacity of 16.81 kg/h was obtained using a 54 mm diameter feeding cylinder and a minimum capacity of 6.62 kg/h for a 42 mm diameter feeding cylinder. It is understood that the machine's capacity increases with the diameter of the feeding cylinder. Maximum capacity was obtained using a 54 mm diameter cylindrical guide, and the minimum for 42 mm. This is because the weight of the plantain increases with size, and the time taken for peeling operation was constant for all sizes of plantain. The peeling efficiency of 96.65 % using a 42 mm diameter feeding cylinder was observed.

A comparison of manual and mechanical peeling was conducted. It is observed that skilled labor can peel approximately 25 kg of plantain in one hour, whereas the power-operated plantain peeler could peel 105 kg in one hour. The peeling capacity of the developed machine is found to be four times more effective than manual peeling.

3.11. Lye Peeling Machine for Small Capacity of Potato

This machine was tested using potato and it sprays pressurized water on the potato soaked in hot NaOH solution. Water pressure from the nozzle is controlled by using potentiometer's pulse width modulation (PWM) method. NaOH treatment concentrations were 9%, 11%, and 13%. The treatments are carried out using three duty cycle values with the analog input setting value on the microcontroller. It resulted in three variations of water pressure i.e., 60% (4.2038 Pa), 80% (5.6051 Pa), and 100% (7,0065 Pa) respectively for low, medium, and high levels. The percentage of perfectly peeled skin close to 100% was obtained at 11% NaOH with a duty cycle value of 60% and 80%; and 13% NaOH with a duty cycle value of 80%. The smallest weight loss calculation is 14.96% at 9% NaOH duty cycle 100%, and the highest percentage of weight loss is 35.89% at 13% NaOH 80% duty cycle (Sandra *et al*., 2021) [25].

3.12. Grating and peeling apparatus for fruits and vegetables

Grating holds great significance, particularly for salad preparation and decorative purposes. For effective execution of the decorative process, it is crucial to have a suitable grater. However, manual peeling by hand can be laborious and time-consuming, necessitating multiple workers and resulting in higher operational costs. To address this, a machine was innovatively developed to combine both grating and peeling functions into a single device. This newly invented machine is specifically designed for domestic use and boasts a portable nature. It incorporates essential components such as a clamping mechanism, grater, peeling blade, movable arm, and a pair of end-cutting blades. Through rigorous testing, the prototype successfully automated the grating and peeling process. Additionally, manual peeling was performed on selected fruits and vegetables to compare the effectiveness. The results demonstrated that the prototype significantly reduced peeling time by 94% compared to manual peeling (Siti *et al*., 2010) [26].

3.13. Jackfruit peeler cum cutter machine

The machine exhibits remarkable capabilities in effectively washing, peeling, and cutting tender jackfruit. It offers versatility by accommodating tender jackfruits of all sizes, boasting an impressive throughput capacity of 25 kg/h. To ensure food safety, all components that come into contact with the food are made of stainless steel, specifically grade 304. The machine's performance was optimized by adjusting parameters such as the rotating speed of the jackfruit, forward speed of the peeling arm, and rotating speed of the cutter, resulting in maximum efficiency and minimal loss during the processing of tender jackfruits.

With a return on investment value of 209.61%, the machine proves to be financially advantageous. Moreover, the investment's pay-back period is exceptionally low, estimated at just 34 working days. These factors make the fabricated machine a highly favorable option, offering lower operating costs, a low breakeven point, and a high return on investment. Additionally, it significantly reduces the costs associated with minimal processing and packaging of tender jackfruit slices (Rana, S. S., 2019) [24].

3.14. Latest peeling methods for tough-skinned fruit and vegetables

Automated or semi-automated techniques are employed for peeling tough-skinned fruits and vegetables like jackfruit, pineapple, wood apple, melon, and pumpkin. However, both methods suffer from significant peeling losses. To address this issue, this research has introduced four novel mechanical peeling methods that leverage the specific mechanical properties of such fruits and vegetables. A groundbreaking approach involves the utilization of an abrasive-cutter brush as the optimal peeling method for tough-skinned produce. This innovative device employs abrasive and cutting forces simultaneously to efficiently remove the peel (Emadi B, 2005) [7]. Notably, the developed method offers consistent peeling efficiency in both concave and convex areas and boasts high productivity. Moreover, it prioritizes eco-friendliness by minimizing water consumption and reducing peeling waste.

3. Working principle of juicer

In a screw juicer, the material is constantly chopped by the screw shaft along with continuous rotation. The screw plays a vital role in moving the material continuously to the end of the cylinder. The fruits squeezed between the inside wall of cylinder and the screw. It creates a crushing effect and increases the internal pressure in the juice and cells of fruits and vegetables, ruptures the cell wall, and separating the juice and pomace (Wu *et al*., 2021) [28].

The juice extraction of fruits and vegetables consists of squeezing, crushing, and pressing to reduce the bulkiness of the fruits and vegetables to pulp and obtain juice. There are two types of extractions;

a) The raw materials are crushed and pressed at a time in single step.
b) The raw materials are crushed first or cut into smaller pieces and these are subsequently pressed in a suitable press.

Broadly, there are four types of equipment used for the extraction of fruit juices

1. Halving and burring machines
2. Continuous screw expeller press
3. Plunger type press
4. Roller type press

Two types of presses are used for pressing the juice from the crushed fruit. They are

a) Basket press.
b) Rack and cloth press

4. Various types of pulpers/juicers

4.1. Orange juice extractor

4.1.1. Manual extraction

One portable manually operated household orange juice extractor was developed. The diameter and height was 160 mm and 350 mm, respectively. It was designed on the basis of beating and chopping, often by macerating. It is mainly consists of a goblet and a manually operated mechanical unit. The mechanical unit consists of a pair of two bearings, bevel gears, and two shafts. The bevel gear casing is constructed by a 2 mm thick mild steel sheet. Similarly, the goblet is formed using a 1 mm thick mild steel sheet. Small sharpened blades are fixed in the impeller shaft. A dynamic seal is put between the bearings, shaft, and goblet to prevent leakage. The goblet and gear casing are connected using an Oldham coupling designed for misalignment. The machine capacity is about 180-220 oranges/h (Aye and Ashwe, 2012) [3].

4.1.2. Mechanical extraction
The design and construction of an orange juice extractor were undertaken to extract pure orange Juice, free of squashed seeds and peels. It has a cutting chamber, which is made up of a rotary shaft, an inclined tray, and knives attached at both ends. The squeezing section comprises the rammer, a crankshaft, and a sieve. The shaft diameter, torque, and power transmitted as 12 mm, 14252 N mm, and 1.5 kW, respectively. The pulley has a linear speed of 10.74 m/s, and the cross-sectional area of the squeezing chamber (flat plate) is 12,000 mm^2 with a force of 5.32 N on the plate due to pressure from the orange. The net force acting on the plate is 3059 N. The machine's capacity and efficiency were 5.73 kg/h and 76.04 %, respectively. More juice can be extracted using this machine than by a turning screw (Maduako, 2015) [16].

The device has a rotary handle through which power is introduced into the system, a spur gear train mounted on a base, a power screw, and a cutting blade that performed the peeling function. The fabricated device has a peeling efficiency of 97 %, generated 2.6 % over peeled and damaged oranges, and has a peeling capacity of about 140 oranges/hr compared to hand peeling that can produce 32 oranges/h. (Ademoh and Akaba, 2015) [1].

5.2. Kendu Pulper
Hmar *et al*., (2018) [12] devised a kendu pulper that involves manual feeding of ripe and matured kendu fruits into the hopper. An optimized amount of water is added to aid smooth flow. The water quantity is fine-tuned through trial and error to ensure optimal flow with minimal water usage. The feeding of fruits and removal of by-products (seeds and peel) occur simultaneously. The feed rollers effectively break the tough outer covering of the kendu fruit and extract the pulp along with partially separated seeds. Subsequently, the primary shaft, equipped with brushes, presses the ruptured fruit against a perforated screen cylinder, extracting the pulp while leaving behind the broken outer covering and seeds.

The pulper has a throughput of 50 kg/h. The overall extraction efficiency of the pulper is 78.36% at an optimized speed of 260 rpm and a feed rate of 2.5 kg/min (Hmar *et al*., 2018) [12].

5.3 Mango Pulper
Mango pulper was developed to help farmers in the countryside in minimizing fruit spoilage. It is constructed by using stainless steel (SS-304) and consists of a mainframe, hopper, teflon brushes mounted shaft, extraction compartment, pulp outlet motor, fruit residue outlet, perforated sieve, and bearings. The machine was tested at different extraction speed levels (500, 900, and 1400 rpm) and feed rates (2.0, 2.5, and 3.0 kg/min. The physicochemical analysis of the extracted pulp was also carried out. Results revealed a maximum pulp yield of 77.9 %, the highest extraction efficiency of 96.03 %, and the highest extraction loss of 9.3%. The mango pulp extraction machine was affordable and easy to operate and maintain (Akram *et al*., 2021) [2].

The optimum operating speed of the electric motor for pulp extraction was 900 rpm for mango fruits, while the optimum mango feed rate was 2.5 kg/min, but it can also operate at 3.0 kg/min.

5.4 Manually operated Cashew Juice Extractor
A manually operated cashew juice extractor working on the screw press principle was designed, fabricated, and tested. Apple crushing was by pressing a wooden piston against a steel-reinforced end plate. Juice output was 1.02 liters/h, and the average juice extraction efficiency was 85.38 % (Ogunsina and Lucas, 2009) [20].

5.5. Motorized Fruit Juice Extractor
Fruits and vegetables are vital elements in human food, but they are highly perishable. On that account, a significant quantity of this worthy produce gets wasted due to improper post-harvest management. Virtually entire fruits and vegetables exhibit short harvesting intervals of roughly 1-2 months. Over this short period, fruits and vegetables are available in ample quantity. There is a need for an effective means to conserve this fruit ingredient for the long term; hence, conserving these fruits in the form of juice is the best way to preserve fruit nutrients. The juice extraction commences with a tiresome manually squeezing method to motorized juice extraction machines worldwide. Various manually and motor-operated machinery is available in the market. The traditional method of hand squeezing is modest and proficient, but it requires more time. Manually functioned machines are cheaper but show limited output, while the motorized extractors are fully automated but may require high power consumption. Manually and motor-powered juice extractors reviewed in this work shall support the developers in designing cost-efficient and affordable machinery that gratifies the demand of juice processors. Several juice extractors accompanied by their corresponding functioning and performance were discussed in this work to promote more refined and superior juice extraction in the future (Patil *et al*., 2021) [21].

Juice extraction is productive or fruitful means of nutrient sustentation. Numerous juice extractors have lasted long, yet certain constraints were linked with this previously practiced extractor. Hence, to improve their performance intends to write reviews. An abundant quantity of fruits is available during the peak harvesting season. Still, much fruit production gets wasted during this period, necessities to be preserved for the period when there is no fruit production which requires a superior mechanical device to extract the juice from fruits. Various manually and power-operated extractors were developed earlier. Several machines were extravagant, high power, and lengthy processing time-consuming in addition to extraction loss, lower efficiency and sedimentation were the common problems with extractors. Hence, there is a significant requirement to advance this prevailing machinery by emphasizing high extract yield, ease in operation and maintenance, hygiene, and affordability to farmers and fruit juice processors.

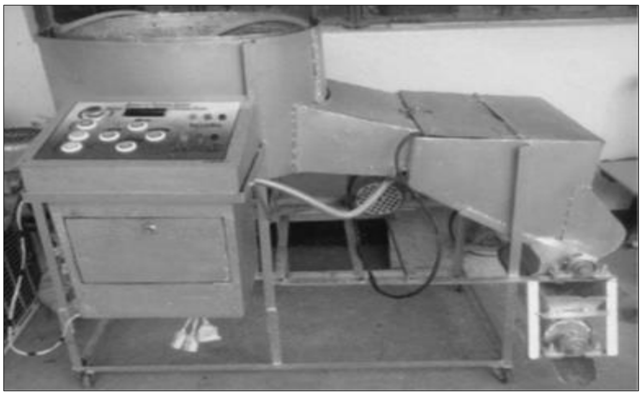


Fig 1: Cassava Peeler

Fig 2: Rubber roller and shaft

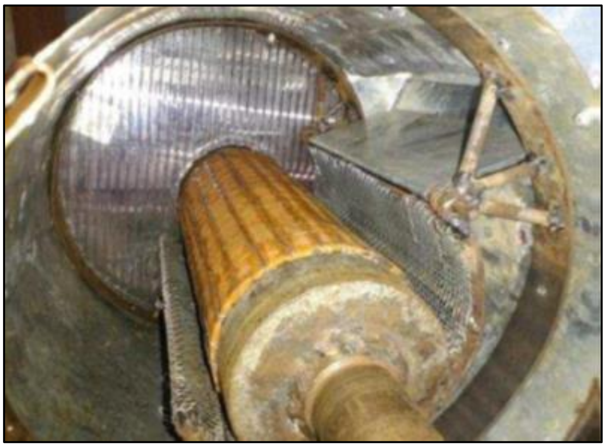


Fig 3: Cylinder-concave unit

Fig 4: Bearing

Fig 5: Garlic Peeler (Front view)

Fig 6: Garlic peeler (Side view)

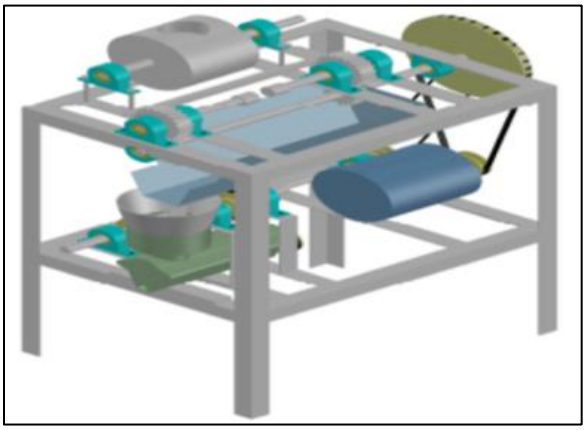


Fig 7: Mechanical peeler cum juice extractor

Fig 8: Jack fruit peeler for kinnow and sweet orange (Mahawar *et al*., 2020)

Fig 8: Manual fruit juice extractor (Eyeowa *et al*., 2017)

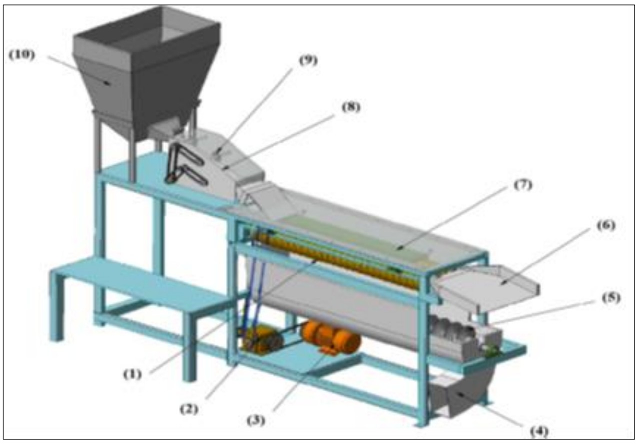
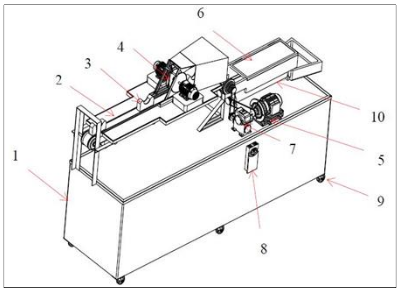


Fig 9: Litchi Peeler (Le *et al*., 2019)



(1. Mainframe. 2. Flat belt. 3. Bucket 4. Cutting tools "saw knife discs".5. Electrical motor 6. Separation mechanism 7. Gear box. 8 Inverter 9. Wheels. 10. Friction drums.)

Fig 10: Onion peeling machine (Ghanem, 2020)

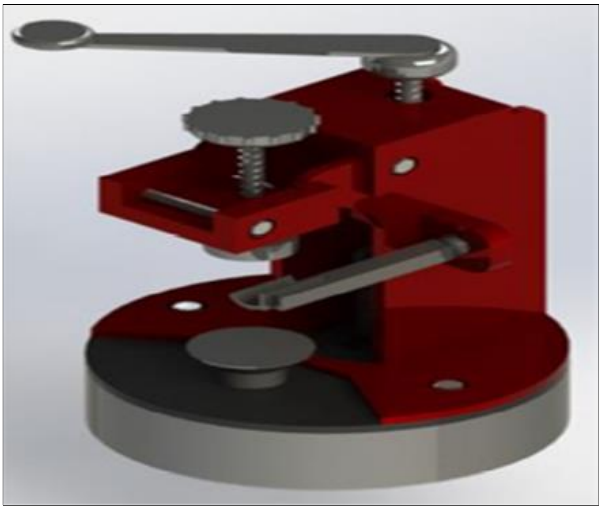


Fig 11: Orange peeling device

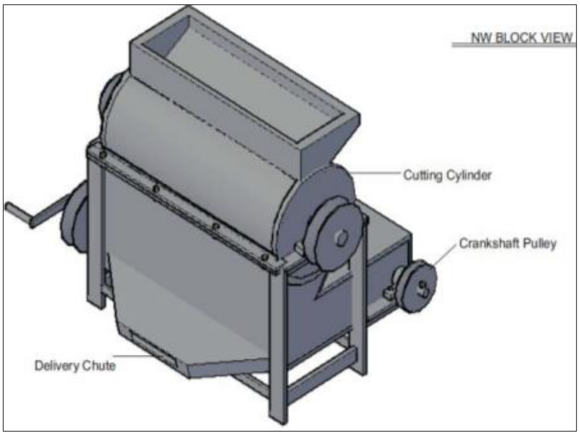


Fig 12: Orange juice extractor (Maduako, 2015)

Fig 13: Pneumatic Pineapple peeling (Madhankumar *et al*., 2021)

Fig 14: Power Operated Plantain Peeler (Athira, 2017)

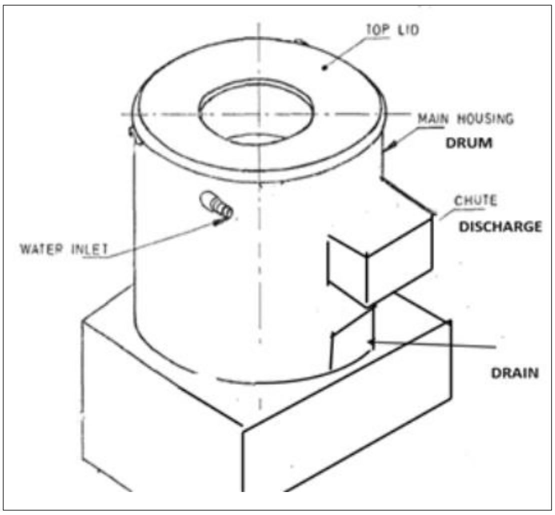
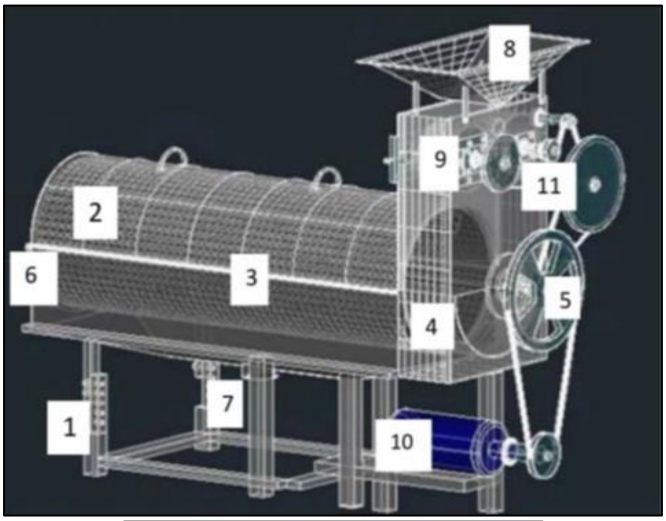
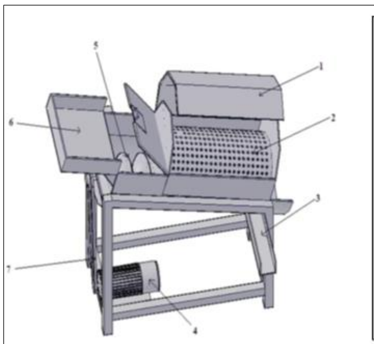


Fig 16: Potato peeler



1. Main frame;
2. Barrel housing;
3. Screen cylinder;
4. Brushes;
5. Main shaft;
6. Seed/skin outlet;
7. Pulp outlet;
8. Hopper;
9. Feed rollers;
10. Prime mover;
11. Power transmission

Fig 15: Isometric view of the designed Kendu pulper (Hmar *et al.*, 2018)



1. Pulp extraction compartment cover,
2. Sieve,
3. Pulp outlet,
4. Electric motor,
5. Auger conveyor,
6. Feeding hopper,
7. V-Belt

Fig 16: Mango pulp extractor (Akram *et al.*, 2021)

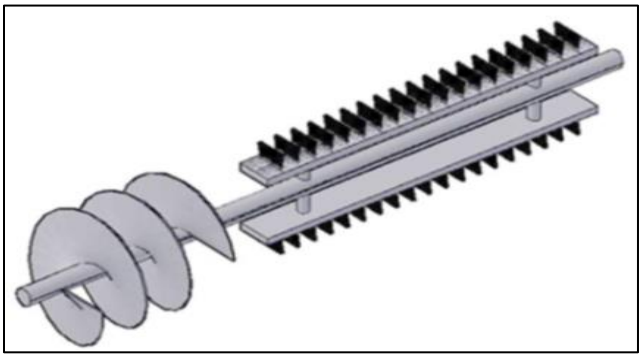


Fig 17: Teflon brushed mounted shaft

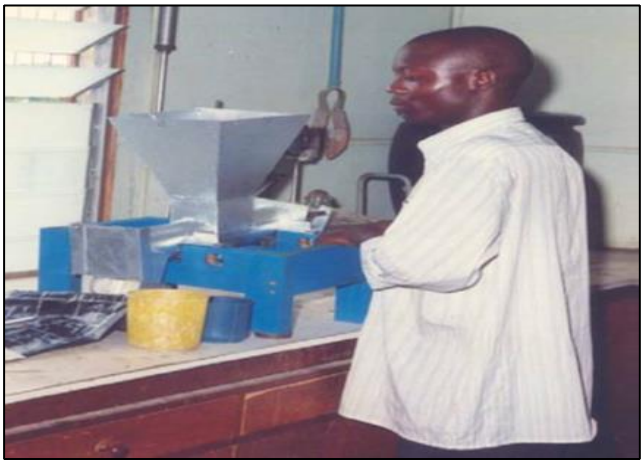


Fig 18: Cashew juice extractor (Ogunsina & Lucas, 2009)

Fig 19: Peeling and cutting machine

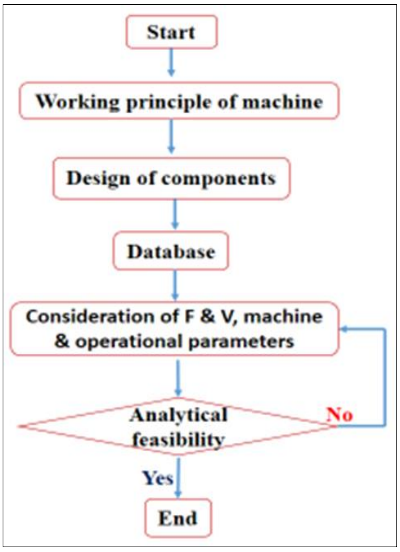


Fig 20: Flow chart of methodology

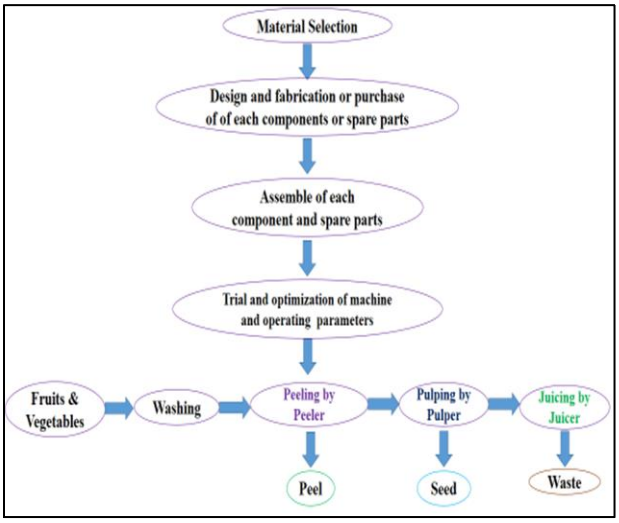


Fig 21: Flow chart of primary processing of F& V

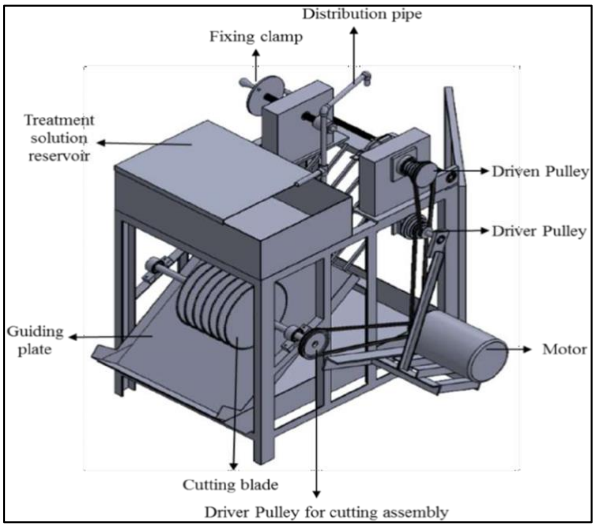


Fig 22: Jackfruit peeler cum cutter

6. Conclusion

It can be concluded that peeling, pulping, and juicing have been recognized as post-harvest operation that improves the value and quality of fruits and vegetables. The principles of operation of peeler, pulper, and juicer depend on their different assembly parts and engineering properties. But, the operation and design parameters, along with the physical and chemical properties of fruit and vegetables that affect the performance of the above machines, are considered to maximize the efficiency and capacity of these machines. Periodic management and preventive maintenance of these machines can lengthen their useful life. It has been revealed that most post-harvest machinery's performance and working conditions tend to decline due to poor management and preventive maintenance. The processing loss of fruit and vegetables has been a peculiar bottleneck in most of these machines. So, researchers and industries should work on peelers, pulper, and juicers with zero processing loss. From the energy point of view, some solar-operated peelers, pulper, and juicers should be developed. This review will help farmers, farm women, SHGs, and entrepreneurs to increase their income using the different peelers, pulper, and juicers because nothing will go right if agriculture and agricultural machinery go wrong.

7. Future Scope

A thorough study is essential to explore the existing machines by eliminating their constraints. A novel advance tool needs to be designed with the aid of developing a reasonably priced juice extractor that ultimately gives constant higher juice yield with low corresponding extraction loss and is simple in operation and maintenance-friendly also.

8. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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