CHAPTER II
REVIEWS OF LITERATURE

This chapter represents the review of literature on physical and mechanical properties of fruits, design and development, performance evaluation of juice extractors and quality assessment of juice. The available information is reported under different sections and subsections.

2.1 Physical and mechanical properties of fruits

Reddy et al. (2004) studied some engineering properties of sapota (*Achras zapota*). Physical properties, namely size, shape, weight, density and frictional properties, namely peak static, peak dynamic and average dynamic Coefficients of Friction (COF) on four common construction surfaces, and mechanical properties, like puncture and compression with respect to storage period for sapota (*Achras zapota*) fruit were measured using standard procedures. The average geometrical mean diameter of sapota was 54.0 mm. Bulk and true densities of sapota were 584.9 kg/m$^3$ and 1040.8 kglm$^3$.

Peak static, peak dynamic and average dynamic COF of sapota varied from 0.24 (for rubber sheet) to 0.30 (for aluminium), from 0.34 (for stainless steel) to 0.39 (for rubber sheet), and from 0.26 (for rubber sheet) to 0.33 (for aluminium), respectively. The fruit firmness was measured as 325.6 N on fourth and 240.7 N on sixth day of harvest.

Sharifi et al. (2007) investigated physical properties of grade one (large), two (medium) and three (small) Oranges (var. *Tompson*). These properties included: dimensions, mass, volume, surface area, porosity and coefficient of static friction. The major, intermediate and minor diameters of the grade two orange were 84.1, 77.4 and 75.5 mm, respectively. Volume and mass of the grade two orange were 217.8 cm$^3$ and 215.4 g, respectively. As for grade two orange piles, the bulk density and fruit density were respectively calculated as 0.44 and 1.03 g.cm$^{-3}$. Porosity of grade one, two and three oranges was 44.64, 49.39 and 51.2%, with their sphericity being 0.948, 0.931 and 0.923, respectively. The static angle of friction of grade two orange on galvanized, glass and plywood surfaces were found to be 20.2, 23.4 and 23.5$^0$, respectively. The three classes of oranges were significantly different from each other.
regarding their physical properties. Orange mass was determined through a polynomial function of third degree involving the average diameter of the orange. The function was evaluated with a determination coefficient of 0.991.

Mirzaee et al. (2009) measured the physical properties of apricot to characterize best post harvesting options. Technological properties such as physical characteristics (linear dimensions, mass, volume, and so on), elasticity modulus, and hydrodynamic characteristics (terminal velocity, drag force, etc.) were determined at 79.61 % (Nasiry), 84.17 % (Rajabali) and 79.84 % (Ghavami) moisture content. The mean values of length, width, thickness, sphericity, mass, elasticity modulus, terminal velocity and drag force of three different apricot fruits were established between 36.94-48.51 mm, 34.11-43.32 mm, 31.65-40.84 mm, 0.84-0.94, 25.56-53.69 g, 0.32-0.53 MPa, 0.17-0.21 m.s\(^{-1}\) and 0.01-0.08 N, respectively.

Vahid et al. (2009) determined the physical properties of pomegranate fruit. Its weight ranged from 103.38 to 505.00 g and fruit volume from 99.41 to 547.88 cm\(^3\). Similarly, average three fruits’ density ranged from 0.91 g.cm\(^{-3}\) to 1.04 g.cm\(^{-3}\) and peel thickness of the fruit was recorded from 1.60 to 6.01 mm.

Riyahi et al. (2011) investigated some physical characteristics of pomegranate, its seeds and arils. Physical properties of fruit were determined and average value of length, width, thickness, geometric mean diameter, sphericity, surface area, criteria project area and porosity were found as 88.12 mm, 82.61 mm, 79.65 mm, 83.33 mm, 0.95 percent, 219.91 cm\(^2\), 57.90 cm\(^2\), 29.402 cm\(^2\) respectively. Coefficient of friction of fruit on wood, glass and galvanized Iron surface were 0.45, 0.72 and 0.84, respectively. Mean values of coefficient of friction on these surfaces were 0.53, 0.31, 0.50 and 0.58, 0.30 and 0.49 for arils and seeds, respectively. Weight ratio different parts of samples were determined and average value were 0.73 for arils respect to fruit and 0.25 for peels respect to fruit.

Solanki et al. (2011) studied the physical and mechanical properties of *neem* fruit and seed relevant to depulping and decorticating. The mean values of length and diameter of fresh *neem* fruit (20.41% m.c.) were 17.66 mm (16.21 mm to 19.00 mm) and 13.18 mm (11.73 to 15.09 mm), respectively. In comparison, the length and diameter of seed extracted from fresh fruit (17.32% m.c.) was 13.82 mm and 8.18 mm and it ranged from 11.06 to 15.10 mm and 5.47 to 10.11 mm, respectively.
Davies (2012) studied the physical and mechanical properties of palm fruit, kernel and nut. The properties were determined at specific moisture content for the three parts of palm fruit: fruit, kernel and nut at 8.3, 10.7 and 9.5% dry basis respectively. The highest axial dimension was observed for palm fruit, 42.32, 28.04, and 34.99 mm corresponded to length width and thickness respectively. Palm fruit had the highest geometric and arithmetic mean diameters values ranged from 21.36 to 29.23 mm and 20.80 mm to 27.80, respectively. The palm fruit had the highest 1000 unit mass value ranged from 6780.14 to 1239.63g while the least value ranged from 1370.75 to 3583.81g was recorded for palm nut. Palm fruit had the highest bulk density 0.71 g.m$^{-3}$ and followed by palm nut. Palm kernel had the lowest bulk density 0.64 g.m$^{-3}$. The mean true density values ranged from 1.01±0.04 to 1.22±0.05 g.m$^{-3}$ for the three parts palm fruit.

Zare et al. (2012) investigated the physical and mechanical properties of Russian olive fruit. Physical and mechanical properties of Russian olive fruits were measured at moisture content of 14.43% w.b. The results revealed that the mean length, width and thickness of Russian olive fruits were 20.72, 15.73 and 14.69mm, respectively. Mean mass and volume of Russian olive fruits were measured as 1.45 g and 2.55 cm$^3$, calculated as 0.81, 0.72 and 8.96 cm$^3$, respectively, while arithmetic mean diameter, geometric mean diameter and equivalent diameter of Russian olive fruits were 17.05, 16.83 and 16.84 mm, respectively. Whole fruit density, bulk density and porosity of jujube fruits were measured and found to be 1.01 g.cm$^{-3}$, 0.29 g.cm$^{-3}$ and 69.5%, respectively. The values of static coefficient of friction on three surfaces of glass, galvanized iron and plywood were 0.35, 0.36 and 0.43, respectively. The skin colour (L*, a*, b*) varied from 9.92 to 16.08; 2.04 to 3.91 and 1.12 to 3.83, respectively. The values of rupture force, deformation, energy absorbed and hardness were found to be between 12.14-16.85 N, 2.16-4.25 mm, 3.42-6.99 N.mm and 17.1-23.85 N.mm.

Hazbavi (2013) studied the determination of engineering properties of pomegranate fruit. The observed length, width, thickness, geometric mean diameter, bulk density and mass of pomegranate fruit were 87.45mm, 80.8 mm, 73 mm, 80.14 mm, 451.6 kg.m$^{-3}$and 227.52 g, respectively. Rupture force for pomegranate fruit was observed as 40.7 N that equal with 18 layers of fruits.
Jalilian Tabar et al. (2013) studied the physical properties of kumquat fruit. The average value of length, width and thickness for the kumquat fruits were 39.5, 25.7 and 25.1 mm, respectively. The mean sphericity was found to be 74.5%, with a standard deviation of 3.5. The sphericity observed varied from 65.9 to 83.0%. True density ranged from 1.0 to 1.3 g cm\(^{-3}\), with the mean 1.2 g cm\(^{-3}\). The average surface area and criterion area were found to be 743.0 and 736.0 mm\(^2\).

Karpoora et al. (2013) studied the physical and engineering properties of tamarind fruit. The tamarind fruits at the moisture content of 25% on dry basis possessed the average length, width and thickness of 64.32 mm, 17.97 mm and 10.24 mm, respectively. The mean values of geometric mean diameter, sphericity index and surface area were 21.12 mm, 0.33 and 141.46 mm\(^2\), respectively. The average values of bulk density, true density and porosity were 603.19 kg m\(^{-3}\), 1063.15 kg m\(^{-3}\) and 42.47%, respectively. Angle of repose during filling and emptying were in an average of 33.53\(^0\) and 49.72\(^0\), respectively. The higher value of coefficient of friction for tamarind fruits was obtained for the mild steel surface followed by galvanized irons and minimum friction was experienced on stainless steel sheet.

Ndubisi et al. (2014) measured some physical, mechanical and thermal properties of four cultivars of African Date fruits and kernels namely ‘digila’, ‘krikri’, ‘sukur’ and ‘trigal’. Average fruit and kernel length of digila, krikri, sukur and trigal cultivars at the moisture contents of 17.85, 11.46, 15.85 and 12.27% (d.b.), respectively, was 38.04 and 21.98 mm, 30.70 and 22.99 mm, 33.23 and 22.40 mm and 36.08 and 22.60 mm. Corresponding average width values were 15.53 and 6.35 mm, 14.80 and 6.92 mm, 17.01 and 7.59 mm and 18.00 and 8.26 mm, for fruits and kernels. Roundness of digila, krikri, sukur and trigal fruit and kernel was 46.10 and 28.78%, 37.10 and 36.78%, 44.35 and 33.10% and 44.31 and 35.84%, respectively. Sphericity of fruit and kernel was, respectively 49.64 and 33.52%, 58.81 and 37.40% (krikri), 47.85 and 35.70% (sukur) and 43.25 and 32.13% (trigal). Bulk density of the fruits of the cultivars was found to be relatively lower than that of their corresponding kernels. True density of fruits was lower than the density of water, while kernels were higher. Porosity of the fruits was 34.0, 35.21, 39.0 and 50.5% for digila, krikri, sukur and trigal and the corresponding kernel porosity was 38.8, 59.5, 30.3 and 48.6%, respectively. The angle of repose of fruit and kernel was found to be 19.82 and 34.94\(^0\) (digila), 18.07 and 33.36\(^0\) (krikri), 21.93 and 29.0\(^0\) (sukur) and 25.49
and 20.20 (trigal). The crushing strength of both fruit and kernel was 6.74 and 10.68, 2.03 and 4.35, 13.15 and 17.64 and 5.63 and 9.67 kN.m⁻³, for digila, krikri, sukur and trigal, respectively. Static coefficient of friction of fruit and kernel varied structural surface. Specific heat varied with cultivar and was higher for the kernel than the fruit.

Kumar et al. (2015) investigated physical and engineering properties of pomegranate fruit and arils. The average fruit mass, length, width and thickness of pomegranates were determined as 208.06 g, 58.04 mm, 72.06 mm and 70.08 mm respectively. On the three different surfaces, static friction coefficient values were found as 0.76 (galvanized steel sheet) and 0.46 (plywood) and 0.84 (glass). The aril ratio and 1000-arils mass were 72% and 278 g respectively.

2.2 Design and development

2.2.1 Design considerations

Ogunsina and Lucas (2008) developed a manually operated cashew juice extractor. The design load was taken as 300 kPa based on the results of compression test. The average minimum axial force obtainable from an adult human being as a power unit was taken as 200 N, and this was assumed to be sufficient to develop the torque needed at a screw length of 300 mm. The power screw thread was square and in a single revolution, the charge of apples advanced by one pitch of the thread. The screw had a mean diameter of 13 mm, a thread thickness of 2 mm and pitch 4 mm. In one stroke of the piston, juice was squeezed from 3 – 5 apples, the volume of which was determined to be 1.2 x 10⁻³ m³.

Olaniyan (2010) developed the small scale orange juice extractor. While designing the machine, considerations such as high processing capacity and efficiency, quality of juice, quality, availability and cost of construction materials were considered. Other considerations included the desire to make the main components with stainless steel to ensure safety and quality of juice. To ensure maximum conveyance, crushing and pressing of raw materials adequate permutations were taken in designing the pressing chamber to accommodate the required quantity of raw materials (orange fruit) and the worm shaft. Also considered was a strong main frame to ensure structural stability and strong support for the machine.
Aviara et al. (2013) designed and developed a multi-fruit juice extractor. The engineering properties of the processed fruits that are relevant to the design, development and performance evaluation were considered. The properties include crushing strength, moisture content, size of feed, true and bulk densities. Other factors considered were strength of machine components, cost of construction, ease of operation and maintenance and energy requirement.

Olaniyan and Obajemih (2014) designed and developed a small scale mango juice extractor. Design considerations focused on the techno-economic status of the micro and small scale fruit juice processors who are the intended users of the machine. While designing the machine, considerations included high juice yield, high extraction efficiency, low extraction loss, high quality of juice and availability, quality and cost of construction materials were care of. Other considerations included the desire to make the extraction chamber and juice outlet with stainless steel to ensure the quality and safety of juice and to design the extraction chamber to accommodate the required quantity of mango fruit. Designing the screw conveyor to ensure maximum conveyance, abrasion and maceration of the mango fruit mesocarp was also considered.

2.2.2 Design of various components

Ishiwu and Oluka (2004) designed and fabricated a juice extractor. The extractor consisted of screw jack, frame, connecting screw rod, pressing mechanism, interlock, feeding pot, receiving pot and discharge mechanism.

Ogunsina and Lucas (2008) designed and developed a manually operated cashew juice extractor. The extractor consists of hopper, cylinder, power screw, turning handle, piston and endplate.

Olaniyan (2010) studied the small scale orange juice extractor. The essential components of the machine include feeding hopper, top cover, worm shaft, juice sieve, juice collector, waste outlet, transmission belt, main frame, pulleys and bearings. In operation, the worm shaft conveys, crushes, presses and squeezes the fruit to extract the juice. The juice extracted was filtered through the juice sieve into juice collector while the residual waste was discharged through waste outlet. The relationship (or) equations are used for designed various components were following.
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**Worm shaft:** The worm shaft is the conveying, crushing and pressing unit of the machine. The diameter of the shaft was determined from the equation as:

\[
d^3 = \frac{16T}{0.27 \pi \delta_0}.
\]

Where, \(d\) is the shaft diameter in m, \(T\) is the maximum torque in N-m, \(\delta_0\) is the yield stress in N/m\(^2\) and \(\pi\) is a constant.

**Machine capacity:** The theoretical capacity of the machine was calculated by the equation

\[
Q = 60 \times \frac{\pi}{4} (D^2 - d^2) \ pN\phi
\]

Where, \(Q\) is the theoretical machine capacity in m\(^3\)/h, \(D\) is the screw diameter in m, \(d\) is the shaft diameter in m, \(p\) is the screw pitch in m, \(N\) is the shaft (rotational) speed in rpm and \(\phi\) is the filling factor.

**Power requirement:** The power required to drive the machine was calculated using an equation.

\[
P = \frac{QL\rho_d g F}{3.6}
\]

Where, \(P\) is the power required to drive the machine in W, \(L\) is the shaft length in m, \(\rho_d\) is the density of orange in kg/m\(^3\), \(g\) is the acceleration due to gravity in m/s\(^2\) and \(F\) is the material (falling) factor.

The power of the electric motor to drive the system was estimated as:

\[
P_m = \frac{P}{\eta}
\]

Where, \(P_m\) is the power of electric motor in W and \(\eta\) is the efficiency of the motor in decimal.

Sylvester and Abugh (2012) designed the components of orange juice extractor. The components of the orange juice extractor broadly classified into the goblet and mechanically operated unit. The goblet consists of the components such as bearing, a bearing support, impeller shaft, a dynamic seal, small sharp blades attached
to the impeller. However, the mechanically operated unit consists of two bearings, two bearing supports, a pair of level gears, two pinions, a gear shaft and a handle. The bearings allow for free rotation of the shafts. The bearing supports hold the bearings in position and the dynamic seal prevents leakage of the juice. The relationship or equations are used for designed the various components were following.

1. Determination of shaft size on the basis of strength.

The maximum shear stress, \( \tau_{\text{max}} \) of the shaft is given by equation.

\[
\tau_{\text{max}} = \left( \frac{16}{\pi d^3} \right) \sqrt{\left( K_m M \right) + \left( K_t T \right)}
\]

Where, max, \( \tau_{\text{max}} \) is the maximum shear stress, \( d \) is the shaft diameter, \( K_m \) is the numerical combined shock and fatigue factor to be applied, \( K_t \) is the corresponding factor to be applied to the computed torques, \( M \) is the bending moment, \( T \) is torque. For this case bending moment is negligible. \( K_t \) is equal to 1.0 for rotating shaft with gradually applied loads.

\[
d = \left( \frac{16}{(\pi \tau_{\text{max}})^{\frac{3}{2}}} \right)
\]

Aviara et al. (2013) designed the multi juice extractor. It consisted of a tool frame, juice extraction encasement, screw conveying tapered shaft, perforated screen base, collection chute, gear box, and electric motor.

Olaniyan and Obajemihi (2014) designed and developed a small scale mango juice extractor. The major components of the extractor included hopper, perforated drum, screw conveyor, juice outlet, waste outlet, frame, electric motor and motor stand. Other components included screw shaft, the juice collector, top cover and the transmission system. In operation, the screw conveyor conveys and presses the mango fruits against the perforated roughened drum. The abrasion/tearing process of the screw on the flesh of the fruit and further pressing against the drum squeeze enough juice out of the fruit. The juice extracted is drained through the perforated mesh of the juice channel into the juice outlet from where it is collected while the residual waste is
collected at the waste outlet. The following equations are used for designed the components.

The power required to drive the machine during extraction operation was determined from the equation given below.

$$P_r = \frac{(D^2 - d^2) \rho g N F L}{8000}$$

where, $P_r$ is the power required to drive the machine, $\rho$ is the density of mango juice, $g$ is the acceleration due to gravity, $F$ is the material factor, $P_a$ is the average screw pitch, $D$ is the outside diameter of screw, $d$ is the inside diameter of screw, $L$ is the length of the screw shaft, and $N$ is the shaft speed.

Olabisi and Adelegan (2015) designed the citrus fruits juice extractor. The machine was made up of hopper, a cylindrical main housing, a shaft carrying well-arranged pressers, a perforated screen and an outlet. The cylindrical main housing consists of an upper and a lower chamber unit. The upper chamber consists of a shaft and two bearings while the shaft was constructed using stainless steel plate of 1.5mm thickness with the presser properly welded on it. The machine is powered by 5hp electric motor with the aid of v-belt and pulleys. The motor and shaft run at 1200rpm and 600rpm respectively for effective pressing. The equations are used for designed the various components were following.

The diameter of the shaft, $d_s$ was determined using standard procedure and equation.

$$d_s^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Where, $M_b$ is the Maximum bending moment, $M_t$ is the maximum twisting moment, $K_b$ combine shock, $K_t$ shock fatigue factor, and $S_s$ is the allowable shear stress.

Power Transmitted by Shaft.

$$T = \frac{P}{2 \pi N}$$

Where, $N$ is the number of revolution per minute, $P$ is power transmitted and $T$ is the torque.
Adanu et al. (2015) designed the orange juice extractor. The extractor consisted of the cutting chamber which is made up of rotary shaft, knives attached at both ends and an inclined tray. The squeezing chamber was made up of crankshaft, the rammer and a sieve.

Adewole et al. (2015) designed and develop a sugarcane juice extractor for small scale industries. The machine grinds the vertically loaded sugarcane stem and presses the macerated stem against the cylindrical cone to extract the juice from the wet baggasse. The machine consisted of the housing, shaft, bearings, keys, pulleys, rollers, hopper, v-belt, adjusters and gears electric motor etc.

2.3 Performance evaluation of juice extractors

Ishiwu and Oluka (2004) developed and carried out performance evaluation of a juice extractor as a function of its extraction efficiency. Performance tests revealed a juice yield, extraction efficiency and extraction loss of 76, 83 and 3%, respectively.

Kailappan et al. (2005) fabricated and evaluated a tomato seed extractor having a capacity of 180 kg of fruits/hr. With a unit cost of $190, the extractor had a seed extraction efficiency of 98.8%. Compared with manual seed extraction method, the extractor had a saving in time and saving in cost of 96.6 and 89.6%, respectively.

Kasozzi and Kasisira (2005) carried out performance of a banana juice extractor. Machine juice extraction efficiency was about 47% as compared to about 69% the extraction efficiency for the traditional manual method. However, the manual extraction time was four times that of the machine.

Abulude et al. (2007) carried out the performance evaluation of juice extractor constructed in Nigeria. The result showed that the machine produced efficiencies of 83.86% and 85.38% and extraction capacities recorded were 1.29 kg.hr$^{-1}$ and 1.23 kg.hr$^{-1}$ for orange and pineapple juices.

Olaniyan (2010) carried out performance evaluation of small scale orange juice extractor. the average juice yield and juice extraction efficiency were 41.6 and 57.4%, respectively. Powered by a 2 hp electric motor, the machine has a capacity of 14 kg.hr$^{-1}$. From the values obtained, juice yield, extraction efficiency and extraction loss were determined by using equation as:
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\[ J_Y \, (\%) = \frac{100W_{JE}}{W_{JE} + W_{RW}} \]

\[ J_E \, (\%) = \frac{100W_{JE}}{x \cdot W_{FS}} \]

\[ E_L = \frac{100[W_{FS} - (W_{JE} + W_{RW})]}{W_{FS}} \]

Where, \( J_Y \), \( J_E \), \( E_L \) are juice yield, extraction efficiency and extraction loss, respectively in%; \( W_{JE} \), \( W_{RW} \), and \( W_{FS} \) are weights of juice extracted, residual waste and feed sample respectively in g and \( x \) is the juice content of orange in decimal. Each test was carried out in triplicates.

Olaoye (2011) carried out performance evaluation of sugarcane juice extractor for small scale industries. The output capacity ranges between 5.32 kg.hr\(^{-1}\) and 12.75 kg.hr\(^{-1}\). At operating speed of 0.36 m.s\(^{-1}\) about 12.75 kg can be extracted in 1 hour. At high operating speed, higher energy is developed resulting in effective maceration and crushing of cane stalk to release more cane juice. The various sizes of cane stalks the extraction of juice followed the same trend of increase of juice extraction at higher peripheral speed while higher juice was recovered with an increase in cane stalk. The machine efficiency increased with an increase in peripheral speed. The juice extractor operated at 60 % of cane juice extraction at operating peripheral speed of 0.36 m/s and the machine developed higher energy that was sufficient to cause effective crushing and extraction of cane juice. Result indicated that low extraction efficiency of 41 % is experienced at low operating peripheral speed of 0.25 m/s.

The output capacity and extraction efficiency of the extractor were evaluated using following equations.

\[ C_0 = \frac{W_j}{T} \]

Where,

\( C_0 = \) Output Capacity (kg.hr\(^{-1}\))
\( W_j = \) Weight of juice extracted (kg)
\( T = \) Total time taken for extraction (hr)

\[ J_i = \frac{W_{M_{cwib}}}{100} \]

Where,
\[ J_p = W - W_d = \text{Juice present (kg)} \]
\[ W = \text{Weight of wet sample (kg)} \]
\[ W_d = \text{Weight of dry sample (kg)} \]
\[ M_{cwb} = \text{Moisture content wet basis} \]
\[ E_{ef} = \frac{W_j}{J_p} \times 100 \]

Where,
\[ E_{ef} = \text{Extraction Efficiency (\%)} \]
\[ W_j = \text{Weight of juice extracted (g)} \]

Olaniyan and Babatunde (2012) developed a small scale sugarcane juice extractor using a screw pressing system and the result of a preliminary test showed a low juice yield of 2.5\% with a grating efficiency of 87.8\%.

Aviara et al. (2013) evaluated performance of a multi-fruit juice extractor. Results of performance analysis showed that type of fruit and peel condition significantly influenced the performance indices at 1 \% level of significance. Percentage juice yield for peeled and unpeeled pineapple, orange and water melon was 79.1 and 68.7 \%, 77 and 69.2 \%, and 89.5 and 89.7 \% respectively. Extraction efficiency was respectively 96.9 \%, 94.3\%, and 96.6 \% for peeled pineapple, oranges and water melon, and their respective unpeeled value was 83.6 \%, 84.2 \%, and 97.1 \%. The extraction loss of peeled and unpeeled fruits was respectively 2.1 and 2.7 \% (pineapple), 2.1 and 2.5 \% (orange), and 2.9 and 2.6 \% (water melon).

Adebayo et al. (2014) carried out performance evaluation of a portable motorized pineapple juice extractor. The two operating factors used for evaluating this machine are extraction speed (S) at three levels (i.e. \( S_1=565 \) rpm, \( S_2=478 \) rpm and \( S_3=380 \) rpm) and feed rate (F) at three levels (i.e. \( F_1=0.5 \) kg.min\(^{-1}\), \( F_2=1.0 \) kg.min\(^{-1}\) and \( F_3=1.5 \) kg.min\(^{-1}\)). Each of these factors was replicated thrice, which resulted into 3x3x3 factorial experimental design. In addition, the performance parameters used for evaluating this prototype are the extraction efficiency (\%), extraction losses (\%) and extraction capacity (lit.hr\(^{-1}\)). The performance evaluation results obtained from this experimental design shows an optimum juice extraction efficiency=87.50\%, juice extraction capacity=26.70 lit.hr\(^{-1}\) with juice extraction losses=12.50\% at \( S_3F_2 \) operating factors (i.e. \( S_3=380 \) rpm and \( F_2=1.0 \) kg/min). The optimum output of this
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prototype was compared with that of manual extraction method which was evaluated
to have manual juice extraction efficiency=97.00%, manual juice extraction capacity
=5.25 lit.hr\(^{-1}\) and manual juice extraction losses=3.08%. Hence, this prototype was
rated to be five times faster than human method of extracting juice from fruits.
The various evaluation expressions used for estimating the performance of this
prototype are stated as follows:

1) Juice extraction efficiency \((E_f)\)

\[
E_f = \frac{m_j}{m_j + m_{jp}} \times 100\%
\]

2) Juice extraction losses \((E_l)\)

\[
E_l = \frac{m_{jp}}{m_j + m_{jp}} \times 100\%
\]

3) Juice extraction capacity \((C_{Ex})\)

\[
C_{Ex} = \frac{V_j}{T} \text{ (lit/hr)}
\]

Where,

\(m_j\) = mass of juice extracted from the fruit materials (kg)
\(m_{jp}\) = mass of juice extracted from the fruit pulp (kg)
\(V_j\) = volume of the juice extracted from the fruit material (lit)
\(T\) = juice extraction time (hr)

Olaniyan and Obajemihi (2014) designed and developed a small scale mango
juice extractor. The machine was tested using freshly harvested mango fruits and
results obtained showed an average juice yield, extraction efficiency and extraction
loss of 34.56%, 55.14% and 10.15%, respectively. These values of juice yield,
extraction efficiency and low level of extraction loss indicate satisfactory performance
of the machine. Powered by a 2.5 hp single-phase electric motor.
Ogblechi and Ige (2014) carried out performance evaluation of a mechanical extractor for date palm fruit juice. The equipment has a capacity of 250 kg fruit/hr with an extraction efficiency of 95%.

Extraction efficiency of the machine was found from the following relationship.

\[
\text{Extraction efficiency} = \frac{\text{quantity of juice extracted (g)}}{\text{maximum mass of juice extractable (g)}}
\]

Quantity of juice extracted = mass of fruit processed – mass of residual cake after oven drying.

Olabisi and Adelegan (2015) evaluated the performance evaluation of citrus fruits’ juice extractor. The fabricated juice extractor has extraction efficiencies of 84%, 87% and 89% for orange, tangerine and lime respectively. In addition, the machine was allowed to run for six hours per day and it was able to extract juice from an average of 3.36, 10.85 and 10.47 tonnes of orange, tangerine and lime respectively.

Adewole et al. (2015) carried out performance evaluation of development of a sugarcane juice extractor for small scale industries. The performance tests carried out on the developed machine showed an efficiency of 65%. The efficiency of the machine was not as high as expected. This is due to the fact that the single set of roller arrangement cannot effectively extract the juice in one pass. In standard sugar mills, the effective extraction of the juice is done by sets of rollers. This ensures a higher efficiency. The extraction efficiency of the machine ranged between 40 and 61% at operating speeds of 0.25 and 0.36 m.s\(^{-1}\). It was observed that this optimum performance of the machine cannot be sustained over a long processing period due to the bluntness development of the perforated grating drum over time. However, conditions that enhanced in maximum operating performance were enumerated.

Adanu et al. (2015) carried out performance evaluation of development of orange juice extractor. The machine performance evaluation was carried out using tangelo and Tiv orange varieties. The actual efficiency of the machine was found to be 76.04% with a capacity of 6 lit.hr\(^{-1}\) (5.73 kg.hr\(^{-1}\)). It was concluded that efficient Juice extraction would be better achieved with the use of this kind of machine than with a turning screw.
Onu and Simonya (2015) performance evaluation of a motorized ginger juice expression machine. The performance of a developed motorized ginger juice expression machine was evaluated to determine the effects of moisture content of ginger and screw shaft speed on the expression efficiency, juice yield, expression loss and throughput capacity. Three levels of moisture content (84, 79 and 72%) (Wet basis) and three levels of screw shaft speed (420, 472 and 660 rpm) at two replications were used for the study. The result showed that mean expression efficiency decreased with increase in screw shaft speed and with decrease in moisture content for the speed and moisture content range studied. The highest expression efficiency of 91.62% and juice yield of 61.28% were obtained at screw shaft speed of 420 rpm and at 72% moisture content (wb). The mean juice yield decreased with an increase in screw shaft speed and with a decrease in moisture content of ginger considered. The lowest expression loss of 11.69% was obtained at 472 rpm and 72% moisture content. The machine had highest throughput capacity of 9.47 kg.hr$^{-1}$ at 420 rpm.

2.4 Quality assessment of juice

Vahid et al. (2009) evaluated the chemical properties of pomegranate juice. Reducing sugars ranged between 13.89 to 29.83 g/100 ml, total soluble solids ranged from 15.17 to 22.03 (°Brix) and titratable acidity ranged between 0.35% and 3.36% in pomegranate juices. pH and vitamin C content also ranged between 2.75-4.14 and 9.68-17.45 mg/100 ml, respectively.

Tasnim et al. (2010) studied the quality assessment of industrially processed fruit juices. The highest quantity of total sugar (17.62%) and reducing sugar (9.99%) was recorded in mango juices while the lowest in orange juices (10.41% and 2.24% respectively) of different companies. In this study, protein contents were comparatively higher in mango juices than in orange juices. The pH of all samples varied from 3.50±0.10 to 4.70±0.05. Vitamin C content was comparatively higher in mango juices.

Usman et al. (2015) studied the quality assessment of the mango-mandarin (kinnow) squash during storage. Results showed that mango-mandarin squash contains pH (3.88-3.26), acidity (1.66-1.24 %), total sugars (45.33-42 %) and total soluble solids (47.67- 44.00 °B).