



Model Selection Using Juice Extraction Efficiency for Optimization of a Newly Developed Juice Machine Performance

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Abstract

Model selection for optimization of performance of the juice extractor has been carried out using +juice extraction efficiency and extraction capacity for a newly developed juice machine. The quadratic model was chosen to predict the EE and EC. It was ascertained that extraction processing parameters influence the EE and EC. The study revealed that the highest juice extraction efficiency of 83.66% was obtained at the machine operating speed of 400 rpm, feed rate of 1.5 kg/min, blanching temperature of 80°C and blanching time of 6 min, while the lowest juice extraction efficiency of 31.63% was obtained at the machine operating speed of 300 rpm, feed rate of 1.0 kg/min, blanching temperature of 20°C and blanching time of 3 min. Also, the highest extraction capacity of 3.89 L/min was obtained at the machine operating speed of 500 rpm, feed rate of 1.0 kg/min, blanching temperature of 60°C and blanching time of 9 min, while the lowest extraction capacity of 0.26 L/min was obtained at the machine operating speed of 200 rpm, feed rate of 1.5 kg/min, blanching temperature of 40°C and blanching time of 6 min. Considering the model with the highest R^2 value and lower standard deviation, quadratic model was selected to predict the percentage juice extraction efficiency and juice extraction capacity using the developed fruit juice extractor. It was observed that all the juice extraction process parameters have direct relationship with EE and EC. This implies that both EE and EC exhibited an increase with increase in the extraction process parameters. Feed rate was found to be the most significant parameter which affects EE and EC. The Model F-values of 3.60 and 3.41, implies that the model is significant. This model can be used to navigate the design space. The model was significant with a very low probability value (0.0095) and a satisfactory coefficient of determination ($R^2 = 0.77$). The high coefficient of determination showed excellent correlations between the independent variables (dehydration parameters). This value indicates that the response (extraction efficiency) model can explain 77% of the total variability in the response. Predicted optimum EE and EC of 81.32% and 3.89 L/min respectively at operating speed of 525.23 rpm, feed rate of 2.13 kg/min, blanching temperature of 54.20°C and blanching time of 8.73 min was obtained with a desirability of 0.977. Under these optimal juice extraction process conditions, the experimental values of 81.56% and 3.57 L/min were obtained for EE and EC respectively. The deviations between experimental and predicted values were low and statistically insignificant. The coefficient of determination (R^2) of 0.77 and 0.76 for EE and EC respectively, show that there is an excellent correlation between the juice extraction parameters (independent variables). Consequently, in view of the range of variables investigated, the chosen models have the adequacy to predict the extraction efficiency and extraction capacity for fruit juice using the developed machine. The developed fruit juice extraction machine serves as a viable option for the small-scale fruit juice processors.

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1. Introduction

A juicer, generally called juice extractor or juicing machine, is a device used in the extraction of juice from various fruits, vegetables, leafy greens or herbs. It separates the juice from the pulp by grinding, crushing or squeezing. They can be manually or mechanically operated and, of course, it affects the productiveness of the device (Jackson, 1988; Morozova 2011; Crocker, 2016) ^[8, 11, 18]. Mechanized juice extractor can save time during processing, improve efficiency, increase capacity, and reduce spoilage and waste faced by small scale farmers. Bhatia (1989) ^[4] listed the important steps in fruit juice processing process to include selection, extraction, de-aeration, filtration, preservation and packaging. To achieve this, researchers have developed

mechanized machines for extracting juice from fruits (Olowonibi and Ozumba, 1999; Bites, Morris and Grand, 2001; Ishiwu and Oluka, 2005; Badmus and Adeyemi, 2006) [6, 9, 24]. Majority of the juice extractors are for medium and large-scale fruit juice extraction.

In another study, Jain and Khurdiya, (2002) [14] used different extraction methods in processing of fruit juice. These methods include the pre-treatment of aonla fruit, juice yield, and juice extraction techniques. The pre-treatment was done with- and without blanching at temperature of 100 °C for 6 min, while the juice yield technique was carried out with- and without water at water/fruit ratio of 1:1. The methods employed in the juice extraction technique were (1) crushing of whole fruits in apple grater and pressing in hydraulic press, (2) crushing of fruit segments after seed removal in apple grater and pressing in hydraulic press, and (3) seed removal and juice extraction through centrifugal juice extractor. The study showed an improved juice yield and 12 % reduction in vitamin C for blanching of fruit at 100 °C for 6 min prior to extraction as compared to juice extracted from unblanched fruits at same temperature and extraction time. Centrifugal juice extraction from blanched fruits without addition of water resulted in higher soluble constituents, high vitamin C contents and a juice yield of 47.8 %.

The work of Oyeleke and Olaniyan, (2007) [28] employed a multi-fruit juice extractor in the processing of fruit juices made from orange, grape, tangerine, water melon and pineapple. The fruit slices were processed by the extractor at 1.5 kg per batch. For slice of 2 cm² sized cut fruits, maximum juice yield of the processed orange was found to be 76 % and 83.30 % for grape. The obtained maximum juice yield values for tangerine, water melon, and pineapple were 82.75%, 96 %, and 71.40 % respectively. Machine extraction efficiency obtained for slice of 2 cm² sized cut fruits of orange, tangerine, water melon, and pineapple were 86.30, 95.20, 94.10, 98.00 and 81.30 % with corresponding extraction losses of 3.30, 20, 3.30, 10 and 6.70 %, respectively. The juice extracted from orange, grape, tangerine, water melon and pineapple had ascorbic acid content of 7.71, 7.08, 27.02, 6.20, and 11.52 mg/100 ml, respectively with pH values of 3.66, 3.23, 4.21, 4 and 4.07 respectively (Jafari *et al.*, 2014) [13].

Trappey, Johnson and Wilson (2008) [33] studied juice extraction methods for fresh mayhaw (*Crataegus opaca Hook*) fruit. The parameters evaluated were percent juice yield, pH, °Bx, titratable acidity (TA), sugar/acid ratio, sugar and organic acid contents and colour of extracted juices. Methods studied were steam extraction using whole fruit with added pulp juice (SEP) or without added pulp juice (SE), cold-press extraction using whole fruit (CPE) or finely ground fruit (CPEG), hot-press extraction using finely

macerated fruit pulp (HPEG), and hot-press extraction in combination with a pectolytic enzyme pretreatment (ENZ). SEP gave highest yield (70.3 %). SEP produced juice with lowest amount of total sugars. The lowest TA value was for SE at 0.51 % and highest for HPEG at 1.28 %. The lowest pH values were for CPE at 2.97 and highest pH value at 1.13 for SE. Cold extraction methods yielded juices with more intense redness and yellowness than did steam extraction (Kasoli and Kasirara 2005; Lefteri, 2007; Milton and Rogers, 2011) [15, 16, 17].

The work of Parihar *et al.* (2009) [29] studied the effect of various extraction processes such as cold extraction, hot extraction, and enzymatic treatment on the juice yield of bael (*Aegle marmelos correa*) fruit. For enzymatic treatment, pectinase enzymes of different concentrations were employed. The results showed that high juice yield of 81 % was obtained through use of enzymatic treatment. The enzymatic method of juice extraction recorded the highest TSS, acidity, vitamin C, colour and overall acceptability of juice at ambient temperature.

The performance of a developed fruit juice extraction machine is normally tested for the juice extraction efficiency and extraction capacity. Optimal performance is expected of every developed machine and there are several optimization models for optimization of machine performance. Quadratic models can be used for predicting the extraction efficiency and extraction capacity of newly developed machines. Previous work has shown that extraction processing parameters are influenced by the extraction efficiency and extraction capacity (Oguntuyi 2013; Olabisi and Adelegun 2015; Bawa, 2025) [5, 19, 21].

In this present work the objective of the work is to carry out model selection using juice extraction efficiency for optimization of a newly developed juice machine. For improved performance these models can be used to predict extraction efficiency and extraction capacity.

2. Materials and Method

2.1. Materials

The materials used in this work include the results of performance test of the motorized juice extractor, data generated during the testing of the machine, computer, and computer software.

- **Description of the fruit Juice Extractor**

The juice extractor was designed to work on the principle of compression and squeezing due to the gradual reduction of clearance between conveyor housing and screw conveyor. It is made up of five units, namely main frame, feed hopper, juice extraction unit, collecting unit, and power and transmission unit (Figure 2).

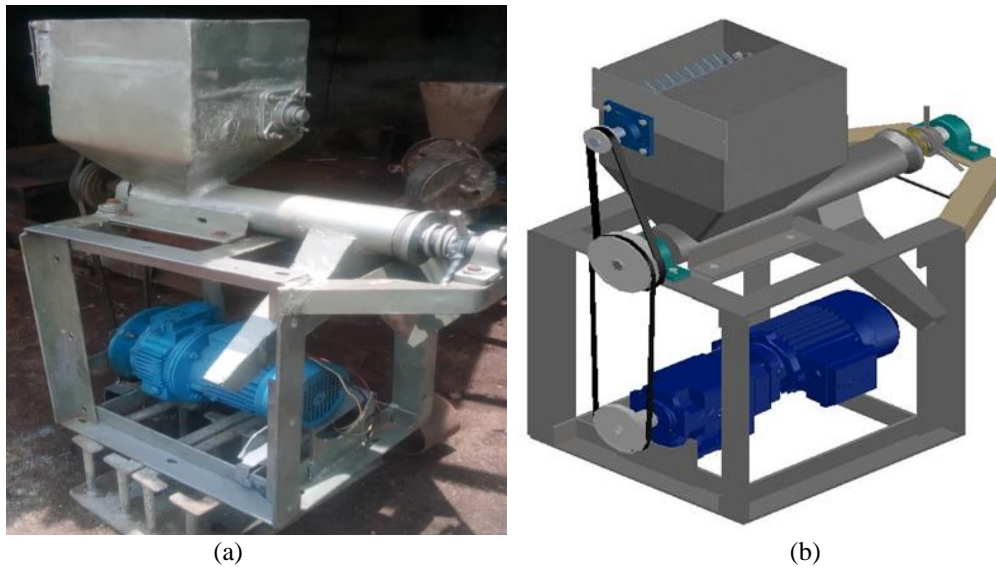


Fig 1: Photograph and, (b) 3D photo-rendering of the fruit juice Extraction Machine

- **Main frame:** The main frame was made up of low carbon steel having an angle cross-section. The tool frames were form the supports and holds the machine components, and gives it a compact design and a sturdy outlook (Figure 2.1).
- **Hopper:** The feed hopper, which was mounted on top of the juice extraction barrel, is a composite of rectangular and trapezoidal shape and inclined at an angle that enabled mass flow of feed into the extraction chamber to be achieved. It was made with cut-out stainless steel sheet of 1.5 mm thickness. Also embedded in the hopper unit is the shredder, which functions to reduce the size of the whole fruit introduced into the hopper (Figure 2.1).
- **Juice extraction unit:** Below the feed hopper base and mounted on the tool frame, is the barrel like juice extraction unit that formed a conveyor housing where juice extraction takes place. Through this housing runs a shaft tapered from one end to the other end and rolled round it is a tapered screw. The shaft and screw assembly known as screw conveyor receives power through the geared motor and runs in a journal bearing. The screw on the conveyor is on the shaft and tapered at the feed entry point to the discharge end. The screw conveyor and housing provide the shear and compressive forces needed to crush the fruit and squeeze out the juice.
- **Collecting unit:** At the bottom of the extraction chamber, is a perforated concave screen made of stainless steel. It permits the juice extracted from the fruit to be filtered from the crushed fibre. The filtered juice drops on an inclined juice collection channel and flows down through the collection chute into the juice collector. The waste discharge chute is located at the end of the extraction run (Figure 2.1).
- **Power and transmission unit:** The power unit consist of a 2 Hp variable geared electric motor which powers the machine via a belt and pulleys and gear box arrangement. The motor is mounted on a seating located at the base of the main frame (Figure 2.1). The shredder is powered through a dual-groove pulley and V-belt from the machine shaft.

2.2. Performance Test of the Machine

Performance testing and evolution were performed on the fabricated motorized fruit juice extraction machine at completion of the construction. The tests were carried out at the designed operation speed of 525.23 rpm. However, the tests were carried out so as to determine the following:

1. The rate of extraction and capacity of machine.
2. Possible leakage in the fabricated machine.
3. Hours or minute per hour the machine can operate.
4. The percentage and the efficiency of the machine.
5. Number of hours, the operator or engineer can operate on it, in order to know the accurate time to dismantle the conveyor or conical restriction section.

The machine performance test was carried out by pouring a known mass of orange fruit into the hopper. The power source was switch on to run the electric motor, which in turn powers the machine. The orange fruit in the hopper were then delivered in to the extraction chamber and the machine was allowed to operate until the material was completely fed and extracted. After that, mass of fruit fed into the machine, mass of juice extracted, mass of residual waste and juice constant of the fruit in decimal were recorded. The juice constant was obtained from the ratio of sum of masses of juice extracted and juice in chaff to the mass of fruit fed in. The mass of juice in chaff was determined using the method of ASAE (1983) as applied by Aviara *et al.* (2008) ^[1], and Oje (1993) ^[20]. This involved oven drying the chaff at 130°C until a constant weight was reached. Each experiment was replicated three times for the peeled oranges.

The performance evaluation of the juice extractor was carried out on the basis of the following indices used by Tressler and Joslyn (1961) ^[35]:

$$\text{Juice yield, } J_y = \frac{100 \times W_{JE}}{W_{JE} + W_{RW}} \% \quad (1)$$

$$\text{Extraction Efficiency, } EE = \frac{100 \times W_{JE}}{xW_{FS}} \% \quad (2)$$

$$\text{Extraction loss, } El \% = \frac{100 [W_{FS} - (W_{JE} + W_{RW})]}{W_{FS}} \% \quad (3)$$

Where W_{RW} = Residual waste/dry chaff (kg), EE = Extraction Efficiency, %; W_{JE} = mass of juice extracted, g; W_{FS} = mass of feed sample, g; x = juice constant of fruit, decimal

$$\text{Extraction Capacity, } EC = \frac{V_J}{T} \tag{4}$$

Where EC = Extraction Capacity, L/min.; V_J = volume of juice extracted from fruit material, litre; T = juice extraction time, min.

2.3. Model Selection for Optimization of Performance of the Juice Extractor

In the selection of a suitable model for the extraction efficiency and extraction capacity, the highest order polynomial where the additional terms are significant and the model is not aliased, insignificant lack-of-fit and the maximization of the ‘‘Adjusted R²’’ and the ‘‘Predicted R²’’ were considered. The cubic model is aliased and cannot be selected; and in terms of higher coefficient of determination (R²) and lower standard deviation values (Olaniyan 2009; Oladejo and Ma, 2016; Umami *et al.*, 2019) [23, 26, 36]. A Design Expert (version 6.0.6) software package for design of experiments was used to analyze and generate model equations for juice extraction efficiency (JEE) and extraction capacity (EC). Four different models namely linear, two factorial interactions (2FI), quadratic, and cubic were used to analyze the responses and the models were fitted to the experimental data using Design Expert software. The final regression model for juice extraction efficiency (EE) is given in Equation 6 as:

$$EE = -73.81 + 0.36O_S + 15.39F_R + 0.76B_T + 4.48B_t - 4.49 \times 10^{-4}O_S^2 - 8.16F_R^2 - 9.86 \times 10^{-3}B_T^2 - 0.33B_t^2 + 0.04O_SF_R - 2.18 \times 10^{-4}O_SB_T + 4.16 \times 10^{-3}O_SB_t + 0.11F_RB_T - 0.49F_RB_t + 9.95 \times 10^{-3}B_TB_t \tag{6}$$

Where EE = Extraction efficiency, %; O_S = Operating speed, rpm; F_R = Feed rate, kg/min; B_T = Blanching temperature, °C; B_t = Blanching time, min.

While the final regression model for juice extraction capacity (EC) is given in Equation 7 as:

$$EC = -9.65 + 0.03O_S + 3.30F_R + 0.01B_T + 0.48B_t - 3.65 \times 10^{-5}O_S^2 - 1.30F_R^2 - 5.07 \times 10^{-4}B_T^2 - 0.04B_t^2 + 3.53 \times 10^{-3}O_SF_R - 2.25 \times 10^{-5}O_SB_T + 1.92 \times 10^{-4}O_SB_t + 0.01F_RB_T - 0.08F_RB_t + 4.27 \times 10^{-3}B_TB_t \tag{7}$$

Where EC = Extraction capacity, kg/min ; O_S = Operating speed, rpm; F_R = Feed rate, kg/min; B_T = Blanching temperature, °C; B_t = Blanching time, min.

2.4. Optimization and Verification of the model

The dependent extraction variables (extraction efficiency and extraction capacity) were optimized based on the 3D surface plots and regression analysis of the independent variables (Operating speed, feed rate, blanching temperature and blanching time). This was done with the aim of obtaining the maximum juice extraction efficiency (EE) and maximum extraction capacity (EC) using Design-Expert software. Predictive models were used to graphically represent the systems. Response surface and ramp for optimization plots of the response variables were utilized to select optimum combinations of operating speed, feed rate, blanching temperature and blanching time for the extraction of fruit juice from the pulp.

The statistical models were validated with respect to the dependent variables within the design space. The experimental results obtained were compared statistically with the predicted values in order to determine the models’ validity using parity plots.

The criteria variables were set such that the independent variables (operating speed, feed rate, blanching temperature and blanching time) would be within a range or minimum from an economical point of view (Olaniyan 2010; Jain *et al.*, 2011) [12, 22]. The main criteria for constraints optimization were maximum possible extraction efficiency and extraction capacity. The desired goals for each process parameter and response is shown in Tables 2.1. In order to optimize the process parameters for the juice extraction process by numerical optimization which finds a point that maximize the desirability function; equal importance of ‘3’ was given to all the four extraction process parameters and the responses (EE and EC).

Table 1: Criteria and output for numerical optimization of extraction process parameters for the performance analysis of the juice extraction

Extraction criteria	Unit	Lower limit	Upper limit	Optimization Goal	Relative Importance
Operating Speed	rpm	200	600	Range	3
Feed rate	kg/min.	0.5	2.5	Range	3
Blanching Temperature	°C	0	80	Range	3
Blanching Time	min	0	12	Range	3
Extraction Efficiency (EE)	%	32.63	83.66	Maximize	3
Extraction Capacity (EC)	L/min	0.08	3.89	Maximize	3

The ramp of the optimization process is shown in Figure 2.2 with optimal extraction process factors operating speed of

525.23 rpm, feed rate of 2.13 kg/min, blanching temperature of 54.20°C and blanching time of 8.73 min.

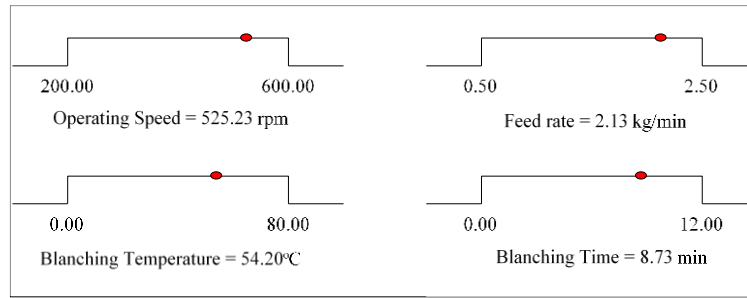


Fig 2: Ramp for optimization of juice extraction process conditions for extraction efficiency and extraction capacity

3. Results and Discussion

3.1. Results

3.1.1. Juice Extraction Machine Performance Analysis

Table 3.1 depicts the average summary of the juice extraction

efficiency and juice extraction capacity at various extraction process condition combinations using 4 factors, 5 levels, factorial Central Composite Rotatable Design (CCRD) of Response Surface Methodology (RSM).

Table 2: Juice extraction efficiency and Extraction capacity at different processing condition combinations

Run	OS (rpm)	FR (kg/min)	BT (°C)	Bt (min)	JEE (%)	JEC (L/min)
1	400.00	1.50	40.00	0.00	41.60	0.28
2	300.00	1.00	20.00	3.00	31.63	1.25
3	500.00	1.00	20.00	3.00	55.31	1.82
4	300.00	2.00	20.00	3.00	46.00	0.97
5	500.00	2.00	20.00	3.00	72.37	3.55
6	300.00	1.00	60.00	3.00	41.31	0.08
7	500.00	1.00	60.00	3.00	57.71	1.55
8	300.00	2.00	60.00	3.00	53.94	1.07
9	500.00	2.00	60.00	3.00	74.74	3.11
10	400.00	1.50	0.00	6.00	40.66	0.95
11	400.00	0.50	40.00	6.00	49.89	0.76
12	200.00	1.50	40.00	6.00	39.09	0.26
13	400.00	1.50	40.00	6.00	69.54	2.58
14	400.00	1.50	40.00	6.00	68.83	2.73
15	400.00	1.50	40.00	6.00	68.80	2.63
16	400.00	1.50	40.00	6.00	69.14	3.83
17	400.00	1.50	40.00	6.00	69.26	3.48
18	400.00	1.50	40.00	6.00	69.43	3.26
19	600.00	1.50	40.00	6.00	49.34	1.42
20	400.00	2.50	40.00	6.00	58.11	2.24
21	400.00	1.50	80.00	6.00	83.66	2.53
22	300.00	1.00	20.00	9.00	46.63	1.21
23	500.00	1.00	20.00	9.00	66.46	3.00
24	300.00	2.00	20.00	9.00	48.57	1.13
25	500.00	2.00	20.00	9.00	79.40	3.67
26	300.00	1.00	60.00	9.00	49.14	1.52
27	500.00	1.00	60.00	9.00	70.14	3.89
28	300.00	2.00	60.00	9.00	59.09	2.52
29	500.00	2.00	60.00	9.00	52.09	3.40
30	400.00	1.50	40.00	12.00	67.60	2.02

3.1.2. Model Selection for Optimization of Machine Performance Using Juice Extraction Efficiency

The comparison of four models (linear, 2FI, quadratic and cubic) for juice extraction efficiency during the performance

analysis the juice extractor is shown in Tables (3.2 – 3.3) and Table 3.4 depicts percent diagnostics case statistics for juice extraction efficiency.

Table 3: Model comparison for juice extraction efficiency

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	9.56	10.65	8.85	9.18
Mean	58.38	58.38	58.38	58.38
C.V.	16.38	18.25	15.15	15.37
PRESS	3227.47	3891.35	6757.75	84955.00
R ²	0.5534	0.5785	0.7707	0.8846
Adjusted R ²	0.4819	0.3567	0.5566	0.5220
Predicted R ²	0.3693	0.2396	-0.3205	-15.6009
Adequate precision	10.295	6.228	7.104	5.238

Table 4: ANOVA for response surface quadratic model for juice extraction efficiency

Source of Variation	Sum of Squares	Df	Mean Square	F-value	Prob > F
<i>Model</i>	3943.92	14	281.71	3.60	0.0095*
<i>A</i>	1552.20	1	1552.20	19.84	0.0005*
<i>B</i>	458.59	1	458.59	5.86	0.0286*
<i>C</i>	127.19	1	127.19	1.63	0.2217
<i>D</i>	693.91	1	693.91	8.87	0.0094*
<i>A</i> ²	551.81	1	551.81	7.05	0.0180*
<i>B</i> ²	114.04	1	114.04	1.46	0.2460
<i>C</i> ²	426.94	1	426.94	5.46	0.0338*
<i>D</i> ²	248.56	1	248.56	3.18	0.0949
<i>AB</i>	66.54	1	66.54	0.85	0.3710
<i>AC</i>	3.04	1	3.04	0.039	0.8465
<i>AD</i>	24.88	1	24.88	0.32	0.5812
<i>BC</i>	19.78	1	19.78	0.25	0.6224
<i>BD</i>	8.66	1	8.66	0.11	0.7440
<i>CD</i>	5.70	1	5.70	0.073	0.7909
<i>Residual</i>	1173.57	15	78.24		
<i>Lack of Fit</i>	1173.10	10	117.31	1258.87	< 0.0001*
<i>Pure Error</i>	0.47	5	0.093		
<i>Cor Total</i>	5117.49	29			

A represents operating speed
 B represents feed rate
 C represents blanching temperature
 D represents blanching time.
 *Significant.

Table 5: Diagnostics Case Statistics for juice extraction efficiency (%)

Standard Order	Actual Value	Predicted Value	Residual	Leverage	Student Residual	Cook's Distance	Outlier t	Run Order
1	59.09	57.82	1.270	0.583	0.223	0.005	0.216	28
2	69.26	69.17	0.093	0.167	0.012	0.000	0.011	17
3	40.66	48.78	-8.120	0.583	-1.422	0.189	-1.477	10
4	39.09	35.14	3.950	0.583	0.692	0.045	0.679	12
5	53.94	49.83	4.110	0.583	0.719	0.048	0.707	8
6	46.63	47.96	-1.330	0.583	-0.232	0.005	-0.225	22
7	41.31	41.48	-0.170	0.583	-0.029	0.000	-0.028	6
8	70.14	66.03	4.110	0.583	0.720	0.048	0.708	27
9	57.71	50.12	7.590	0.583	1.330	0.165	1.368	7
10	42.60	39.42	3.180	0.583	0.557	0.029	0.544	2
11	58.11	69.75	-11.640	0.583	-2.039	0.388	-2.317	20
12	67.60	67.88	-0.280	0.583	-0.049	0.000	-0.047	30
13	49.34	67.31	-17.970	0.583	-3.147	0.924	*	19
14	69.14	69.17	-0.027	0.167	-0.003	0.000	-0.003	16
15	48.57	48.92	-0.350	0.583	-0.062	0.000	-0.060	24
16	66.46	63.33	3.130	0.583	0.549	0.028	0.536	23
17	49.14	52.40	-3.260	0.583	-0.571	0.030	-0.558	26
18	79.40	72.45	6.950	0.583	1.217	0.138	1.238	25
19	68.83	69.17	-0.340	0.167	-0.042	0.000	-0.040	14
20	69.54	69.17	0.370	0.167	0.046	0.000	0.045	13
21	83.66	79.60	4.060	0.583	0.711	0.047	0.698	29
22	74.74	66.63	8.110	0.583	1.420	0.188	1.475	9
23	55.31	49.80	5.510	0.583	0.965	0.087	0.963	3
24	49.89	52.27	-2.380	0.583	-0.416	0.016	-0.405	11
25	72.37	61.87	10.500	0.583	1.839	0.316	2.019	5
26	46.00	43.33	2.670	0.583	0.468	0.020	0.455	4
27	32.63	46.37	-13.740	0.583	-2.407	0.541	-2.968	1
28	52.09	57.99	-5.900	0.583	-1.033	0.100	-1.036	21
29	68.80	69.17	-0.370	0.167	-0.045	0.000	-0.044	15
30	69.43	69.17	0.260	0.167	0.033	0.000	0.032	18

* Case(s) with |Outlier T| > 3.50

3.1.3 Model Selection for Optimization of Machine Performance Using Juice Extraction Capacity

The comparison of four models (linear, 2FI, quadratic and cubic) for the extraction capacity during the performance

analysis of the juice extractor is shown in Tables (3.4 – 3.5) and Table 3.6 depicts percent diagnostics case statistics for juice extraction capacity.

Table 6: Analysis of Variance for extraction capacity

Source Model	Sum of Square	DF	Mean Square	F Val	Prob >F
A	18.37	1	18.37	30.79	< 0.0001
B	2.86	1	2.86	4.79	0.0382
C	18.62	1	18.62	31.21	< 0.0001
D	0.20	1	0.20	0.33	0.5697
Residual	14.92	25	0.60		
Lack of Fit	14.86	20	0.74	63.25	0.0001
Pure Error	0.059	5	0.012		
Cor Total	54.97	29			

Table 7: ANOVA for response surface quadratic model for juice extraction capacity

Source of Variation	Sum of Squares	Df	Mean Square	F-value	Prob > F
Model	29.420	14	2.100	3.41	0.0122*
A	10.090	1	10.090	16.37	0.0011*
B	4.180	1	4.180	6.79	0.0199*
C	0.570	1	0.570	0.93	0.3512
D	4.520	1	4.520	7.34	0.0161*
A ²	3.660	1	3.660	5.94	0.0277*
B ²	2.880	1	2.880	4.68	0.0471*
C ²	1.130	1	1.130	1.83	0.1958
D ²	3.370	1	3.370	5.47	0.0337*
AB	0.500	1	0.500	0.81	0.3833
AC	0.032	1	0.032	0.053	0.8217
AD	0.053	1	0.053	0.086	0.7735
BC	0.250	1	0.250	0.41	0.5337
BD	0.230	1	0.230	0.37	0.5500
CD	1.050	1	1.050	1.71	0.2113
Residual	9.240	15	0.620		
Lack of Fit	7.910	10	0.790	2.98	0.1202
Pure Error	1.330	5	0.270		
Cor Total	38.660	29			

A represents operating speed; B represents feed rate; C represents blanching temperature; D represents blanching time. *Significant

Table 8: Diagnostics Case Statistics for juice extraction capacity (L/min)

Standard Order	Actual Value	Predicted Value	Residual	Leverage	Student Residual	Cook's Distance	Outlier t	Run Order
1	2.52	2.27	0.250	0.583	0.489	0.022	0.477	28
2	3.48	3.09	0.390	0.167	0.551	0.004	0.538	17
3	0.95	1.97	-1.020	0.583	-2.003	0.375	-2.261	10
4	0.76	0.33	0.430	0.583	0.855	0.068	0.847	12
5	1.07	1.25	-0.180	0.583	-0.348	0.011	-0.337	8
6	1.21	1.12	0.091	0.583	0.180	0.003	0.174	22
7	0.08	0.27	-0.190	0.583	-0.382	0.014	-0.371	6
8	3.40	2.75	0.650	0.583	1.285	0.154	1.316	27
9	1.55	1.01	0.540	0.583	1.060	0.105	1.065	7
10	1.25	0.64	0.610	0.583	1.208	0.136	1.228	2
11	2.24	2.62	-0.380	0.583	-0.757	0.053	-0.745	20
12	2.02	2.55	-0.530	0.583	-1.049	0.103	-1.053	30
13	1.42	2.92	-1.500	0.583	-2.960	0.818	*	19
14	3.83	3.09	0.740	0.167	1.040	0.014	1.043	16
15	1.13	1.11	0.019	0.583	0.037	0.000	0.036	24
16	3.00	2.27	0.730	0.583	1.445	0.195	1.505	23
17	1.52	1.78	-0.260	0.583	-0.512	0.024	-0.499	26
18	3.67	2.97	0.700	0.583	1.391	0.180	1.439	25
19	2.73	3.09	-0.360	0.167	-0.495	0.003	-0.483	14
20	2.58	3.09	-0.510	0.167	-0.705	0.007	-0.692	13
21	3.89	3.95	-0.056	0.583	-0.111	0.001	-0.107	29
22	3.11	2.69	0.420	0.583	0.828	0.064	0.819	9
23	1.82	1.56	0.260	0.583	0.519	0.025	0.506	3
24	0.27	0.95	-0.680	0.583	-1.349	0.170	-1.390	11
25	3.55	2.73	0.820	0.583	1.609	0.242	1.709	5
26	0.97	1.11	-0.140	0.583	-0.277	0.007	-0.268	4
27	0.28	0.82	-0.540	0.583	-1.056	0.104	-1.060	1
28	2.53	2.58	-0.052	0.583	-0.102	0.001	-0.099	21
29	2.63	3.09	-0.460	0.167	-0.635	0.005	-0.622	15
30	3.26	3.09	0.170	0.167	0.244	0.001	0.236	18

* Case(s) with |Outlier T| > 3.50

3.1.4. Optimization and Validation of Machine Performance for Extraction Efficiency

The optimization results for the goal of maximizing the

optimum value of the extraction efficiency (EE) for the juice extraction process during the performance analysis of the developed juice extraction machine is shown in Figure 3.13.

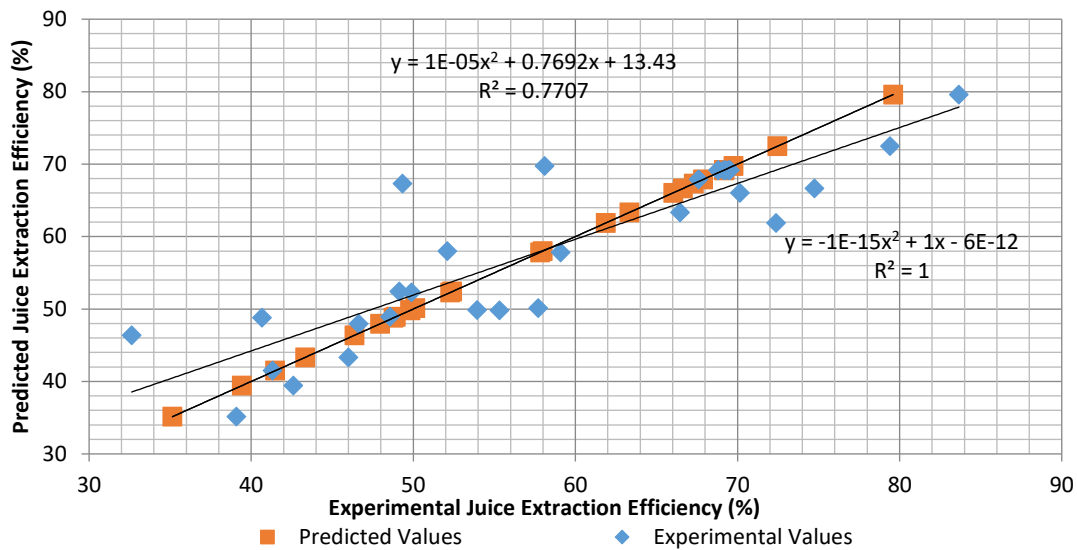


Fig 3: Comparison of the predicted and experimental values for the juice extraction efficiency

3.1.5. Optimization and Validation of Machine Performance for Extraction Capacity

The optimization results for the goal of maximizing the

optimum value of the extraction capacity (EC) for the juice extraction process during the performance analysis of the developed juice extraction machine is shown in Figure 3.14.

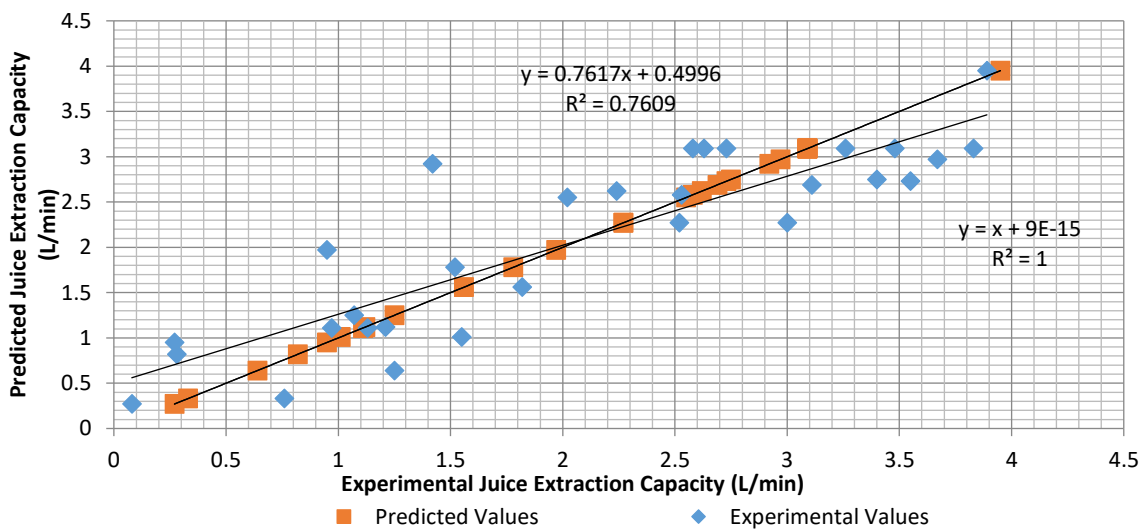


Fig 4: Comparison of the predicted and experimental values for the juice extraction capacity

4. Discussion

Table 3.1 shows result for the juice extraction efficiency and capacity at various levels combination of operating speed, feed rate, blanching temperature and blanching time. For the range of extraction process conditions considered in the expression process of juice from orange, the highest juice extraction efficiency of 83.66% was obtained at the machine operating speed of 400 rpm, feed rate of 1.5 kg/min, blanching temperature of 80°C and blanching time of 6 min, while the lowest juice extraction efficiency of 31.63% was obtained at the machine operating speed of 300 rpm, feed rate of 1.0 kg/min, blanching temperature of 20°C and blanching time of 3 min as shown in Table 3.1. Also, the highest extraction capacity of 3.89 L/min was obtained at the machine operating speed of 500 rpm, feed rate of 1.0 kg/min,

blanching temperature of 60°C and blanching time of 9 min, while the lowest extraction capacity of 0.26 L/min was obtained at the machine operating speed of 200 rpm, feed rate of 1.5 kg/min, blanching temperature of 40°C and blanching time of 6 min as shown in Table 3.1. The juice extraction efficiency ranges from 31.63 to 83.66% while the juice extraction capacity ranges from 0.26 to 3.89 L/min (Table 3.1). This compares favourably with the maximum juice extraction efficiencies of other developed machines for fruits (Oyeleke and Olaniyan, 2007; Trappey, Johnson and Wilson, 2008; Parihar *et al.* 2009) [28, 29, 33]

In Figure 3.1, it was observed that an increase in operating speed and feed rate leads to increase in extraction efficiency after which there was a corresponding decrease in extraction efficiency at higher speed (Olaniyan and Obajemihi 2014)

[25].

Considering the model with the highest R^2 value and lower standard deviation, quadratic model was selected to predict the percentage juice extraction efficiency and juice extraction capacity using the developed fruit juice extractor as depicted in Tables 3.2 and 3.5. The positive terms in the equation signify direct relationship between the extraction process conditions and their interactions with extraction efficiency (EE) and extraction capacity (EC), while the negative terms signify an inverse relationship between the extraction process conditions with extraction efficiency (EE) and extraction capacity (EC). It was observed that all the juice extraction process parameters have direct relationship with EE and EC. This implies that both EE and EC exhibited an increase with increase in the extraction process parameters. Feed rate was found to be the most significant parameter which affects EE and EC (Simmonds 2000; Onwualu 2006; Singh *et al.*, 2012; Syvester and Ashwe 2012; Ulrich and Eppinger 2012) [26, 30, 31, 34]

The Model F-values of 3.60 and 3.41 in Tables 3.3 and 3.6 respectively implies that the model is significant. Respectively, there are only 0.95% and 1.22% chances that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, D, A^2 , C^2 , D^2 are significant model terms, where A, B, C and D represent operating speed, feed rate, blanching temperature and blanching time respectively (Tables 3.3 and 3.6). This implies that the operating speed, feed rate, blanching temperature and blanching time all have significant effects on the juice extraction efficiency and extraction capacity with the operating speed having the greatest influence on the extraction efficiency and capacity. Therefore, the four juice extraction process conditions influenced the quantity of juice from the fruit using the developed juice extraction machine. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. However, that is not necessary for the selected model as there are several significant terms.

The "Lack of Fit F-values" of 1258.87 as represented in Table 3.3 implies the Lack of Fit is significant. There is only a 0.01% chance that a "Lack of Fit F-value" this large could occur due to noise. Significant lack of fit is bad as the aim is for the model to fit. "Adeq Precision" measures the signal-to-noise ratio. A ratio greater than 4 is desirable. Therefore, the ratio of 7.104 indicates an adequate signal (Table 3.2). This model can be used to navigate the design space. The model was significant with a very low probability value (0.0095) and a satisfactory coefficient of determination ($R^2 = 0.77$). The high coefficient of determination showed excellent correlations between the independent variables (dehydration parameters). This value indicates that the response (extraction efficiency) model can explain 77% of the total variability in the response. Table 3.4 shows diagnostics case statistics for juice extraction efficiency. The table shows that the prediction model was able to have close fit with the actual values of extraction efficiency in some prediction but not all the actual values. Significant differences exist in some cases (Bawa, 2025) [5].

The "Lack of Fit F-value" of 2.98 as depicted in Table 3.6 implies the Lack of Fit is not significant relative to the pure error. There is a 12.02% chance that a "Lack of Fit F-value"

this large could occur due to noise. Non-significant lack of fit is good as the aim is for the model to fit. "Adeq Precision" measures the signal-to-noise ratio. A ratio greater than 4 is desirable. Therefore, the ratio of 6.617 indicates an adequate signal (Table 3.5). This model can be used to navigate the design space. The model was significant with a very low probability value of 0.0122 and a satisfactory coefficient of determination, R^2 of 0.76. The high coefficient of determination showed excellent correlations between the independent variables (operating speed, feed rate, blanching temperature and blanching time). This value indicates that the response (extraction capacity) model can explain 76% of the total variability in the response. Table 3.7 shows diagnostic case statistics for juice extraction capacity. The prediction model for the extraction capacity showed some significant variation from the actual values in some instances as confirmed above from R^2 Value of 0.76 (Jain *et al.*, 2011) [12]. From the optimization result as represented in Figures 3.1 and 3.2 for the maximum optimum predicted values in the range of 200 - 600 rpm for operating speed, 0.5 - 2.5 kg/min for feed rate, 0 - 80°C for blanching temperature and 0 - 12 mins for blanching time, the predicted optimum extraction efficiency of 81.32 % and extraction capacity of 3.89 L/min with desirability of 97.7% at optimal operating speed of 525.23 rpm, feed rate of 2.13 kg/min, blanching temperature of 54.20°C and blanching time of 8.73 min was obtained (Umani *et al.*, 2019) [36].

A test run under the obtained optimal juice extraction process conditions of operating speed of 525.23 rpm, feed rate of 2.13 kg/min, blanching temperature of 54.20°C and blanching time of 8.73 min respectively, was carried out in order to validate the quadratic model for both the EE and EC of the developed fruit juice extraction machine, an experimental EE and EC values of 81.56% and 3.57% was obtained respectively.

In comparison of the predicted and experimental results for the optimum EE and EC, it can be seen that there was an excellent agreement between the experimental and predicted values for extraction efficiency and extraction capacity as obtained from the parity plot between the predicted and the actual values as shown in Figures 3.1 and 3.2. The correlation between the predicted and experimental values for the juice extraction efficiency and extraction capacity gave an R^2 values of 0.7707 and 0.7609 respectively which indicated that the predicted values and experimental values have a reasonable agreement. The deviation between predicted and experimental values were found to be low and ranged between 0.01- 0.40 for extraction efficiency and 0.01 - 0.82 for extraction capacity (Simmonds 2000; Onwualu 2006; Singh *et al.*, 2012; Syvester and Ashwe 2012; Ulrich and Eppinger 2012) [27, 30, 31, 34]. Hence, the generated quadratic model has the accuracy to predict both the EE and EC of orange using the developed fruit juice extraction machine (Bawa, 2025) [5].

5. Conclusion

Model selection for optimization of performance of the juice extractor has been carried out using juice extraction efficiency and extraction capacity for a newly developed juice machine. The quadratic model was chosen to predict the EE and EC. It was ascertained that extraction processing parameters influence the EE and EC. The following findings were obtained from the study:

1. the highest juice extraction efficiency of 83.66% was

obtained at the machine operating speed of 400 rpm, feed rate of 1.5 kg/min, blanching temperature of 80°C and blanching time of 6 min, while the lowest juice extraction efficiency of 31.63% was obtained at the machine operating speed of 300 rpm, feed rate of 1.0 kg/min, blanching temperature of 20°C and blanching time of 3 min.

2. Also, the highest extraction capacity of 3.89 L/min was obtained at the machine operating speed of 500 rpm, feed rate of 1.0 kg/min, blanching temperature of 60°C and blanching time of 9 min, while the lowest extraction capacity of 0.26 L/min was obtained at the machine operating speed of 200 rpm, feed rate of 1.5 kg/min, blanching temperature of 40°C and blanching time of 6 min
3. Considering the model with the highest R^2 value and lower standard deviation, quadratic model was selected to predict the percentage juice extraction efficiency and juice extraction capacity using the developed fruit juice extractor
4. It was observed that all the juice extraction process parameters have direct relationship with EE and EC. This implies that both EE and EC exhibited an increase with increase in the extraction process parameters. Feed rate was found to be the most significant parameter which affects EE and EC.
5. The Model F-values of 3.60 and 3.41, implies that the model is significant.
6. This model can be used to navigate the design space. The model was significant with a very low probability value (0.0095) and a satisfactory coefficient of determination ($R^2 = 0.77$). The high coefficient of determination showed excellent correlations between the independent variables (dehydration parameters). This value indicates that the response (extraction efficiency) model can explain 77% of the total variability in the response.
7. Predicted optimum EE and EC of 81.32% and 3.89 L/min respectively at operating speed of 525.23 rpm, feed rate of 2.13 kg/min, blanching temperature of 54.20°C and blanching time of 8.73 min was obtained with a desirability of 0.977. Under these optimal juice extraction process conditions, the experimental values of 81.56% and 3.57 L/min were obtained for EE and EC respectively.
8. The deviations between experimental and predicted values were low and statistically insignificant. The coefficient of determination (R^2) of 0.77 and 0.76 for EE and EC respectively, show that there is an excellent correlation between the juice extraction parameters (independent variables). Consequently, in view of the range of variables investigated, the chosen models have the adequacy to predict the extraction efficiency and extraction capacity for fruit juice using the developed machine. The developed fruit juice extraction machine serves as a viable option for the small-scale fruit juice processors.

References

1. Aviara NA, Stittu SK, Haque MA. Development and performance evaluation of a guna seed extractor. *Agric Eng Int CIGR Ejournal*. 2008;10:1-20.
2. American Society of Agricultural Engineers. ASAE handbook. St. Joseph (MI): ASAE; 1983.
3. Badmus GA, Adeyemi NA. Design and fabrication of a small-scale whole pineapple fruit juice extractor. *Proc Niger Inst Agric Eng*. 2004;26:285-91.
4. Bhatia SC. Canning and preservation of fruit and vegetable. 2nd ed. New Delhi: Small Industry Research Institute; 1989. 138 p.
5. Bawa AP. Development, testing, and extraction process optimization of a motorized juice extractor [MEng dissertation]. Uyo: Department of Mechanical and Aerospace Engineering, University of Uyo; 2025.
6. Badmus GA, Adeyemi NA. Design and fabrication of a small-scale whole pineapple fruit juice extractor. *J Niger Inst Agric Eng*. 2006;2:80-5.
7. Bates RP, Morris JR, Crandall PG. Principles and practices of small and medium scale fruit juice processing. 1st ed. Florida: University Press of Florida; 2001. 230 p.
8. Crocker P. A brief history of juicing [Internet]. Hoboken (NJ): Wiley; 2016 [cited 2019 Mar 24]. Available from: <http://www.dummies.com/food-drink/recipes/a-brief-history-of-juicing/>.
9. Ishiwu CN, Oluka SI. Development and performance evaluation of a juice extractor. *J Niger Inst Agric Eng*. 2005;3:172-90.
10. Khurmi RS, Gupta JK. A textbook of machine design. New Delhi: Eurasia Publishing House; 2005. 356 p.
11. Jackson. Food preservation system. In: Food and vegetable food cycle technology science. Book no. 2. United Kingdom: United Nations Development Fund for Women (UNIFEM); 1988. 42 p.
12. Jain SK, Khurdia DS. Studies on juice extraction of aonla (*Embllica officinalis* Gaertn.) cv. 'Chakaiya'. *J Food Sci Technol*. 2011;39(5):515-6.
13. Jafari M, Sabzevari A, Vakilian KA. Effects of planting methods on yield and morphological traits of three chickpea cultivars in rain fed conditions. *Russ Agric Sci*. 2014;40(5):339-43.
14. Jain SK, Khurdia DS. Studies on juice extraction of aonla (*Embllica officinalis* Gaertn.) cv. 'Chakaiya'. *J Food Sci Technol*. 2002;39(5):515-6.
15. Kasoli G, Kasirara LL. Design and performance evaluation of a banana juice extractor. In: African Crop Science Conference Proceedings. Vol. 7. 2005. p. 1381-4.
16. Lefteri C. Making it: manufacturing techniques for product design. London: Laurence King Publishing; 2007. 155 p.
17. Milton A, Rodgers P. Portfolio. Product design 1. London: Laurence King Publishing; 2011. 125 p.
18. Morozova T. The history of a juicer. How it began [Internet]. 2011 [cited 2019 Mar 24]. Available from: http://bt.web-3.ru/sokovizimalka/?act=full&id_article=2553.
19. Oguntuyi VF. Evaluation, development and performance of a manually operated orange juice extracting machine. *Int J Res Dev*. 2013;2(1):257-64.
20. Oje K. Some engineering properties of thevetia nut. *J Agric Eng Technol*. 1993;1:38-45.
21. Olabisi O, Adelegan G. Design, construction and performance evaluation of citrus fruits' juice extractor. *Int J Eng Res Technol*. 2015;9:1372-8.
22. Olaniyan AM. Development of a small-scale orange juice extractor. *J Sci Technol*. 2010;47(1):105-8.
23. Oladejo OO, Ma TA. Fundamentals of engineering for agriculture. Enugu: Immaculate Publication Limited;

- 2016.
24. Olowonibi MM, Ozumba IC. Development of domestic juice extractor. Conference paper presented at: Department of Processing and Environmental Control Engineering, National Centre for Agricultural Mechanization (NCAM); 1999; Idofian, Kwara State, Nigeria.
 25. Olaniyan AM, Obajemihi OI. Design, development and test of a small-scale mango juice extractor. *J Agric Sci Technol B*. 2014;4:1-7.
 26. Olaniyan AM. Development of a small-scale orange juice extractor. *Food Sci Technol*. 2009;47(1):105-8.
 27. Onwualu AP, Akubuo CO, Ahaneku IE. Fundamentals of engineering for agriculture. Enugu: Immaculate Publication Limited; 2006.
 28. Oyeleke FI, Olaniyan AM. Extraction of juice from some tropical fruits using a small-scale multi-fruit juice extractor. In: African Crop Science Conference Proceedings. Vol. 8. 2007. p. 1803-8.
 29. Parihar P, Tomar AK, Kumar S. Effect of various extraction processes on the juice recovery of bael (*Aegle marmelos* Correa) fruits. *J Trop For*. 2009;25(1):49-53.
 30. Simmonds DC. Fruit juice and soft drinks. In: Ranken MD, editor. Food industry manual. 21st ed. London: Leonard Hill; 2000. 120 p.
 31. Singh A, Kumar S, Sharma HK. Effect of enzymatic hydrolysis on the juice yield from bael fruit pulp. *Am J Food Technol*. 2012;7(2):62-72.
 32. Sylvester AA, Ashwe A. Design and construction of an orange juice extractor. In: Proceedings of the world congress on engineering. Vol. 3. 2012. p. 131-44.
 33. Trappey AF, Johnson CE, Wilson PW. Use of a commercial pectolytic enzyme to extract juice from frozen Mayhaw (*Crataegus opaca* Hook.) fruit. *Int J Fruit Sci*. 2008;7(1):77-86.
 34. Ulrich KT, Eppinger SD. Product design and development. 5th ed. New York: McGraw-Hill Companies; 2012. 185 p.
 35. Tressler A, Joslyn PN. Use of a commercial pectolytic enzyme to extract juice from frozen Mayhaw (*Crataegus opaca* Hook.) fruit. *Int J Fruit Sci*. 1961;7(1):77-86.
 36. Umani FO, Shamsudeen A, Paul KN, Samuel AD. Product design and development. 5th ed. New York: McGraw-Hill Companies; 2019. 185 p.

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