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Optimization of Grating and Dewatering of a Cassava Processing Machine Using Surface Response Methodology

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ABSTRACT: Grating and dewatering are major units' operations in cassava processing. The impacts of grater speed, screw expeller speed and compression spring load on both grating and dewatering responses using a locally developed cassava processing machine have been determined using surface response methodology. Grater speed (1100, 1200. 1300, 1400 and 1500 rpm), Screw expeller speed (150, 200, 250, 300 and 350 rpm), compression spring load (100, 200, 300, 400 and 500 N) and cassava tuber (TMS 30110, TMS 419 and TMS 30395) were independent variables. The responses were machine capacity, throughput, process time and machine efficiency. Performance index results of machine capacity for all three cassava varieties were between 97.56 and 105.26 kg/h for TMS 30110; 104.90 and 115.83 kg/h for TMS 419 while it was 97.09 and 115.08kg/h for TMS 30395. The throughput for TMS 30110 ranges between 68. 49 and 85.05 kg/h, TMS 419 ranged between 83.39 and 97.47 kg/h and TMS 30395 ranged between 67.89 and 94. 19 kg/h. The process time for the three varieties ranged between 5.14 and 6.18 minutes. The machine efficiency for TMS 30110 ranged between 70.2 and 80.8%, TMS 419 ranged between 79.5 and 83.8% while it was 69.6 and 83.5% for TMS 30395. The moisture content for the three varieties ranged between 52 and 46% wet basis. Increased in machine speed, screw expeller speed and compression spring load resulted in enhanced machine capacity, throughput and efficiency but reduced process time. All parameters investigated were significant ($P<0.05$). The equations created could be used to forecast and predict the machine capacity, throughput, process time and efficiency as affected by machine speed and compression spring load.

KEYWORDS*:* Optimization, grating. dewatering, machine, surface response methodology.

1. INTRODUCTION

Cassava (*Manihot esculenta*) is grown mainly in developing countries like Africa, Brazil, Indonesia, Philippines, Thailand and China (Olutayo and Agbetoye, 2022). It is one of the major roots and tuber crops produce in Nigeria. This is because, it is a tolerant of drought condition and poor soil (Burns *et al*., 2010). Cassava is a very important crop as a carbohydrate which supplies energy, it is a dicotyledonous perennial shrub with palmate leaves. The edible portion is the root, the flower is borne at the end of the stem and ranges in colour from greenish purple to light yellow. The optimum mean daily temperature is between 18^0 C and 35^0C and the minimum temperature the plant can tolerate is 10^0C (Burns *et al*., 2010). There are numerous uses of cassava, but the use of cassava root in food and other industrial applications is limited by the rapid post-harvest physiological deterioration (PPD), which decreases shelf-life and degrades its quality attributes (Sanchez *et al.,* 2006). Converting cassava root to other types of food products with longer shelf-life, add root valve and improves post-harvest quality (Falade and Akingbala, 2010). For this reason, cassava is usually sold as a processed product in the form of *garri, fufu, pupuru* and cassava flour (Ahiakwo *et al*., 2015). Nigeria is the largest producer of cassava in Africa, this becomes evidence from statistics of cassava production reported by Food and Agricultural Organization FAO, 2013[a] and reported by Olutayo *et al*., (2022). FAO (2013[b]) reported that production of cassava in Nigeria has reached 54 million metric tons. In tropical part of Africa, it has become the most important crop in terms of land areas devoted for its production and the proportion it contributed to the human diet. It is known globally as a cheap source of calorie in human diet and animal feeds especially in Africa where it accounts for 60 % of root crops consumption. Cassava is primarily a source of carbohydrate and contains very little protein or fat. The approximate composition of the cassava tuber is starch, 20-30 %; protein, 2-3 %; water, 75-80 %; fat, 0.1 %; fiber, 1.0 %; ash, 1-1.5 % (IITA, 2013[b]). Currently, it is fast becoming a foreign exchange earner due to its new status as a major industrial raw material for the production of wide varieties of flour-based and starch-based products such as *Lafun* (fermented flour), *garri* (flakes), High Quality Cassava Flour (HQCF), alcohol for fuel, glue, starch and so on

(Agbetoye, 2005). Today, about 60% of cassava is used for industrial purposes while 40% is consumed by the households as reported by Ovat and Odey, (2018). The processing steps which involves peeling, washing, grating, dewatering, pulverizing, sieving and frying/drying (Olutayo and Agbetoye, 2022) are still being done in the same old way. The interest of this research is to optimize cassava grating and dewatering units of a locally developed cassava processing machine using response surface methodology.

2. MATERIALS AND METHODS

Table 2.1: Experimental design

Variables	Level	
Cassava tuber variety	TMS 30110, TMS 419, TMS 30395	**3 levels**
Grater Speed	1100, 1200, 1300, 1400, 1500 rpm	**5 levels**
Screw Expeller Speed	150, 200, 250, 300, 350 rpm	**5 levels**
Pressure Spring force	100, 200, 300, 400, 500 N	**5 levels**

2.1 Experimental Procedure and methodology

The experiment was divided into two parts. Grating experiment and Combine (grating and dewatering) experiment. For the grating experiment, three cassava varieties (TMS 30110, TMS 419, TMS 30395) selected for experiment were based on their proven qualities, the stem of the three varieties of cassava planted and used for the experiment were obtained from IITA. A variety was used at a time while varying the grater speed ranging from 1100, 1200, 1300, 1400 and 1500 rpm at 100 rpm as interval recommended by Darlene *et al*. (2019) and Adzimah and Gbadam (2009). The tubers were peeled, washed and weighed before grating into mash. A measured quantity was used for the machine stabilization. Experimental samples of 10 kg were considered at each run. The samples were fed into the machine at a given speed and replicated three times. The mean output in kg and operation time in minutes were recorded. Similarly, for the grating and dewatering experiment. Screw expeller speed and spring force were introduced. The tubers were peeled, washed and weighed before grating into mash. Experimental samples of 10 kg were considered at each run. The samples were fed into the machine at a constant grating optimum speed 1400 rpm, screw expeller speeds ranging from 150 to 350 rpm at 50 rpm interval as recommended by Kolawole (2012) and all the five spring of 100 N, 200 N, 300 N,400 N, and 500 N were used and replicated three times before changing the speed, which was done by replacing pulley diameters. 10 kg of cassava tuber each of 45 samples were used for the grating experiments while 135 samples were used for grating and dewatering experiments. The mean outputs of the machine (mash cake in kg, moist starch in litres) and operation time in minutes were recorded to determine the throughput and efficiency of the machine.

2.2 Statistical Analysis

Three times replicated all the experimental process and valves were registered. The gathered information was analyzed statistically using regression analysis and Analysis of variance (ANOVA) to determine their meaning at 5% level of significance. Design expect was used to generate mathematical models. Models adequacy was evaluated by determination coefficient (R^2) and lack of fit test.

2.3 Optimization

The following limitations were implemented in optimizing the grating and dewatering procedure: maximizing grater and screw expeller speed, compression spring load, minimizing mash moisture content. Grating and dewatering time was minimized among the responses while maximizing throughput ability, grating and dewatering effectiveness. Using the Design Expert Statistical Package, appropriate combinations of grater speed, screw expeller speed and compression spring load producing the highest outcomes were achieved. Cassava tubers were grated and dewatered under these conditions and the results compared to the predicted valves in order to validate the optimal factors.

3. RESULTS AND DISCUSSIONS

3.1 Effect of Grater Speed factor on Performance Response

Three cassava (TMS 30110, TMS 419 and TMS 30395) varieties respectively described the outcomes acquired for the responses (machine capacity, throughput, process time and efficiency). the mash output of the grater increased as speed increased up to 1400 rpm but no further increment was observed after 1400 rpm across the three varieties tested. the highest output obtained from TMS 30110 was 8.84 kg, while it was 9.02 kg for TMS 419 and 8.71 kg for TMS 30395 variety as presented in Tables 3.1, 3.2 and 3.3 respectively. Therefore, it can be deduced that the highest mash output was obtained at 1400 rpm grater speed in all the varieties tested. This agreed with the recommendation of Darlene *et al*. (2019) and Okonkwo *et al.* (2016) that the output of the grater increased between 1350 – 1400 rpm grating speed.

Table 3.1: Performance Evaluation indices of the Grater for TMS 30110 Cassava variety

Run NO	Grater speed (rpm)	Product discharged (kg)	Clogged Mash (kg)	Mash MC (% wb)	Process Time (mins)	Machine Cap. (kg/h)	Throughput Cap. (kg/h)	Eff. (%)
1	1100	7.88	1.03	72	3.70	162.16	127.78	78.8
2	1100	7.92	0.88	72	3.65	168.07	130.19	79.2
3	1100	7.96	0.86	72	3.65	168.07	130.84	79.6
4	1200	8.18	0.78	72	3.70	162.16	132.65	81.8
5	1200	8.22	0.82	72	3.66	163.93	134.75	82.2
6	1200	8.26	0.92	72	3.58	167.60	138.44	82.6
7	1300	8.36	0.81	72	3.56	168.54	140.89	83.6
8	1300	8.38	0.83	72	3.65	164.38	137.75	83.8
9	1300	8.28	0.76	72	3.48	172.41	142.76	82.8
10	1400	8.74	0.67	72	3.35	179.12	156.54	87.4
11	1400	8.80	0.62	72	3.38	177.52	156.21	88
12	1400	8.81	0.64	72	3.40	176.47	155.47	88.1
13	1500	8.78	0.58	72	3.42	175.44	154.04	87.8
14	1500	8.61	0.71	72	3.51	170.94	147.18	86.1
15	1500	8.58	0.89	72	3.50	171.43	147.09	85.8

Table 3.2: Performance Evaluation indices of the Grater for TMS 419 Cassava variety

Run NO	Grater speed (rpm)	Product discharged (kg)	Clogged Mash (kg)	Mash MC (% wb)	Process Time (mins)	Machine Cap. (kg/h)	Throughput Cap. (kg/h)	Eff. (%)
1	1100	7.95	1.04	72	3.65	164.38	130.68	79.5
2	1100	7.98	1.10	72	3.62	165.75	132.27	79.8
3	1100	7.92	0.88	72	3.66	163.93	129.84	79.2
4	1200	8.10	1.08	72	3.69	162.61	131.71	81
5	1200	8.30	0.86	72	3.53	169.97	141.08	83
6	1200	7.92	0.92	72	3.45	173.91	137.74	79.2
7	1300	8.46	0.94	72	3.62	165.75	140.22	84.6
8	1300	8.42	0.86	72	3.50	171.43	144.34	84.2

9	1300	8.47	0.73	72	3.58	167.60	141.96	84.7
10	1400	8.83	0.65	72	3.35	179.10	158.15	88.3
11	1400	8.85	0.62	72	3.38	177.52	157.10	88.5
12	1400	8.90	0.58	72	3.36	178.57	158.93	89
13	1500	8.61	0.61	72	3.42	175.44	151.05	86.1
14	1500	8.59	0.58	72	3.51	170.94	146.84	85.9
15	1500	8.79	0.54	72	3.48	172.41	151.55	87.9

Table 3.3: Performance Evaluation indices of the Grater for TMS 30395 Cassava variety

Run NO	**Grater speed (rpm)**	**Product discharged (kg)**	**Clogged Mash (kg)**	**Mash MC (% wb)**	**Process Time (mins)**	**Machine Cap. (kg/h)**	**Throughput Cap. (kg/h)**	**Eff. (%)**
1	1100	7.91	0.88	72	3.70	162.16	128.27	79.1
2	1100	7.94	1.02	72	3.57	168.07	133.45	79.4
3	1100	7.98	1.04	72	3.61	166.21	132.63	79.8
4	1200	8.20	0.91	72	3.69	162.61	133.33	82
5	1200	8.22	1.05	72	3.53	169.97	139.72	82.2
6	1200	8.30	0.82	72	3.45	173.91	144.35	83
7	1300	8.35	0.84	72	3.52	170.46	142.33	83.5
8	1300	8.41	0.84	72	3.50	171.43	152.91	84.1
9	1300	8.39	0.76	72	3.42	175.44	147.19	83.9
10	1400	8.81	0.62	72	3.35	179.11	157.79	88.1
11	1400	8.79	0.53	72	3.38	177.52	156.04	87.9
12	1400	8.84	0.62	72	3.36	178.57	157.86	88.4
13	1500	8.46	0.86	72	3.42	175.44	148.42	84.6
14	1500	8.52	0.74	72	3.51	170.94	145.64	85.2
15	1500	8.40	0.72	72	3.48	172.41	144.83	84

3.2 Effect of Spring load factor on Performance Response

The effect of compression spring loads (100 N, 200 N, 300 N, 400 N and 500 N) was tested against the screw expeller speeds (150 rpm, 200 rpm, 250 rpm, 300 rpm and 350 rpm). The spring loads and the screw expeller speeds were used in dewatering grated mash. These were selected based the recommendation of Kolawole (2012). 1400 rpm grater speed was constant and tested on the three selected cassava varieties (TMS 30110, TMS 419 and TMS 30395), the screw expeller speed was varied from 150 to

350 rpm while the compression spring load was also varied from 100 to 500 N in each case of the experiment and the process was replicated three times. The effect of spring load on throughput was tested at various screw expeller speed as presented in Tables 3.4, 3.5 and 3.6 respectively. The throughput increased as speed and spring load increased from 150 to 300 rpm screw expeller speed and 100 to 400 N, but no further increment after 300 rpm. However, it was observed that the highest throughput and efficiency was recorded at 300 rpm screw expeller and at 400 N spring load in the three varieties of cassava tested. This indicated that the throughput and efficiency increased with increased in screw expeller speed up to 300 rpm Kier and Jesal (2015) also revealed similar observation.

Table 3.4: Performance Evaluation indices of the machine speed for TMS 30110 Cassava variety

Run NO	Spring Load (N)	Product discharged (kg)	Vol. of starch (litres)	Clogged Mash (kg)	Product MC (%wb)	Process Time (mins)	Machine Cap. (kg/h)	Throughput Cap. (kg/h)	Eff. (%)
1	100	6.50	0.52	1.62	55	6.15	97.56	68.49	70.2
2	100	6.58	0.58	1.11	52	6.10	98.36	70.43	71.6
3	100	6.60	0.58	1.07	54	6.10	98.36	70.62	71.8
4	200	6.78	0.67	1.08	52	6.08	98.68	73.52	74.5
5	200	6.84	0.81	1.16	54	6.09	98.52	75.37	76.5
6	200	7.02	0.76	1.04	49	6.06	99.01	77.03	77.8
7	300	7.10	0.86	1.11	49	5.96	100.67	80.13	79.6
8	300	7.08	0.76	0.90	48	5.92	101.35	79.46	78.4
9	300	7.07	0.81	1.12	48	5.90	101.69	80.14	78.8
10	400	7.10	1.04	0.16	45	5.82	103.09	83.92	81.4
11	400	7.10	1.02	0.89	46	5.78	103.81	84.29	81.2
12	400	7.08	1.00	0.72	48	5.70	105.26	85.05	80.8
13	500	7.11	0.94	0.94	48	5.70	105.26	84.74	80.5
14	500	7.06	0.99	0.99	46	5.84	102.74	82.71	80.5
15	500	7.10	1.02	1.02	46	5.72	104.89	85.17	81.2

Table 3.5: Performance Evaluation indices of the machine speed for TMS 419 Cassava variety

Run NO	Spring Load (N)	Product discharged (kg)	Vol. of starch (litres)	Clogged Mash (kg)	Product MC (%wb)	Process Time (mins)	Machine Cap. (kg/h)	Throughput Cap. (kg/h)	Eff. (%)
1	100	7.25	0.70	1.05	54	5.72	104.90	83.39	79.5
2	100	7.28	0.69	0.89	52	5.68	105.64	84.19	79.7
3	100	6.88	1.02	1.15	52	5.62	106.76	84.34	79
4	200	6.86	1.05	1.17	50	5.70	105.26	83.26	79.1

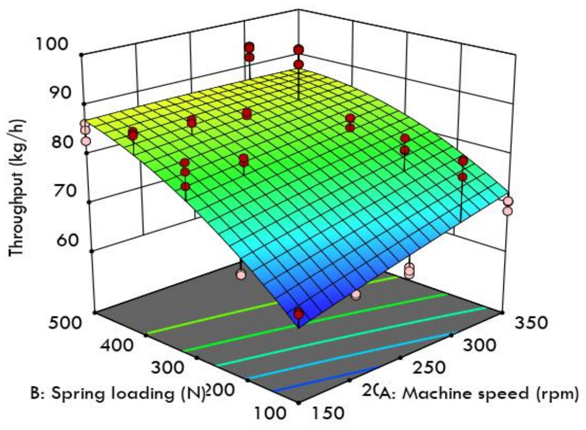
5	200	7.29	0.69	1.02	48	5.69	105.45	84.15	79.8
6	200	7.26	0.70	1.13	50	5.64	106.38	84.68	79.6
7	300	7.24	0.62	0.96	48	5.41	110.91	89.39	80.6
8	300	7.20	0.70	1.02	49	5.56	107.92	87.41	81
9	300	7.39	0.73	0.89	48	5.60	107.14	82.39	81.2
10	400	7.37	1.11	0.70	45	5.18	115.83	97.07	83.8
11	400	7.45	1.12	0.68	46	5.20	115.39	96.58	83.7
12	400	7.40	1.15	0.77	45	5.14	116.73	97.47	83.5
13	500	7.21	1.15	0.68	46	5.28	113.64	95.00	83.6
14	500	7.28	1.10	0.87	45	5.30	113.21	94.88	83.8
15	500	7.26	1.06	0.86	46	5.22	114.94	95.63	83.2

Table 3.6: Performance Evaluation indices of the machine speed for TMS 30395 Cassava variety

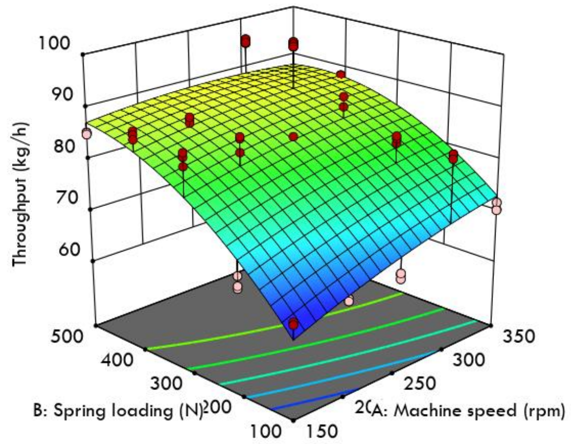
Run NO	**Spring Load (N)**	**Product discharged (kg)**	**Vol. of starch (litres)**	**Clogged Mash (kg)**	**Product MC (%wb)**	**Process Time (mins)**	**Machine Cap. (kg/h)**	**Throughput Cap. (kg/h)**	**Eff. (%)**
1	100	6.42	0.54	1.05	53	6.18	97.09	67.57	69.6
2	100	6.44	0.57	0.89	50	6.20	96.77	67.89	70.1
3	100	6.82	0.50	0.96	54	6.08	98.68	72.24	73.2
4	200	7.10	0.68	1.17	48	6.04	99.34	77.28	77.8
5	200	7.24	0.84	1.06	52	5.96	100.67	81.34	80.5
6	200	7.15	0.70	1.02	50	6.00	100	78.50	78.5
7	300	7.18	1.06	1.03	48	5.62	106.76	87.97	80.8
8	300	7.20	0.84	1.00	50	5.68	105.64	85.35	80.4
9	300	7.20	0.81	0.98	49	5.71	105.08	84.27	80.2
10	400	7.25	1.10	0.99	46	5.20	115.39	96.35	83.5
11	400	7.23	1.08	0.86	45	5.24	114.50	95.15	83.1
12	400	7.26	1.06	0.78	46	5.30	113.21	94.19	83.2
13	500	7.18	0.94	0.92	46	5.28	113.64	92.27	81.2
14	500	7.24	0.98	1.02	44	5.24	114.50	94.12	82.2
15	500	7.16	1.12	0.87	48	5.32	112.78	93.38	82.8

Statistical analysis of machine process

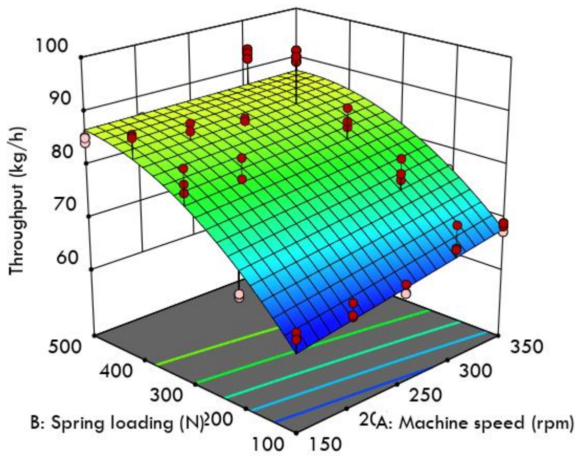
Figure 3.1 shows the 3D surface for the effect of machine speed and spring load on the throughput for the TMS 30110, TMS 419 and TMS 30395 varieties respectively. Increase in the speed and spring load increased the throughput of the machine for all varieties.



TMS 30110 Variety



TMS 419 Variety



TMS 30395 Variety

Fig. 3.1: The 3D surface plot for the effect of machine speed and spring load on the throughput for the three varieties

Table 3.7: The developed models for the throughput of the machine

Variety	Model Name	Model	Eqn No
TMS 30110	Linear	$Q = 56.66 + 2.8E - 02S + 0.051L$	4.13
	Factorial	$Q = 46.2 + 0.07S + 0.09L - 1.39 - 04SL$	4.14
	Quadratic	$Q = 38.55 + 0.083S + 0.14L - 1.39E - 04SL - 2.57E - 05S^2 - 8.81E - 05L^2$	4.14
TMS 419	Linear	$Q = 57.79 + 0.031S + 0.0\ 51L$	4.15
	Factorial	$Q = 47.73 + 0.071S + 0.084L - 1.34 \times 10^{-4}SL$	4.16
	Quadratic	$Q = 31.47 + 0.13S + 0.16L - 1.34 \times 10^{-4}SL - 1.24E - 04S^2 - 1.31 \times 10^{-4}L^2$	4.17
TMS 30395	Linear	$Q = 56.75 + 0.019S + 0.05L$	4.18
	Factorial	$Q = 50.85 + 0.042S + 0.076L - 7.87 \times 10^{-5}SL$	4.19
	Quadratic	$Q = 41.75 + 0.039S + 0.16L - 7.87 \times 10^{-5}SL + 6.29 \times 10^{-6}S^2 - 1.35 \times 10^{-4}L^2$	4.20

Table 3.8: The goodness of fit statistics of the developed models for the throughput of the machine

Variety	Statistics	Linear	Factorial	Quadratic
TMS 30110	R^2	0.663	0.687	0.713
	Adjusted R^2	0.654	0.673	0.692
	MSE	29.117	27.473	25.895
	RMSE	5.396	5.241	5.089
	AIC	255.788	252.380	249.799
	SBC	262.741	261.650	263.704
	PC	0.365	0.349	0.337
TMS 419	R^2	0.619	0.639	0.695
	Adjusted R^2	0.609	0.624	0.673
	MSE	35.939	34.547	30.052
	RMSE	5.995	5.878	5.482
	AIC	271.576	269.564	260.966
	SBC	278.528	278.834	274.871
	PC	0.412	0.401	0.358
TMS 30395	R^2	0.742	0.749	0.806
	Adjusted R^2	0.735	0.738	0.792
	MSE	23.820	23.502	18.625
	RMSE	4.881	4.848	4.316
	AIC	240.729	240.672	225.086
	SBC	247.681	249.942	238.991
	PC	0.280	0.280	0.227

R^2 is the coefficient of determination, MSE is the mean squared error, RMSE is the root mean squared error, AIC is the Akaike information criterion, SBC is the swaschwarz Bayesian criterion, and PC is the pitman closeness.

Table 4.2 show the goodness of fit statistics of the develop models, the coefficient of determination of the linear models were 0.663, 0.619, and 0.742 for the throughput of the TMS 30110, TMS 419 and TMS 30395 varieties respectively. This results show that the machine speed and spring load can only predict the linear variation in the throughput with an accuracy of 66.3%, 61.9% and 74.2% under the TMS 30110, TMS 419 and TMS 30395 respectively.

The coefficient of determination of the factorial models were 0.687, 0.639 and 0.749 for the throughput of the TMS 30110, TMS 419 and TMS 30395 respectively. This results also show that the machine speed (S), spring load (L) and the interaction between the factors (SL) can only predict the variation in the throughput with an accuracy of 68.7%, 63.9%, and 74.9% under the TMS 30110, TMS 419 and TMS 30395 respectively. The coefficient of determination of the model increased to 0.713, 0.695, and 0.806 for the throughput of the TMS 30110, TMS 419 and TMS 30395 respectively at the quadratic element of the variable was introduce to the models. This result show that the machine speed (S), spring load (L), factor interaction (SL), and the quadratic factors (S^2, L^2) can only predict the variation in the throughput with an accuracy of 71.3%, 69.5%, and 80.6% under the TMS 30110, TMS 419 and TMS 30395 respectively.

Table 3.9: Analysis of variance (ANOVA) for the throughput of the machine under TMS 30110 variety

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	4435.704	887.141	34.259	0.0000
S	1	293.049	293.049	11.317	0.0013
L	1	3832.954	3832.954	148.020	0.0000
SL	1	145.840	145.840	5.632	0.0204
S^2	1	0.868	0.868	0.034	0.8553
L^2	1	162.994	162.994	6.294	0.0145
Error	69	1786.739	25.895		
Corrected Total	74	6222.443			

Table 3.10: Analysis of variance (ANOVA) for the throughput of the machine under TMS 419 variety

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	4725.187	945.037	31.447	0.0000
S	1	354.294	354.294	11.789	0.0010
L	1	3856.850	3856.850	128.339	0.0000
SL	1	134.764	134.764	4.484	0.0378
S^2	1	20.076	20.076	0.668	0.4166
L^2	1	359.203	359.203	11.953	0.0009
Error	69	2073.590	30.052		
Corrected Total	74	6798.777			

Table 3.11: Analysis of variance (ANOVA) for the throughput of the machine under TMS 30395 variety

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	5354.850	1070.970	57.500	0.0000
S	1	132.390	132.390	7.108	0.0096
L	1	4792.557	4792.557	257.313	0.0000
SL	1	46.398	46.398	2.491	0.1191
S^2	1	0.052	0.052	0.003	0.9581
L^2	1	383.454	383.454	20.588	0.0000
Error	69	1285.154	18.625		
Corrected Total	74	6640.004			

Tables 3.9 – 3.11 shows the analysis of variance (ANOVA) for the throughput of the machine under TMS 30110, TMS 419 and TMS 30395 respectively.

The machine speed, the spring load, factor interaction and quadratic of spring load has significant effect ($P<0.05$) on the throughput of the machine. The quadratic function of the machine speed is not significant for all the varieties and the interaction of factors is not significant for TMS 30395 showing the influence of varietal difference. The variation throughput of the machine significantly ($P<0.05$) depends on the spring load with highest F value (148.02, 128.33, 257.3) for TMS 30110, TMS 419 and TMS 30395 respectively and the lowest P value (<0.001) followed by the machine speed.

4. CONCLUSION

The research concludes the following findings:

i. All parameters investigated were important at a meaning point of 5% level of significant.
ii. Increase in machine speed, compression spring load increased the throughput, capacity and efficiency.
iii. Increase in machine speed and compression spring load decreased the process time.
iv. The equations created could be used to forecast and predict the machine throughput, capacity, process time and efficiency as affected by machine speed and compression spring load.

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