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Performance Evaluation of Grating and Dewatering Units of a Cassava Processing Machine

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I. INTRODUCTION

Cassava (*Manihot esculenta,* Crantz) is produced and consumed in developing countries (Bello *et al*., 2020). It is highly productive, tolerant of poor soils and periods of drought and is relatively disease free and pest resistant (Burns *et al*., 2010). It provides a major source of energy for over 500 million people world-wide (FAO, 2013[a]). Cassava is diversified into different food products and these products are available all year round thus making cassava an important staple food for many rural households in Nigeria (IITA/ICS/USAID, 2015).

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 (FAO, 2013[b]). 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). In 2001, it was estimated that 16% of cassava root production was utilized as an industrial raw material in Nigeria (Ajao and Adigun, 2019). Today, about 60% of cassava is used for industrial purposes while 40 % is consumed by households as reported by Ovat and Odey (2018). Cassava is the most perishable of roots and tubers and can deteriorate within two to three days after harvesting. In the words of Lasisi *et al*. (2019) "the major limitation of cassava is its rapid post-harvest deterioration which often begins within 24 hours after harvest". Furthermore, according to Kolawole (2012) labour is becoming more expensive for the processing of cassava tuber which involves peeling, washing, grating, dewatering, pulverizing, sieving and frying/drying. These processes are still being done in the same old way. Traditional tools were the options available, and the result of using this usually led to low productivity, poor labour efficiency and high post–harvest losses (Kolawole *et al*., 2010). The end product sometimes may not be hygienic. In Nigeria, a Federal Government directive on 10% cassava flour utilization in wheat-based baking flour has triggered a serious hike in demand for cassava, therefore making it very difficult to meet up with the demand and specification required.

This study presents the performance evaluation of grating and dewatering units of a locally fabricated cassava processing machine to determine the optimum crop and machine speeds for the maximum production of starch, mash cake for HQCF and other cassava products.

II. MATERIALS AND METHODS

2.1 Machine Description and Operation

The components of the cassava processing machine were assembled and mounted on the fabricated rigid frame as presented in plate1. The peeled, washed cassava tuber is fed into the machine through the hopper, under gravity the tuber slides into the fast rotating grater, the grated mash drops into the screw expeller chamber, the screw conveys and rotate the mash on a rigid sieve also there is compression force as a result of a pressure spring load on the rotating shaft of the screw that compress the mash, thereby liberate the moist starch through the sieve and the mash cake discharged through the other outlet.

Plate 1: Cassava processing machine

Plate 2: Tabletop Digital Scale Model SC-30

2.2 Experimental Design

Satisfactory performance of the machine at 75% production efficiency, mash cake moisture content between 45-47% wet basis, further experiment was designed to evaluate the machine operational parameters. The experiment considered three varieties of cassava tuber TMS 30110, TMS 419 and TMS 30395, five grating speeds ranging from 1100 to 1500 rpm at 100 rpm interval to determine the optimum variety and optimum grating speed. Five screw expeller speeds ranging from 150 to 350 rpm at 50 rpm interval and five level of pressure spring force at 100, 200, 300, 400 and 500 N (Table 1)

Table 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 N, 200 N, 300 N, 400N, 500 N**	**5 levels**

2.3 Experimental Procedure

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 varieties were obtained from IITA farm. A variety was used at a time while varying the grating speed ranging from 1100, 1200, 1300, 1400 and 1500 rpm at 100 rpm as interval recommended by Okonkwo *et al.* (2016). 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 using Tabletop Digital Scale Standard Precision Model SC-30 (Plate 2) were considered at each run. The samples were fed into the machine at a given speed and replicated three times. The output in kg and operation time in minutes were recorded. Similarly, for grating and dewatering experiments. 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. 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 samples were fed into the machine at a constant optimum grater speed 1400 rpm.

Machine Throughput (Tp): This is the rate of production. That is, the quantity of product produced over a certain period of time.

$$Tp = \frac{\text{Output mass of cassava mash/cake in kg } (Q2)}{\text{Time taken for grating and dewatering } (t)} \quad (1)$$

Machine Capacity (Mc)= This is the maximum output that a machine can produce with respect to time, assuming all the products are good.

$$Mc = \frac{\text{Input mass of cassava tuber in kg (Q1)}}{\text{Time taken for the operation (t)}} \quad (2)$$

Machine Efficiency (η) = This is the percentage of input to output of the machine.

$$\eta = \frac{\text{Output mass of cassava mash/cake in kg (Q2)}}{\text{Input mass of the cassava tuber in kg (Q1)}} \quad (3)$$

III. RESULTS DISCUSSIONS

3.1 Effect of grater speed on mash output

The effect of grater speed on the mash output was tested on the three varieties of cassava tuber. The three varieties of the cassava tuber (TMS 30110, TMS 419 and TMS 30395) were tested against five grater speeds (1100, 1200, 1300, 1400 and 1500 rpm). The varieties were selected based on its proven qualities and the recommendation by IITA. The five speeds were also selected for the performance evaluation based on the recommendation of Okonkwo (2016) and Doydora *et al*. (2017).

For the TMS 30110 variety, the output obtained ranges from 7.78 kg to 8.67 kg. 1400 rpm speed has the highest mash output of 8.67 kg, while 1100 rpm has the lowest output of 7.78 kg.

For the TMS 419 variety, the output ranges from 7.95 kg to 9.02 kg. 1400 rpm speed has the highest output of 9.02 kg, while 1100 rpm has the lowest output of 7.95 kg.

For the TMS 30395 variety, the output obtained ranges from7.56 kg to 8.54 kg. 1400 rpm speed has the highest mash output of 8.54 kg, while 1100 rpm has the lowest output of 7.56 kg.

From the results obtained in figure1, the maximum output was obtained at 1400 rpm grater speed on the three varieties of cassava tested. This agreed with the recommendation of Kier *et al*. (2015) that the output of the grater increases between 1300 – 1500 rpm grating speed. This indicated that the capacity of output increased with increased in grater speed. Ovat and Odey 2018 also revealed similar observation.

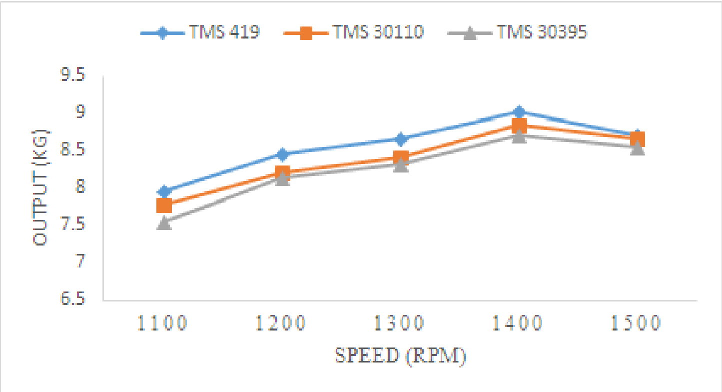

Fig. 1: Effect of Grater Speed on Mash Output

3.2 Effect of spring load on throughputs

The effect of spring load on throughput was tested and determined using equation (1) at various screw expeller speed as presented in Figure 2, the throughput increased as speed increased from 150 to 300 rpm screw expeller speed, so also the compression spring load increased the throughput from 100 N to 400 N, but no increment was observed after 300 rpm and 400 N respectively.

For TMS 30110, the throughput ranges from 58.17 kg/h to 95.88 kg/h. The highest throughput was recorded at 300 rpm expeller speed of 95.88 kg/h at 400 N spring load, while 150 rpm screw expeller speed at 100 N spring load has the lowest throughput of 58.17 kg/h.

For TMS 419, the throughput ranges from 64.86 kg/h to102.82 kg/h. The highest throughput was recorded at 300 rpm expeller speed of 102.82 kg/h at 400 N spring load, while 150 rpm screw expeller speed and 100 N spring load has the lowest throughput of 64.86 kg/h.

For TMS 30395, the throughput ranges from 57.64 kg/h to 94.86 kg/h. The highest throughput was recorded at 300 rpm expeller speed of 94.86 kg/h at 400 N spring load, while 150 rpm screw expeller speed and 100 N spring load had the lowest throughput of 57.64.

However, it was observed that the highest throughput was recorded at 300 rpm screw expeller and at 400 N spring load in the three varieties of cassava tested. This indicated that the capacity of throughput increased with increased screw expeller speed up to 300 rpm Kolawole (2012) also revealed similar observations.

3.3 Effect of spring load on efficiency and moisture content at various speed

The effect of spring load on moisture content and efficiency of the machine was tested at various screw expeller speeds on the three selected cassava varieties. The efficiency of the machine increased as screw expeller speed and spring load increased up to 300 rpm and 400 N respectively, but the moisture content reduced but no increment was observed when the speed and spring load increased to 350 rpm and 500 N respectively across the varieties tested. The moisture content of the cassava cake decreased from the initial moisture content 72% cassava mash, as the spring load increased. The efficiency and the moisture content was determined in each case using equation (3) and moisture metre respectively as presented in Figure 3. The moisture content of TMS 30110 cassava cake ranges from 54 % to 46% wet basis, from initial moisture content 72% wb cassava mash, while the efficiency ranges from 60.2 % to 83.9%. The moisture content of TMS 419 cassava cake ranges from 52 % to 44% wet basis, while the efficiency ranges from 66.7 % to 88.6%. The moisture content of TMS 30395 cassava cake ranges from 54 % to 46% wet basis, while the efficiency ranges from 58.6 % to 83%.

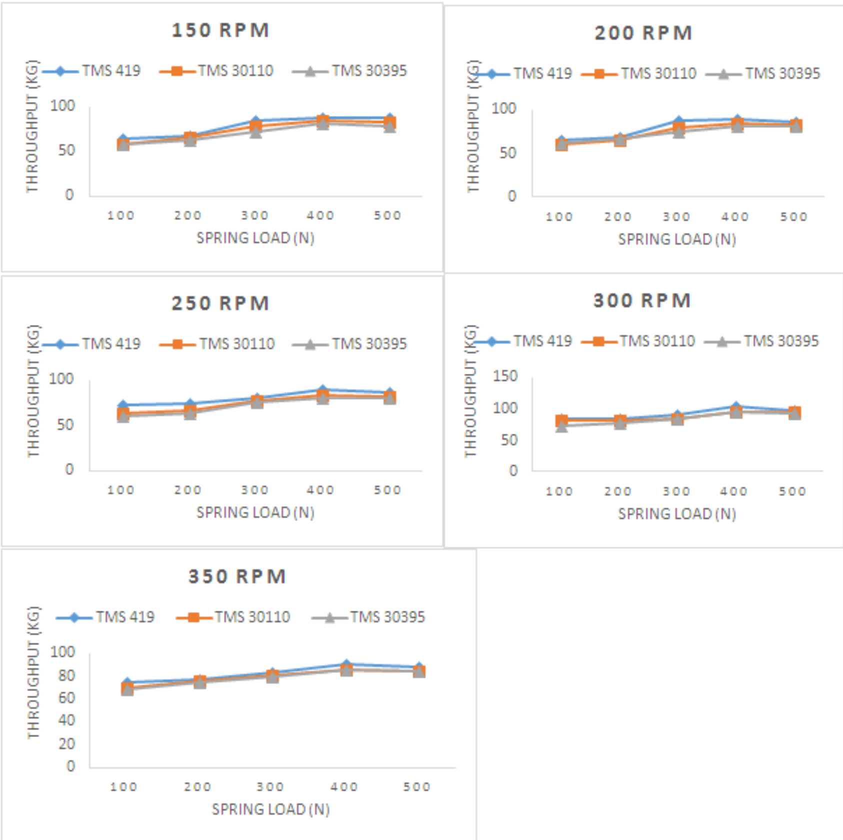

Fig. 2: Effect of Spring load on Throughputs at various Speed

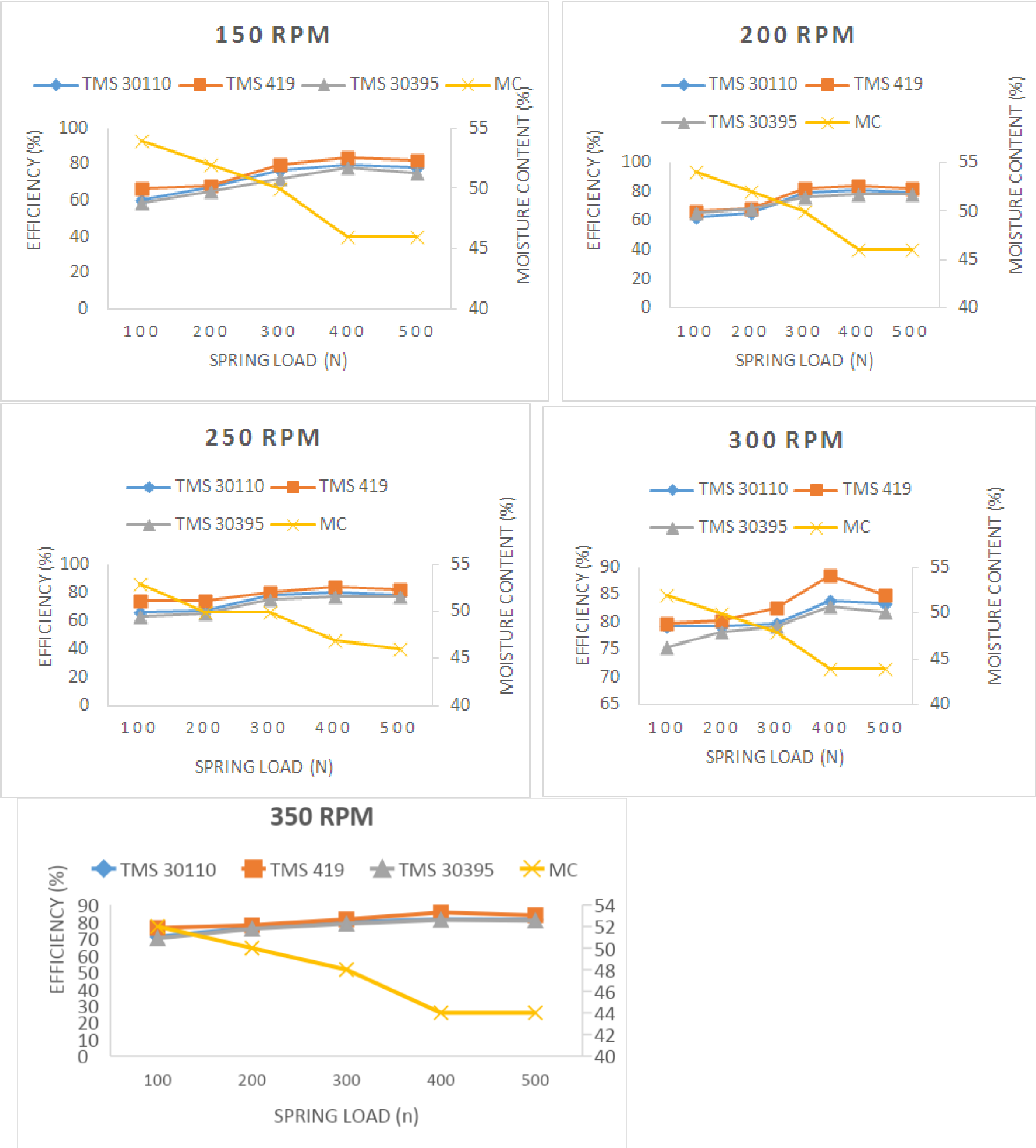

Fig. 3: Effect of Spring load on Efficiency and Moisture Content at various Speed

IV. CONCLUSIONS

The grating and dewatering units of the cassava processing machine were evaluated. Five grater speeds (1100, 1200, 1300 1400 and 1500 rpm), five dewatering speeds (150, 200, 250, 300, and 350 rpm) and five compression spring loads (100, 200, 300, 400 and 500 N) were tested on three recommended cassava varieties (TMS 30110, TMS 419 and TMS 30395). Both the grated cassava mash and the dewatered mash cake came out very clean, free from foreign materials. The machine operates with minimum human contact, a reduction in the risk of cyanide exposure. The quality and the quantity obtained from the machine met the requirement of the stakeholders. 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 results from performance evaluation of the cassava processing machine showed that, 1400 rpm grater speed has the highest of 184.40 kg/h grating capacity and 158.06 kg/h throughput from 10 kg TMS 419 of cassava tuber in the grating experiment. Also in the combine machine (grating and dewatering) experiment, 1400 rpm grater speed, 300 rpm screw expeller speed and 400 N compression spring load has the highest of 115.98 kg/h machine capacity, 102.82 kg/h throughput, 1.15 litres of moist starch, 45% wb moisture content and 88.6% efficiency respectively from 10 kg cassava tuber varieties. The moisture content 45% wb obtained was within recommended value. Also clogged and losses recorded during machine operation were negligible.

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