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Performance Evaluation of a Yam Pounder Cum Boiler

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***Abstract*—** Pounded-yam popularly called "Iyan" in Yoruba land, south west of Nigeria is traditionally prepared with wooden mortar and pestle, but due to associated problems with the preparation of the food, a motorised Yam Pounder Cum Boiler was designed and fabricated in the Department of Agricultural and Bio-Environmental Engineering, Auchi Polytechnic, Auchi Nigeria. The performance evaluation of the machine was carried out using a factorial experiment in a Randomised Complete Block Design (RCBD) involving three levels of speed (380, 479 and 565rpm) and three levels of feedrate (0.6, 1.2, 1.8kg) in three replications. The result obtained was statistically analysed using SPSS 16.0 software for Analysis of Variance (ANOVA) and Duncan's New Multiple Range Test (DNMRT) to determine the level of significant among the treatment factors. The performance parameters considered for measurement are Pounding Efficiency (%), Pounding Capacity (kg/hr) and Percentage of Lumps (%). The results from the investigation obtained are 93%, 100.80 kg/hr and 7%, for Optimum Pounding Efficiency, Pounding Capacity and Percentage of Lumps respectively at Speed of 380 rpm and Feedrate of 1.8kg/min. Also, the result of the statistical analysis shows that the machine speed, feedrate and the interactions between them are all significant factors on the Pounding Capacity, Percentage of Lumps and Pounding Efficiency of the machine at 5% confidence level.

***Keywords*—** Pounded-yam (Iyan), lump, yam-pounder, feed rate, mortar and pestle.

I. INTRODUCTION

Pounded-yam is a special food that is eaten all over the parts of Nigeria and Africa at large. Boiled yam is pounded in a mortal to form a mass of sticky-bond starchy food called pounded-yam or "Iyan" in Yoruba land located in south-west of Nigeria. It is eaten together with a choicest soup like ogbono, ewedu and spinach with egusi soup. Any of these soups when eaten together with pounded-yam form a special delicacy in Nigeria. The egusi-vegetable soups, when garnished with dried fish or bush meat like grasscutter, form a balance diet when eaten together with pounded-yam that is purely a carbohydrate food.

Yam is the common name for its entire species and it is a perennial herbaceous vine crop. The different species like Discorea esculenta (white yam), Discorea cayenensis (yellow yam), Discorea rotundata and Discorea alata (greater yam) can be used for preparing pounded-yam [1]-[3]. Yam is widely cultivated and consumed for its starchy tubers all over Africa, Asia and Latin America [4]-[6]. It is an important source of carbohydrate for many people in sub-sahara region, especially in West Africa [7], [3]. The World yam production was estimated at 29.1 million metric tonnes and 96% of these yams came from West Africa with 26.6 million metric tonnes being produced in [4], [8]. Yam is observed to have lower Glycemic Index than potato tuber [9]. This attribute make yam provides a more sustained energy that protects the consumer against diabetes and obesity [10]. According to [11] as reported by [3], Discorea rotundata was analysed to have nutritional qualities of 80% starch, 7% protein, 1.7% lipid, 7% mineral, 3% fibre and 64% moisture content with 385kcal energy from 100g of white yam.

Wooden mortar and pestles are the local tools that are being used in preparing pounded-yam traditionally, but recently machines were designed to handle the processing of pounded-yam in Nigeria. Among the researchers that have worked on Yam Pounders are [3], [4], [8] and [11] just to mention few names. The population figure of Nigeria is over 160 million and about 80% of this population preferred eating pounded-yam on a daily basis all over the country. However, due to hardship involved in traditional method of pounding yam, about 90% of Nigeria population now settles for other food like rice, indomie, beans, bread, boiled yam e.t.c. Most house wives in Nigeria today could no longer pound boiled yam with mortar and pestles, instead, they resort into cooking boiled yam with fried egg or cooking western dishes like Indomie, spaghetti and jolof rice for their household. However, research has shown that most husbands and children in Nigeria today still prefer eating pounded-yam, but they are being denied of it by the wife in such household who could not go through the rigour of preparing pounded-yam. Preparing this popular local dish "Iyan" with traditional method is a serious problem in Nigeria today.

Traditional method of preparing pounded-yam involves peeling of yam tubers, cutting it into pieces, washed and carefully arranged in a pot with water for boiling. The pieces of yam with water in a pot is left on the fire to boil for about 40 to 50 minutes, after which the boiled yam is transferred into the

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mortar one by one in preparation for pounding operation. The traditional yam pounding process involves 2 – 3 strong men or women depending on the size of mortar and the quantity of boiled yam in the mortar. Each of these pounders holds a pestle in his or her hands with which he or she pounds. The two or three pounders do the pounding repeatedly in a systematic way until the texture of the pounded-yam become smooth and soft, without lumps as shown in Figure 1.

Figure 1. Pictorial view of men pounding yam traditionally with mortar and pestle.

The pounding operation usually last for about 30 – 40 minutes depending on the quantity of boiled yam in the mortar. Thereafter, the pounded-yam is served in flat plate with choicest soup and meat served along with it in another plate. This pounding operation is observed to be stressful and time consuming. It is these problems discussed below that make most housewives in Nigeria avoid preparing pounded-yam for their household except on special occasions. The associated problems with traditional yam pounding method are briefly summarized as follows: body fatigue, time consuming, unhygienic preparation and poor coloration with impurity. Therefore, the main objectives of this research are to design a functioning and efficient Yam Pounder with Boiler with the hope of providing solution to the problems associated with the traditional method of preparing pounded yam and to carry out the performance evaluation of the machine.

II. MATERIAL AND METHOD

1. *Description the Yam-pounder*

Fig. 2 shows the pictorial view of the motorized yam pounder with boiler and the samples of pounded-yam prepared with the pounding machine. The materials used in fabricating the yam-pounder were carefully selected to avoid excessive weight and to ensure high level of food hygiene in material handling. The average weight of the pounding machine is 41.30kg. The yam boiling and pounding pots of this machine were fabricated from stainless steel. The two compartments of the pounder cum boiler are described as follows:

The yam pounder with the boiler unit is an electrically operated motorized machine designed to cook and pound pieces of fresh yam with rotary beater mechanism. The yam-pounder with boiler was designed to process the pounded-yam through the boiling and pounding stages hygienically. The major aim of this design is to fabricate a portable and affordable efficient yam pounder for a household with maximum of six people. The machine was designed with two compartments, the cooking and the pounding compartments.

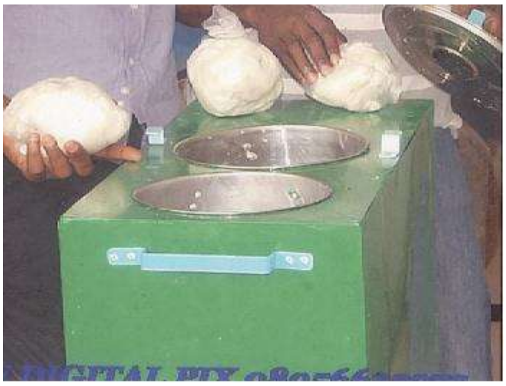

Figure 2. Pictorial view of the Pounder with Boiler

A. *Yam Boiling Compartment*

Figure 3 shows the boiling compartment of the yam pounder. The aim of adding yam boiler to this design is to maximize the available cooking space, power source and to prevent the use of firewood or separate kerosene stove for cooking the yam. The yam boiling section is made up of electric coil and a stainless boiler-pot that was placed directly on the coil. The heat transfer method is by conductor.

Figure 3. Boiling Compartment in operation with pieces of boiled yam

B. *Yam Pounding Compartment*

The pounding compartment is as shown in plan-view in Fig. 4. The compartment is made up of a pounding beater in a stainless pot with cover. The pot maximum pounding volume was estimated at 0.025m3. The beater of the pounder was mounted on the driving shaft with a belt pulley as shown in Fig.1. The bigger pulley on the driving shaft transmits power from the electric motor to the pounding compartment through the V-belt.

Figure 4. Pounding Compartment in pounding operation

C. The Frame of the Pounding machine

The frame of this machine is made up of angle bar and hollow rectangular bar made from mild-steel. The frame holds the two compartments together and at the same time housed the electric motor that generates the required power for operating the yam pounder. The various dimensions of the machine frame and the position of the electric motor is as shown in sectional view in Fig. 1.

2. Performance Procedure

The tuber of yam used in carry out performance evaluation of the machine was peeled, sliced into small sizes, and weighed as shown in Fig. 5. The pieces of yam were neatly arranged into the stainless pot with water in it as shown in Fig. 3. The pieces of yam boiled for 40-45 minutes then transferred into the stainless pounding pot. Little water was added to the boiled yam with the pot cover tightly fixed. The pounder was switched on for 50 – 60 seconds, after which the pounder was switched off. It takes maximum of 2 minutes to prepare a quality pounded-yam with this prototype.

Figure 5. Weighing machine with pieces of boiled yam

The yam pounder cum boiler after fabrication was evaluated with series of runs of weighed boiled yam. Two operating factors and three output parameters were used for the evaluation of the pounding machine. The two operating factors used are operating speeds at three levels (i.e. 565 rpm, 479 rpm and 380rpm) and feedrate at three levels (i.e. 0.5 kg/min,1.0kg/min, and 1.5kg/min). Each experimental run was replicated thrice. Hence, the machine was evaluated using a 3x3x3 factorial experiment in a Randomized Complete Block Design (RCBD) and the data obtained were statistically analyzed for analysis of variance and Duncan's New Multiple Range Test (DNMRT) using SPSS 16.0 software to estimate the effects of the two operating factors on the performance parameters of the yam-pounder. However, the performance parameters for this prototype are the Pounding efficiency, (εP), Percentage of lumps (εL) % and Pounding Capacity, (CP) kg/hr.

3. Measurements and Calculation

The three performance parameters considered for measurement are the Pounding efficiency (εP), Percentage of lump (εL)% and the pounding Capacity (CP) kg/hr and derived mathematical expressions used for estimating the performance of the Yam-pounder with boiler are stated in (1), (2) and (3) as follow:

Yam Pounding Efficiency, (ε_P)

$$\varepsilon_P = \frac{M_{wp}}{M_{wp} + M_L} \times 100\% \quad (1)$$

Percentage of lump, (εL)

$$\varepsilon_L = \frac{M_L}{M_{wp} + M_L} \times 100\% \quad (2)$$

Pounding Capacity (C_P)

$$C_p = \frac{M_{wp}}{T_P} \text{ (Kg/hr)} \quad (3)$$

Where,

M_B = Mass of boiled yam fed into the pounder (kg)

M_L = Mass of Lumps picked-up in the pounded-yam (kg)

M_{wp}= Mass of well pounded yam (kg)

M_{wp}= M_B – M_L (kg)

T_P = Total time taken for pounding operation (hr)

III. Results And Discussion

The data generated for the calculated average value of pounding capacity, pounding efficiency and percentage lumps at different federates are as shown on the Table 1.

Table 1: average values of pounding capacity, pounding efficiency and percentage lumps at different federate using the pounding machine.

TABLE.I Average values of pounding capacity, pounding efficiency and percentage lumps at different federate using the pounding machine

Speed (rpm)	federate (kg/min)		
	0.6	1.2	1.8
Pounding Capacity (kg/hr)			

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580	0.42±0.006	0.40±0.010	0.35±0.006
483	1.09±0.006	1.08±0.006	1.02±0.006
363	1.68±0.006	1.64±0.006	1.57±0.006
b. Pounding Efficiency (%)			
580	70.0±0.580	66.0±0.290	58.0±0.760
483	91.0±1.000	90.0±1.000	85.0±0.500
363	93.0±0.290	91.0±1.260	87.0±0.500
c. Percentage Lumps (%)			
580	30.0±0.560	34.0±0.290	42.0±0.500
483	9.0±0.500	10.0±0.290	15.0±0.500
363	7.0±0.290	9.0±0.290	1.3.0±0.290

TABLE.IV Analysis of Variance (ANOVA) for the Effects of Speed and Feedrate on Percentage Lumps

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3912.685[a]	8	489.086	2.935E3	.000*
Intercept	9482.815	1	9482.815	5.690E4	.000*
speed	298.019	2	149.009	894.056	.000*
feedrate	3579.796	2	1789.898	1.074E4	.000*
speed * feedrate	34.870	4	8.718	52.306	.000*
Error	3.000	18	.167		
Total	13398.500	27			
Corrected Total	3915.685	26			

*Significant at $P \leq 0.05$

Each value is the mean of triplicate ± standard deviation of the pounding capacity, pounding efficiency and percentage lumps at different federate.

The Result of Statistical Analysis of Variance (ANOVA) for the effect of speed and feedrate on the pounding capacity, pounding efficiency and percentage lumps is as shown on the Table 2, Table 3 and Table 4 respectively.

TABLE.II Table 3: Analysis of Variance (ANOVA) for the Effects of Speed and Feedrate on Pounding Capacity of the Machine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.956[a]	8	.870	2.134E4	.000*
Intercept	28.480	1	28.480	6.990E5	.000*
speed	.030	2	.015	371.545	.000*
feedrate	6.924	2	3.462	8.497E4	.000*
speed * feedrate	.002	4	.001	13.727	.000*
Error	.001	18	4.074E-5		
Total	35.436	27			
Corrected Total	6.957	26			

*Significant at $P \leq 0.05$;

TABLE.III Analysis of Variance (ANOVA) for the Effects of Speed and Feedrate on Pounding Efficiency of the Machine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4054.741[a]	8	506.843	882.887	.000*
Intercept	178526.676	1	178526.676	3.110E5	.000*
speed	306.019	2	153.009	266.532	.000*
feedrate	3702.019	2	1851.009	3.224E3	.000*
speed * feedrate	46.704	4	11.676	20.339	.000*
Error	10.333	18	.574		
Total	182591.750	27			
Corrected Total	4065.074	26			

*Significant at $P \leq 0.05$

The Tables show that the two factors (i.e speed and feedrate) and interactions between them are all significant on the pounding capacity, pounding efficiency and percentage of lumps of the machine at $p \leq 0.05$. Further analysis of the result using Dunce's New Multiple Range Test (Table 5) was carried out to know the level of significant among the treatment factors.

Parameters	Feedrate (kg/min)			Speed (rpm)		
	0.6	1.2	1.8	580	483	363
Pounding Capacity (kg/hr)	0.3900[a]	1.0622[b]	1.6288[c]	1.0600[c]	1.0400[b]	0.9811[a]
Pounding Efficiency (%)	64.778[a]	88.833[b]	90.333[c]	84.833[c]	82.333[b]	76.778[c]
Percentage Lumps (%)	35.000[c]	11.389[b]	9.833[a]	15.278[a]	17.722[b]	23.222[c]

Mean with different letters are significantly different at 5% confidence level

The Duncan's new multiple range test shows the degree of significance differences in each of the factors. It can be observed from the table that the pounding capacity, pounding efficiency and percentage lumps obtained at different levels of speeds and feedrates are significantly different from one another.

A. Effect of Operating Factors on the Pounding Capacity of the Machine

The effects of pounding speed and feedrate on the pounding capacity of the machine is as shown in Figure 6, which shows that the pounding capacity of the machine increases with increase in feeding rate and the pounding speed of the machine.

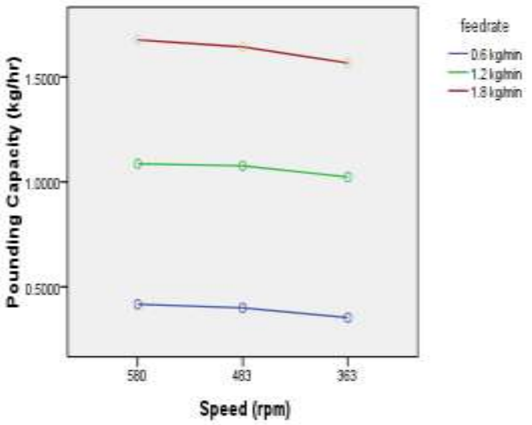

Figure 6. Effect of Pounding Speed and Feedrate on the Pounding Capacity of the Machine

B. Effect of Operating Factors on the Pounding Efficiency of the Machine

The effects of pounding speed and feedrate on the pounding efficiency of the machine is as shown on the figure 7. The figure shows that the pounding capacity of the machine also increases with increase in feeding rate and the pounding speed of the machine.

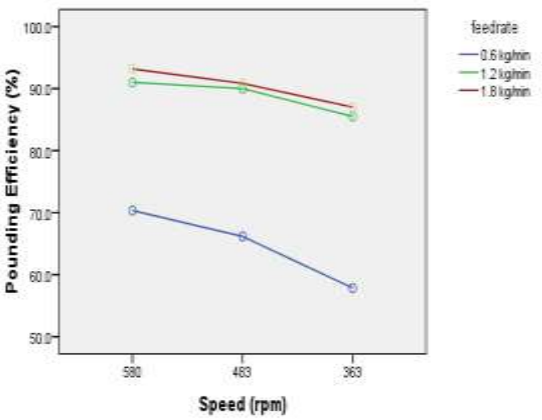

Figure 7. Effect of Pounding Speed and Feedrate on the Pounding Efficiency of the Machine

C. Effect of Pounding Speed and Feedrate on the percentage lumps

The effects of pounding speed and feedrate on the percentage of lumps found in pounded yam prepared using the machine is as shown on the figure 8. The figure shows that the percentage of lumps increases with decrease in feeding rate and pounding speed of the machine.

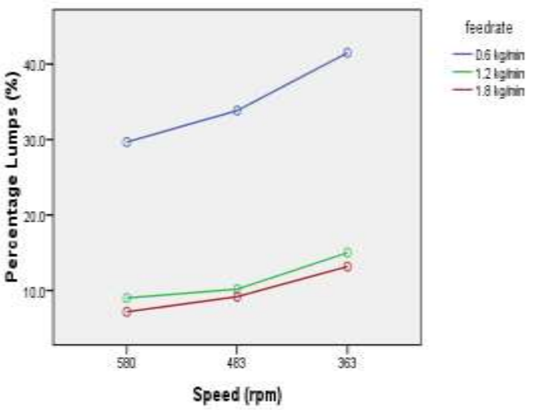

Figure 8. Effect of Pounding Speed and Feedrate on the percentage lumps

IV. CONCLUSION

In conclusion, results of the various investigations made in this study shows that good interactions exist between the investigated operating factors and the performance parameters of this yam pounder. The results obtained during the investigations are:

- The optimum pounding efficiency of this prototype was estimated to be 93% at optimum operating speed of 380 rpm and Feedrate of 1.8kg/min.
- In addition, pounding capacity of this prototype was estimated to be 1.68kg/min (or 100.80 kg/hr) at optimum operating speed of 380 rpm and federate 1.5 kg/min. Therefore, the man-hour per kilogramme for preparing of pounded yam with this prototype was estimated at 0.009921hr/kg (or 0.595mim/kg).

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- However, percentage of lump for this prototype was estimated at about 7% at the optimum operating speed of 380 rpm and Feedrate of 1.5kg/min.
- Hence, the pounding speed of 580 rpm and the feeding rate of 1.8 kg/min are recommended as optimum operatory factors for this yam pounder, because the performance parameters were observed to be good at this point.
- Also, the result of the statistical analysis carried out on the machine shows that both the pounding speed and the feedrate have significant effect on the pounding capacity, percentage lumps and pounding efficiency of the machine. That is, the higher the operating speed and feedrate, the higher the pounding capacity and pounding efficiency of the machine with lower percentage of lumps found in the pounded yam.
- Traditional yam pounding method was observed to have the highest pounding efficiency, of 97% with lowest percentage of lump of 3%. Also, the Tradition yam pounding capacity was estimated at 0.058kg/min (or 3.48kg/hr). Hence, the man-hour per kilogramme for preparing pounded-yam manually was estimated at 0.2874hr/kg or 17.24min/kg. This result shows that the traditional method is more efficient but very slow and full of drudgery. However, this prototype was rated to be about 29 times faster than the traditional method of preparing pounded-yam with high level of hygiene.

REFERENCE

[1] International Institute of Tropical Agriculture, IITA "Root and Tuber Systems" 2008

[2] S. P. Ayodeji, and T. E. Abioye "Development and Performance Evaluation of a parboiling machine for poundo-yam flour processing plant". Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS). 2 (5): 853 – 857. 2011.

[3] J. O. Olaoye and S. N. Oyewole, "Optimization of some "poundo" yam production" parameters. Agric. Eng. Int: CIGR Journal, 14 (2): 1 – 15. 2012.

[4] A. O. Odior, and E. S. Orsarh, "Design and Construction of a Ya m Pounding Machine". International Journal of Natural and Applied Sciences (IJNAS). 4 (3): 319 – 323. 2008.

[5] H. D. Mingouna,., M. M. Abang and R. Asedu, "Harnessing Modern Biotechnology for Tropical Tuber Crop Improvement: Yam (Discorea spp.) molecular breeding". [Online]. 2003

[6] J. Brand-miller, J. Burani, and K. Foster-powell, "The Glucose Revolution Pocket Guide to the top 100 low GI Foods". ISBN 1-56924-500-2. 2003

[7] N Akissoe, C. Mestres, J. Hounhouigan, and M. Nago, "Biochemical Origin of Browning During the Processing of Fresh Yam (Dioscorea spp.) into Dried Product". Journal of Agric. Food Chem. 53 (7): 2552-2557. 2003.

[8] D. E Kay "Root crops. Tropical Development and Research Institute", London. 1987

[9] S. Walsh, "Plant Based Nutrition and Health". ISBN 0-907337-26-0.NY. 2003.

[10] T. Egbe, T. Agbor, and S. Trench, "Variability in the Chemical Composition of Yams Grown in Cameroon. In Tropical Root Crops production and uses in Africa". 3rdedition. 1984

[11] G. A, Makanjuola, "A machine for preparing pounded-yam and similar foods in Nigeria".Appropriate Technology. 1 (2): 9-11. 1974.

[12] S. P. Ayodeji, O. M. Olabanji,. and M. K. Adeyeri, "Design of a Process Plant for the Production of Poundo Yam". International Journal of Engineering (IJE). 6 (1):10 – 24. 2012