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# A Development and Evaluation of a Vertical Yam-Pounding Machine

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**Abstract:** A vertical yam pounding machine having a similar operational principle to the traditional method of pounding was developed. The machine consists of a shaft, pulleys, V-belts, bearings, an electric motor, a vertical pounder, a gear train and a pounding bowl. White yam was used to carry out a performance evaluation of the developed machine compared to a commercial yam pounder QASA® (LBQ041A, made in China) yam pounding machine and pounded yam from the traditional method of using mortar and pestle. It was observed that the traditional pounding operation, the developed and the QASA® yam pounding machines gave 89.73, 96.24 and 98.25% of well-pounded yam excluding lumps. However, the QASA® yam pounding machine is limited to a maximum of 4 kg mass of boiled yam. The average throughputs of the traditional pounding operation, the developed and the QASA® yam pounding machines were 20.3, 39.46 and 47.34 kg/h, while pounding times were 18 min, 10 min, and 5 min respectively. The developed machine had comparable quality with similar sensory scores with regards to the taste, aroma, stretchability, and mouldability to the one from the traditional method. It also had a comparative long-life span, and overall acceptability score and was preferred over the pounded yam produced by QASA® pounding machine.

**Keywords:** mortar; pounded-yam; pounding-bowl; pounding-force; traditional-pounding; vertical-pounding

## 1 INTRODUCTION

Pounded yam is the choicest sumptuous food being prepared and eaten all over Nigeria and West Africa at large. It is being processed from yam tubers. Boiled yam when pounded in a wooden mortar traditionally forms a mass of sticky-bond starchy food called pounded-yam or 'Iyan' in Yoruba, 'nriji' in igbo and 'shokora' in Hausa tribes in Nigeria. The Ekiti people are known for their love for pounded yam which is laborious to prepare for consumption. Research has shown that yam pounding traditionally using mortar and pestle is unhygienic, labour intensive and sometimes leads to musculo-skeletal disorders, especially for commercial pounders [1].

Pounding yam traditionally, occasionally changes the colour of yam due to some bleaching or peeling off in mortar as force is being applied via the pestle during the pounding process. In the quest for eliminating this stressful process of preparation, various machines had been developed by researchers [1-8] using beater which does not pound the yam in an actual sense but rather does size reduction, disintegration, dispersion, and homogenization to a variety of solid which directly cuts the cooked sliced yam into piece, "stirs" the yam in an horizontal direction, this is similar to paddle mixer/high speed mixer used in food processing industry, due to its operational design and this affects the textural quality of the pounded yam. Existing yam pounding machines are mostly for family use and the set-up principles make them difficult to upgrade for commercial use because of the associated high torque and speed requirement.

This research work made use of a vertical dumbbell shaped pounder like the traditional pestle for pounding, scrapper, pounding bowl and gear train to mention but a few. It can be used for wide range pounding (commercial and domestic) can be easily upscale, requires low torques and cost effective. It is user friendly.

The aim of this work is to develop and evaluate a vertical yam pounding machine with operational principles mimicking the traditional pounding system. To evaluate the sensory and textural characteristics of pounded yam produced by the developed machine in comparison to a commercial yam pounder and pounded yam from the traditional method of using mortar and pestle.

## 2 METHODOLOGY

### 2.1 Design Calculations

**The pounder.** The pounder was made from stainless steel solid rod in the form of a dumbbell shape.

**Volume of the scrapper.** The scrapper was made from stainless steel of length 200 mm, breadth of 15 mm and thickness of 3 mm.

**The volume of the pounding bowl.** $V_{pb}$ = volume of the pounded yam + volume of the pounder + volume the of scrapper (1)

#### 2.1.1 Determination of Pounding Force and Power Requirement

The pounding force is the force required to pound the yam to the required texture.

Pounding force = mass of the pounder × gravitational force (2)

**Pounding pressure.** $P_p = \frac{\text{Pounding force}}{\text{Area of pounding}}$. (3)

Area of the pounder, $A_p$ = surface area of the frustum head + surface area of the cylindrical rod:

$$A_p = \pi \cdot h_f \cdot (R_b + r_t) + 2\pi \cdot r_c \cdot (L_c + r_c). \quad (4)$$

**Torque acting on the pounder.** The torque acting on the pounder $T_p$ = pounding force × perpendicular distance travelled by the pounder from the line of action.

#### 2.1.2 Determination of Pulley Size

**The pounding mechanism pulley.** Assuming a speed ratio of 5 and using a driving pulley of 70 mm.

$$Speed\ ratio = \frac{speed\ of\ driving\ shaft}{speed\ of\ driven\ shaf} = = \frac{diameter\ of\ driven\ pulley}{diameter\ of\ driving\ pulley} = \frac{5}{1} = \frac{d_2}{70}. \quad (5)$$

$d_2$ = diameter of driven pulley (the eccentric shaft) = 350 mm
Since the ratio of transmission is 5:1, the diameter of the large pulley (pounding mechanism pulley) = $5d_2$
Speed of the electric motor pulley $n_e$ =1440 rpm
Speed of the pounding mechanism can be determined using:

$$\frac{n_p}{n_e} = \frac{D_e}{D_p}. \quad (6)$$

Where: $n_p$ – speed of pounding mechanism; $D_p$ – diameter of pulley on pounding mechanism; $n_e$ – speed of electric motor:

Therefore,

$$n_p = \frac{n_e \cdot D_e}{D_p} = \frac{1440 \cdot 0.07}{0.350} = 288 \text{ rpm}. \quad (7)$$

### 2.1.3 Power Required by the Pounding Mechanism

Power required by the pounding mechanism ($P_{pm}$),

$P_{pm}$ = Pounding torque × Angular speed (8)

Angular speed

$$\omega_{pm} = \frac{2\pi \cdot n_p}{60} = \frac{2\pi \cdot 288}{60} = 30.16 \text{ rad/s}. \quad (9)$$

Hence,

$$P_{pm} = T_{pm} \cdot \omega_{pm} = 3.18 \text{ N} \cdot \text{m} \times 30.16 \text{ rad/s} = 95.91 \text{ W}.$$

### 2.1.4 Power Required to Revolve the Pounding Bowl

$P_{pb}$ = Torque × Angular speed of gear train (10)

$$\omega_{pb} = \frac{2\pi \cdot n_{ps}}{60} = \frac{2\pi \cdot 72}{60} = 7.5 \text{ rad/s} \quad (11)$$

$$P_{pb} = T_{pb} \cdot \omega_{pb} = 3.18 \text{ N} \cdot \text{m} \times 7.5 \text{ rad/s} = 23.85 \text{ W}.$$

### 2.1.5 Total Power Required by the Machine

Total power required by the machine = Power required to revolve the pounding bowl + Power required by the pounding mechanism

$$P_T = P_{pb} + P_{pm} = 23.85 \text{ W} + 95.91 \text{ W} = 119.76 \text{ W}. \quad (12)$$

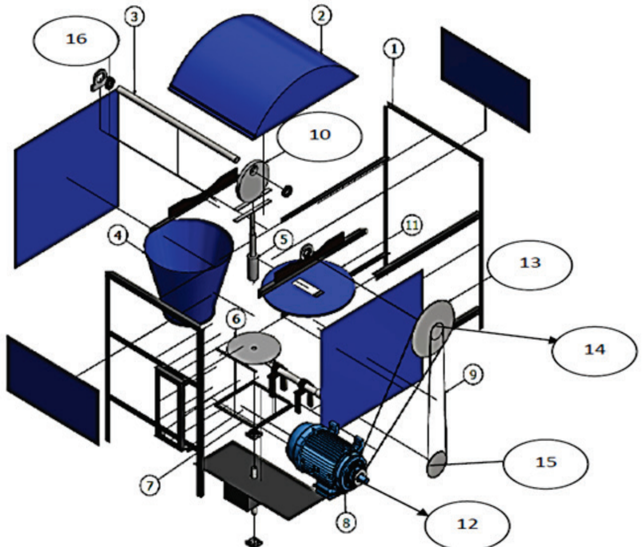
Considering the service factor by the National Electrical Manufacturers Association standard service factor of 1.25 was used, therefore the minimum power requirement for the developed machine = 1.25×119.76 = 149.7 W.

**Table 1** Description of the developed vertical yam pounder

| S/N | Part | Description | Dimension | Material | Quantity |
|---|---|---|---|---|---|
| 1 | The Pounder | A cylindrical dumbbell-shaped device designed to carry out the pounding process | $L_c$ = 0.2 m, $r_c$ = 0.025 m, $R_c$ = 0.038 m | Stainless Steel | 1 |
| 2 | The Scrapper | Scrapes the wall of the pounding bowl thereby aiding the churning and tumbling process as the pounding progresses | $L_s$ = 0.2 m, $B_s$ = 0.015 m. $T_s$ = 0.003 m | Stainless Steel | 2 |
| 3 | The Pounding Bowl | Is the frustrumic-chamber where the sliced boiled or cooked yams are poured for pounding | $R_b$ = 0.153, $r_b$ = 0.102 m. $H_b$ = 0.1903 m | Stainless Steel | 1 |
| 4 | The Base Plate | A circular plate mounted on the Gear Train that carries the pounding bowl rail slot | $D$ = 0.204 m | Mild Steel | 1 |
| 5 | Concentric Shaft | Carries the vertical pounder which converts the rotatory motion of electric motor into reciprocating motion for the pounder | $D$ = 0.030 m, $L$ = 0.8 m | Stainless Steel | 1 |
| 6 | Pulleys | Use for power transmission | 350.70 and 280 | Mild Steel | 3 |
| 7 | V-Belt | Transmit power from the electric motor to the concentric shaft of the pounding unit | A75 and A66 | Rubber | 2 |
| 8 | Gear Train | An arrangement of toothed wheels revolves the pounding bowl. | The gear tooth is 40 while the pinion tooth is 8, hence the reduction ratio is 5 to 1. | Mild Steel | 1 |
| 9 | Pounding Bowl Rail. | This provides ease for sliding in and out of the pounding bowl on the slot of the train | $L$ = 0.24 m, $B$ = 0.16 m | Mild Steel | 1 |
| 10 | Machine Frame and Housing | This houses the assembled components | $H$ = 0.85 m. $B$ = 0.50 m, $L$ = 0.60 m | Mild Steel | 1 |

## 2.2 Performance Evaluation using the three Methods of Pounding

White yam was used to evaluate the machine. The yams were manually peeled, sliced into small sizes, and weighed. The sliced yams were steam cooked. The cooked yam of masses 2, 4, 6, 8, 10 and 12 kg were pounded each using the traditional method, the developed vertical pounding machine and the QASA (LBQ041A, made in China) pounding machine sold in the market. The pounded samples were examined to determine the mass of well-pounded yam, the mass of lumps and the time taken for pounding each mass by various methods were recorded.




| PART LIST | | |
|---|---|---|
| ITEM | QTY | DESCRIPTION |
| 1 | 1 | Machine frame |
| 2 | 1 | Machine housing |
| 3 | 2 | Shaft |
| 4 | 2 | Pounding bowl |
| 5 | 1 | Pounder |
| 6 | 1 | Gear train |
| 7 | 1 | Pounding bowl rail |
| 8 | 1 | Electric motor |
| 9 | 2 | v-belt |
| 10 | 1 | Eccentric shaft |
| 11 | 1 | Cover |
| 12 | 1 | Pulley |
| 13 | 1 | Pulley |
| 14 | 1 | Pulley |
| 15 | 1 | Pulley |
| 16 | 1 | Ball Bearing |

**Figure 1** Exploded view of the developed vertical yam pounding machine

### 2.2.1 Yam Pounding Efficiency

The yam pounding efficiency ($E_p$) was determined using the following relationship:

$$E_p = \frac{m_{wp}}{m_{wp} + m_l} \cdot 100\%. \ [10] \tag{13}$$

Percentage of lump was determined using

$$E_l = \frac{m_l}{m_{wp} + m_l} \cdot 100\%. \ [10] \tag{14}$$

The pounding capacity $C_p$ was determined using

$$C_p = \frac{m_{wp}}{t_p} \left(\frac{\text{kg}}{\text{h}}\right). \ [10] \tag{15}$$

Where: $m_b$ – mass of boiled yam fed into the pounder (kg); $m_l$ – mass of lumps picked in the pounded yam (kg); $m_{wp}$ – mass of well-pounded yam (kg).

$$m_{wp} = m_b + m_l \ \text{(kg)}. \tag{16}$$

The description of the parts, dimensions, materials and quantities of the developed vertical yam pounder are presented in Tab. 1**.** The exploded view and the picture of the developed vertical pounding machine are presented in Figs. 1 and 2 respectively.

**Figure 2** The developed vertical yam pounding machine

### 2.2.2 Acceptability Test of Pounded Yam

Sensory evaluation of the pounded yam was carried out using a panellist in a sensory laboratory. Participants were given orientation and instructions regarding what was required for the test such as what kind of judgment and evaluation was to be made, handling of samples and the use of questionnaires. Three food samples were investigated with code names MOPD, QMPD and DMPD. Where: MOPD - Pounded Yam Produced by Mortar (Traditional Method of Pounding); QMPD - Pounded Yam produced by QASA® Machine; DMPD - Pounded Yam produced by Developed Machine.

The questionnaires consisted of food quality (such as Aroma, Stretchability, Mouldability, Appearance and Taste) that provided general information regarding what types of tests were to be performed, what kind of information that was requested, and what to think about when performing the test use hedonic scale (ranging from 9 = like extremely to 1 = dislike extremely).

### 2.2.3 Data Analysis

The t-test analysis was used to determine whether there were differences among the performances of developed machine compared to a commercial yam pounder QASA® (LBQ041A, made in China) yam pounding machine and pounded yam from the traditional method of using mortar and pestle.

## 3 RESULTS AND DISCUSSION

### 3.1 Pounding Time

Pounding time increases as feed mass increases as shown in various pounding methods in Tabs. 2, 3 and 4. The Pounding time of the developed machine differs from the previous pounding machine developed by other researchers. The developed machine. had pounding times ranging from 3.06, 6.50, 8.30, 11.10, 13.07 and 16.08 minutes for 2, 4, 6, 8, 10, 12 kg respectively. Oke et al. [9] reported a pounding time of 30, 40, and 60 seconds for feed masses of 1, 1.5 and 2 kg while Onuoha et al., [7] reported 1, 1.7, 2, 2.3 and 2.5 minutes for feed masses of 2, 2.5, 3, 3.5 and 4 kg respectively. It was observed that the developed machine had a higher pounding time compared to others, this is due to the difference in pounding mechanism involved. However, the pounding time of the traditional method was observed to increase as the feed mass increases similarly QASA® pounding machine.

**Table 2** Performance Evaluation of the Traditional Method of Pounding

| | $m_t$ (kg) | $m_l$ (kg) | $m_{wp}$ (kg) | $E_l$ (%) | $E_p$ (%) | $t_c$ (min) | $t_p$ (min) | $C_p$ (kg/h) |
|---|---|---|---|---|---|---|---|---|
| | 2.00 | 0.080 | 1.920 | 4.000 | 96.000 | 25.00 | 7.42 | 15.526 |
| | 4.00 | 0.220 | 3.780 | 5.50 | 94.500 | 37.00 | 12.15 | 18.667 |
| | 6.00 | 0.550 | 5.450 | 9.167 | 90.830 | 42.00 | 15.10 | 21.657 |
| | 8.00 | 0.850 | 7.150 | 10.625 | 89.375 | 47.00 | 19.25 | 22.286 |
| | 10.00 | 1.650 | 8.350 | 16.500 | 83.500 | 51.00 | 23.30 | 21.502 |
| | 12.00 | 1.900 | 10.100 | 15.833 | 84.167 | 56.00 | 27.12 | 22.345 |
| *Mean* | 7.00 | 0.875 | 6.125 | 10.271 | 89.729 | 43.00 | 17.39 | 20.331 |
| *SD* | 3.741 | 0.751 | 3.015 | 5.161 | 5.161 | 11.045 | 7.282 | 2.715 |

**Table 3** Performance Evaluation QASA Pounding Machine

| $m_t$ (kg) | $m_l$ (kg) | $m_{wp}$ (kg) | $E_l$ (%) | $E_p$ (%) | $t_c$ (min) | $t_p$ (min) | $C_p$ (kg/h) |
|---|---|---|---|---|---|---|---|
| 2.00 | 0.020 | 1.98 | 1.000 | 99.000 | 25.00 | 2.50 | 47.52 |
| 4.00 | 0.070 | 3.93 | 1.75 | 98.250 | 37.00 | 5.00 | 47.16 |

**Table 4** Performance Evaluation of the Developed Pounding Machine

| $m_t$ (kg) | $m_l$ (kg) | $m_{wp}$ (kg) | $E_l$ (%) | $E_p$ (%) | $t_c$ (min) | $t_p$ (min) | $C_p$ (kg/h) | |
|---|---|---|---|---|---|---|---|---|
| 2.00 | 0.030 | 1.970 | 1.500 | 98.500 | 25.00 | 3.06 | 32.83 | |
| 4.00 | 0.090 | 3.910 | 2.250 | 97.750 | 37.00 | 6.50 | 36.92 | |
| 6.00 | 0.155 | 5.845 | 2.583 | 97.420 | 42.00 | 8.30 | 42.25 | |
| 8.00 | 0.210 | 7.790 | 2.625 | 97.380 | 47.00 | 11.10 | 42.11 | |
| 10.00 | 0.570 | 9.430 | 5.700 | 94.300 | 51.00 | 13.00 | 46.15 | |
| *Mean* | 7.00 | 0.334 | 6.666 | 3.763 | 96.239 | 43.00 | 9.673 | 39.953 |
| *SD* | 3.742 | 0.356 | 3.419 | 2.494 | 2.495 | 11.045 | 4.687 | 4.659 |

**Table 5** Performance Evaluation of the Traditional Method of Pounding

| $m_t$ | $m_l$ | $m_{wp}$ | $E_l$ | $E_p$ | $t_p$ | $C_p$ |
|---|---|---|---|---|---|---|
| 2 | 0.08±0.00[a] | 1.92±0.00[a] | 4.00±0.00[a] | 96.15±0.21[e] | 7.43±0.01[a] | 15.53±0.00[a] |
| 4 | 0.22±0.01[b] | 3.78±0.00[b] | 5.52±0.02[b] | 94.52±0.02[f] | 12.2±0.06[b] | 18.67±0.01[b] |
| 6 | 0.55±0.00[c] | 5.45±0.00[c] | 9.17±0.00[c] | 90.83±0.01[d] | 15.12±0.03[c] | 21.67±0.02[d] |
| 8 | 0.85±0.00[d] | 7.15±0.00[d] | 10.63±0.01[d] | 89.38±0.00[c] | 19.26±0.01[d] | 22.30±0.02[e] |
| 10 | 1.65±0.00[e] | 8.35±0.00[e] | 16.52±0.02[f] | 83.49±0.01[b] | 23.35±0.07[e] | 21.52±0.02[c] |
| 12 | 1.92±0.02[f] | 10.12±0.02[f] | 15.83±0.00[e] | 84.17±0.00[a] | 27.13±0.01[f] | 22.35±0.00[f] |

Mean values with different superscript are significantly difference ($p < 0.05$)

**Table 6** Correlation Matrix between Performance Parameter of the Traditional Pounding Method

| | $m_t$ | $m_l$ | $m_{wp}$ | $E_l$ | $E_p$ | $t_p$ | $C_p$ |
|---|---|---|---|---|---|---|---|
| $m_t$ | 1 | | | | | | |
| $m_l$ | .975** | 1 | | | | | |
| $m_{wp}$ | .998** | .961** | 1 | | | | |
| $E_l$ | .970** | .979** | .959** | 1 | | | |
| $E_p$ | -.970** | -.978** | -.960** | -1.000** | 1 | | |
| $t_p$ | .999** | .973** | .997** | .967** | -.968** | 1 | |
| $C_p$ | .850** | .725** | .874** | .796** | -.800** | .846** | 1 |

** Correlation is significant at the 0.01 level (2-tailed).

**Table 7** Performance evaluation of the developed vertical yam pounding

| $m_t$ | $m_l$ | $m_{wp}$ | $E_l$ | $E_p$ | $t_p$ | $C_p$ |
|---|---|---|---|---|---|---|
| 2 | 0.03±0.00$^a$ | 1.97±0.00$^a$ | 1.52±0.02$^a$ | 98.48±0.03$^e$ | 3.62±0.03$^a$ | 32.85±0.02$^a$ |
| 4 | 0.09±0.00$^b$ | 3.92±0.01$^b$ | 2.24±0.01$^b$ | 97.75±0.01$^d$ | 6.43±0.11$^b$ | 36.88±0.06$^b$ |
| 6 | 0.16±0.00$^c$ | 5.85±0.00$^c$ | 2.56±0.03$^c$ | 97.40±0.04$^c$ | 8.32±0.03$^c$ | 42.35±0.14$^e$ |
| 8 | 0.21±0.00$^d$ | 7.81±0.02$^d$ | 2.63±0.01$^d$ | 97.37±0.02$^c$ | 11.11±0.01$^d$ | 42.16±0.07$^d$ |
| 10 | 0.57±0.00$^e$ | 9.43±0.01$^e$ | 5.74±0.06$^e$ | 94.28±0.03$^b$ | 13.68±0.04$^e$ | 42.36±0.08$^e$ |
| 12 | 0.95±0.00$^f$ | 11.05±0.00$^f$ | 7.92±0.01$^f$ | 92.08±0.00$^a$ | 16.83±0.04$^f$ | 39.46±0.01$^c$ |

Mean values with different superscript are significantly difference ($p < 0.05$)

**Table 8** Correlation matrix between performance parameter of the vertical pounding machine

| | $m_t$ | $m_l$ | $m_{wp}$ | $E_l$ | $E_p$ | $t_p$ | $C_p$ |
|---|---|---|---|---|---|---|---|
| $m_t$ | 1 | | | | | | |
| $m_l$ | .915** | 1 | | | | | |
| $m_{wp}$ | .999** | .897** | 1 | | | | |
| $E_l$ | .910** | .996** | .892** | 1 | | | |
| $E_p$ | -.910** | -.996** | -.892** | -1.000** | 1 | | |
| $t_p$ | .998** | .932** | .995** | .926** | -.926** | 1 | |
| $C_p$ | .683* | 0.36 | .710** | 0.373 | -0.375 | .643* | 1 |

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

**Table 1** Correlation of the sensory attributes for the overall acceptability of the pounded yam samples

| | Appearance | Aroma | Stretchability | Mouldability | Taste | Overall Acceptability |
|---|---|---|---|---|---|---|
| Appearance | 1.0000 | | | | | |
| Aroma | 0.9728 | 1.0000 | | | | |
| Stretchability | -0.9933 | -0.9396 | 1.0000 | | | |
| Mouldability | -0.9968 | -0.9513 | 0.9994 | 1.0000 | | |
| Taste | -0.9653 | -0.8785 | 0.9890 | 0.9830 | 1.0000 | |
| Overall Acceptability | -0.9911 | -0.9334 | 0.9998 | 0.9986 | 0.9914 | 1.0000 |

**Table 10** Analysis of variance of results obtained for sensory test

| | Appearance | Aroma | Stretchability | Mouldability | Taste | Overall Acceptability |
|---|---|---|---|---|---|---|
| MOPD | 7.02±1.19$^a$ | 6.84±1.24$^a$ | 7.96±1.04$^b$ | 7.78±1.25$^b$ | 7.88±1.35$^b$ | 7.84±1.22$^b$ |
| QMPD | 7.73±1.25$^b$ | 7.14±1.27$^a$ | 6.12±1.57$^a$ | 5.33±1.69$^a$ | 7.26±1.21$^a$ | 6.68±0.99$^a$ |
| DMPD | 6.98±1.70$^a$ | 6.72±1 26$^a$ | 7.82±1.1.21$^b$ | 7.69±1.39$^b$ | 7.74±1.27$^b$ | 7.73±1.09$^b$ |

Where: $m_t$ – feed mass (kg), $m_l$ – mass of lumps (kg), $m_{wp}$ – mass of well pounded yam (kg), $E_l$ – efficiency of lumps (%), $E_p$ – efficiency of well pounded yam (%), $t_c$ – cooking time (min), $C_p$ – pounding capacity (kg/h), $t_p$ – pounding time (min).

### 3.2 Pounding Efficiency of the Machine

The test ran with various weights of yam for the developed machine as shown in Tab. 4. The efficiency of pounding ranges from 92.083% to 98.50% the optimum efficiency of the machine was observed to be 98.5% at a feed mass of 2 kg of cooked yam and a pounding time of 3.06 minutes and the least pounding efficiency of 92.083% was obtained at a feed mass of 12 kg while 98.19, 98.80 and 93% optimum pounding efficiency at 1, 2.5 and 1.8 kg were recorded by Oke et al. [9], Onuoha et al. [7] and Adebayo et al. [10] respectively.

It is worth to note that the pounding efficiency of the machines decreases as the feed mass increases for all the machines. While the highest percentages of lumps present were found at a feed mass of 12.00 kg at 7.92% and 15.83% for the developed machine and traditional method respectively. Oke et al. [9], reported 1.81, 0.57 and 1.38% for feed mass of 1, 1.5 and 2 kg which shows that the percentage of lumps increases as feed mass increases.

### 3.3 Pounding Capacity

The QASA machine could not pound more than 4 kg of mass with 98.25% of well-pounded yam at 5 minutes similarly, the performance evaluation carried out on the developed machine showed it had an average pounding efficiency of 96.24%, an average pounding time of 10 minutes, an average lump percentage of 3.76% at an average feed rate of 7 kg and an average pounding capacity of 39.08 kg/h. Which translates to a pounding time of 1.2 min per person (that is 12 people for 10 min and 60 person for an hour). Oke et al. [9], and Adebayo et al. [10] reported an average pounding capacity of 31.71 g/s, 1.68 kg/min and pounding efficiency of 99.18, 93% respectively this is due to the stirring mechanism.

### 3.4 Power Required

The minimum power required to operate the developed vertical yam pounding machine was 149.7 W while the minimum power required for other machines that use beater were 483.632 W [3], 483.632 W [11]; 663.59 W [5] while that of Onuoha et al. [7] was powered using a 6 HP petrol engine. It is worth noting that the developed machine requires less power (energy consumption) and could be upscaled easily due to fewer torques required for pounding, unlike the previously designed machines that required high torque and high speed for its operation.

Tab. 5 shows the mean value of performance for the traditional method of pounding. $m_l$, $m_{wp}$, $E_l$, $E_p$, $t_p$ and $C_p$ ranged from 0.08 to 1.92; 1.92 to 10.12; 4.00 to 15.8; 96.15 to 83.49; 7.43 to 27.13 and 15.53 to 22.35 respectively. All dependent variables significantly ($p < 0.05$) increased with increasing total mass ($m_t$) except $E_p$. This was corroborated by correlation matrix in Tab. 6, indicating a negative correlating value (>85%). The mass of lump, mass of well pounded yam, efficiency of lumps, and pounding time highly positively correlated with the feed mass while the pounding capacity moderately positively correlated with the feed mass. However, the efficiency of well pounded yam highly negatively correlated with the feed mass. The higher the feed mass the higher the mass of lumps, mass of well pounded yam, efficiency of lumps and the pounding time. However, the efficiency of well pounded yam decreased with the feed mass (Tab. 6).

Tab. 7 shows the mean value of performance for the developed yam pounding machine. $m_l$, $m_{wp}$, $E_l$, $E_p$, $t_p$ and $C_p$ ranged from 0.03 to 0.95; 1.97 to 11.05; 1.52 to 7.92; 98.48 to 92.03; 3.62 to 16.83 and 32.85 to 39.46 respectively. All dependent variables significantly ($p<0.05$) increased with increasing total mass ($m_t$) except $E_p$. This was corroborated by correlation matrix in Tab. 8, indicating a negative correlating value (>68.3%). The higher the matrix value, the higher the correlating factor. $E_p$ also correlated negatively with $m_l$, $m_{wp}$, $E_l$, $t_p$ and $C_p$. The mass of lump, mass of well pounded yam, efficiency of lumps, and pounding time highly positively correlated with the feed mass while the pounding capacity moderately positively correlated with the feed mass. However, the efficiency of well pounded yam highly negatively correlated with the feed mass. The higher the feed mass the higher the mass of lumps, mass of well pounded yam, efficiency of lumps and the pounding time. However, the efficiency of well pounded yam decreased with the feed mass (Tab. 8).

The optimum efficiencies of the developed machine, QASA machine and traditional pounding method were observed to be 98.5%, 99% and 96% for 2 kg of cooked yam and pounding times of 3.6 min, 2.5 min, and 7.42 min respectively.

Tab. 10 shows the analysis of variance of the sensory /acceptability test result carried out on the three samples of pounded yam served to panelists of 50 persons. The mean value for sensory evaluation of pounded yam is depicted in Tab. 9. Appearance, aroma, stretchability, mouldability, taste and overall acceptability values ranged from 6.98 to 7.73, 6.72 to 7.14, 6.12 to 7.96, 5.33 to 7.78, 7.26 to 7.88 and 6.68 to 7.84, respectively. A significant difference ($p < 0.05$) was observed for all sensory attributes except for aroma. The result also indicated that samples of MOPD and DMPD have similar sensory scores for all sensory attributes ($p > 0.05$).

In terms of appearance and aroma, QMPD was rated the highest. A closer look at the results obtained showed that the appearance of the QASA® pounding machine was rated higher than the mortar and pestle (MOPD) and the developed pounding machine (DMPD). The reason for this could be because of the difference in neatness and mechanisms of their operations.

QMPD used an entirely mixing (shearing) mechanism which may not have produced much operational heat that could enhance discolouration because of non-enzymatic browning. Similarly, the aroma of QMPD was better rated compared to the two pounding systems. This may be due to the more spontaneous loss of volatility that forms the aroma of the product. QMPD operation is fully enclosed whereas DMPD and MOPD are partially and fully open. The result further shows that it could be possible to replace the old technology of mortar and pestle used by the indigenous processor with a mechanical one and still arrive at a very close or better result.

Correlation analysis (Tab. 9) showed that stretchability and mouldability were the most correlated sensory attribute to the overall acceptability of the pounded yam sample. It is interesting to note that these two properties are textural attributes. This confirms the reports of previous studies [12, 13] that pounded yam as a food product is more relished for its textural attributes.

### 3.5 Mechanism of Operation

The developed machine was made up of a vertical pounder which pounds the yam in a reciprocating motion (impact-based) and scrappers that scrapes the wall of the revolving pounding bowl while previous pounding machines developed by researchers and QASA machine used beaters for milling, disintegration, and homogenization of the yam particle in a horizontal direction to form a texture of pounded yam.

## 4 CONCLUSION

A first-of-its-kind vertical yam pounding machine has been developed. It does actual pounding with an operational principle similar to the traditional pounding method, unlike previous designs that mills the yam.

Performance evaluation and acceptability tests carried out on the developed machine showed that the Pounded yam produced with the developed machine has comparable quality with similar sensory scores with regards to the taste, Aroma, stretchability and mouldability to the one from the traditional method. Both had comparative long-life span, and overall acceptability score and was preferred over the pounded yam produced by QASA® pounding machine. Based on this study, it can be concluded that the developed machine can replace the traditional method of pounding.

### Notice

This invention has been patented in Nigeria on 08/08/2022 with Patent Number NG/PT/NC/2022/6296.

## 5 REFERENCES

[1] Craig, T. (2011). The Design of a Yam Pounding Machine, B. Engrg. The project, Department of Mechanical Engineering,

Federal University of Technology, Akure, Nigeria. Retrieved on 12 June 2019 at from: https://www.researchgate.net/publication/303802127

[2] Makanjuola, G. A. (1974). A Machine for Preparing Pounded-Yam and Similar Foods in Nigeria. *Appropriate Technology, 1*(2), 9-11.

[3] Odior, A. O. & Orsarh, E. S. (2008). Design and Construction of a Yam Pounding Machine. *International Journal of Natural and Applied Sciences (IJNAS), 4*(3), 319-323. https://doi.org/10.4314/ijonas.v4i3.49868

[4] Osueke, C. O. (2010). *Design and Construction of a yam pounding machine*. Department of Mechanical/Production Engineering Enugu State University of Science and Technology, Enugu State, Nigeria.

[5] Ikechukwu, G. A. & Muncho M. J. (2015). Development of a Motorized Yam Pounding Machine Design to Improve Standard of Living for Sustainable Economic Development in Nigeria. *Proceedings of the World Congress on Engineering 2015 Vol II (WCE 2015)*, July 1-3, 2015, London, U.K.

[6] Godswill, O., Essienubong, I. A. & Orhorhoro, E. K. (2016). Comparative Analysis of Yam Pounding Machine and the Traditional Pounding Method. *International Academic Journal of Innovative Research, 3*(12), 1-12.

[7] Onuoha, S., Atanda, E. O. & Unuigbe, M. O. (2019). Design, Fabrication and Testing of Yam Pounding Machine. *Journal of Mechanical and Civil Engineering, 16*(1), 68-78.

[8] Olaleye, S. A., Arisoyin, A. G., Omoniyi, O., Elemide, O. A. & Okunola, A. (2020). Development of indigenous yam pounding machine for home use. *IOP Conf. Series: Earth and Environmental Science*, 445. https://doi.org/10.1088/1755-1315/445/1/012010

[9] Oke, M. O., Akinbode, A. O., Sadiq, I. L., Sulaiman, K. A., Olaniyan, S. A. & Hussein, J. B. (2017). Development and Evaluation of an Improved Electromechanical Yam Pounding Machine. *LAUTECH Journal of Engineering and Technology, 11*(1), 24-32.

[10] Adebayo, A. A., Yusuf, K. A. & Oladipo, A. (2014). Fabrication and Performance Evaluation of a Yam Pounder Cum Boiler. *Scientia Agriculturae, 8*(3), 112-120.

[11] Oweziem, B. U., Chinwuko, E. C., Ezeliora, C. D., & Obaseki, E. (2015). Design, fabrication and characterization of an electric-powered yam pounding machine. *American Journal of Mechanical Engineering and Automation, 2*(2), 26-35.

[12] Nindjin, C., Otokore, D., Hauser, S., Tshcannen, A., Farah, Z. & Girardin, O. (2006). Determination of relevant sensory properties of pounded yams (Dioscorea spp.) using a locally based descriptive analysis methodology. *Food Quality and Preference, 18*(2), 450-459. https://doi.org/10.1016/j.foodqual.2006.05.005

[13] Otegbayo, B., Aina, J., Abbey, L., Sakyi-Dawson, E., Bokanga, M. & Asiedu, R. (2007). Texture profile analysis applied to pounded yam. *Journal of Texture Studies, 38*, 355-37. https://doi.org/10.1111/j.1745-4603.2007.00101.x

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