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Performance Evaluation of Garri Rotary Fryer with Brush Scrapping Device

D.H Oladebeye[1], W. A, Issa[2], E.R Adefidipe.[3]

1(Mechanical Engineering Department, TheFederal Polytechnic, Ado Ekiti, Nigeria)
2(Mechanical Engineering Department, Kwara State University, Malete, Nigeria)
3(Olusegun ObasanjoCentrefor EngineeringInnovation, The Federal Polytechnic, Ado Ekiti, Nigeria)

Abstract:

A gari rotary fryer with brush scrapping device designed using Computer Aided Design (CAD), and fabricated.The paddle shaft is driven by a synchronous electric motor of 3.75kw with 1460rpm. The turn out as being recorded from performance evaluation given at 3kg of cassava mash fried produced 2.7kg in 6minutes at an average temperature of 77^{0}C. After considering the mass before frying, mass of charcoal used for frying, moisture loss, mass of net gari fried, time for frying, moisture loss, mass of gari net gari fried, time for frying and rate of frying, the machine has an efficiency of 90%.

Keywords: Cassava, gari, performance, frying machine

I. INTRODUCTION

Gari frying is the most critical unit operation in the processing of cassava into gari. It is also a combination of simultaneous cooking and drying processes. Gari is a processed fermented product from cassava and is consumed in Nigeria as well as in most countries of the West African coast and in Brazil. Though a dehydrating process, gari frying is not a straight forward drying process. The product is first cooked with the moisture in it and then dehydrated. The heat intensity during frying affects the quality of the product. The moisture content of dewatered and sieved cassava mash is between 50 to 65% which has to be reduced to 12% after the frying operation. At the end of the frying operation, the product is still hot and a little bit damp, it is then left to cool and dry in a cool dry shade until the moisture content is reduced to 12%. At the villages, gari is fried in shallow iron pans, or in the more traditional areas in earthenware pans, over an open wood fire.

Nigeria is the world largest producers of Cassava. Nigeria cassava production is by far the largest in the world, a third more than production in Brazil and almost doubles the production of Indonesia and Thailand in other African countries, The Democratic Republic of Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda. Nearly 90% of cassava production in Nigeria is for domestic food production and produced by smallholder farmers, (DADTCO, 2011).

II. LITERATURE REVIEW

The review of previous developments in gari frying machines shows that during gari frying operations, the moisture content reduces and most of the small lumps developed are broken down by constant pressing and agitation, the heat is then increased in order to further cook and dehydrate the product. This product is still hot and a little damp at the end of the frying operation. It is then left to cool and dry in a cool dry shade until the moisture content is reduced to 12% (Ikechukwu and Maduabum, 2012). Earlier design on gari production plants did not produce the desired acceptable cassava product for the consumers. The designers of those plants did not take into account the specifications of the existing local technology. Traditionally, gari is fried by women in shallow earthenware cast-iron pans (agbada, Nigerian ibo) over a wood fire. Women use spatula-like paddles of wood or calabash sections to press the sieved mash against the hot surface of the frying pan and turn it vigorously to avoid caking. The operator sits sideways by the fireplace while frying. The discomfort due to heat and the sitting posture of the operator have been of concern to researchers.

In the present day Nigerian market, the are few mechanized gari processing plants. As a result, some new designs and improvements have been made by Nigerian Engineers and manufacturers to solve the problems associated with the models already in the market. Some of these models are:

Newell Dunford model by Newell Dunford Company in London and Federal Institute of Industrial Research (FIIRO), Oshodi in Nigeria; Fabrico model by Fabrico company in Nigeria; UNN model (University of Nigeria, Nsukka) designed by Odigboh and Ahmed (1982); Unibadan model designed by Igbeka and Akinbolade (1986) in the University of Ibadan, Nigeria and Ajayi and Olakunle (2010) gari fryer.

The University of Ibadan improved gari fryer (Igbeka J.E.) is made of a fireplace oven with a chimney and a frying pan. Details of the construction can be obtained in Egba (1987).Fields tests amongst gari producers showed that the improved models had the following advantages over the village fryer:

(a) The nuisance of smoke was totally eliminated.
(b) Sweating by the operator was drastically reduced as a result of the improved fireplace.
(c) The capacity and rate of frying were increased. (e.g. 5kg dewatered and sieved mash took 20 min to fry as opposed to 1hr).
(d) Improved working environment.

The resent work is to carry out the performance evaluation of Gari Rotary Fryer with brush scrapping device to determine the frying rate, efficiency and the capacity of the machine.

III. TESTING OF THE GARRI ROTARY FRYER .

The machine was test run to ascertain its proper functionality. The shaft was ensured it was properly seated to prevent excessive vibration; the paddles on it were tested to ensure the wire brush hasmoderate rubbing effect against the wall of the drum. The machine was ensured to run at the required speed and moderate vibration. Lastly, the belt tension was tested to ensure the tight and slack are in order to prevent the flying out of the belt from the pulley grooves.

IV. PERFORMANCE EVALUATION AND RESULT

Dewatered cassava mash 25kg was used to test for the performance evaluation of the machine. After sieving this cassava mash, the sieved cassava mash was weigh to be 21kg,it divided into seven samples of 3kg each. Individual sample was fed into the machine one after the other and the machine runs for some time to fry them. The charcoal of 7.1kg was set burning which supplied heat to the machine. The resilience time for individual sample was taken and recorded.

Machine parameter used for the test are wire brush, paddle rotation, motor speed of 1460rev/mm, 5hp prime mover, and heat supplied by the charcoal and frying of the cassava mash

.$M_{b1} = M_{b2} = M_{b3} = M_{b4} = M_{b5} = M_{b6} = M_{b7}$ = 3kg (Mass of samples before frying)

M_a = mass of sample after frying (kg)

M_{Laf} = mass loss after frying due to moisture removed (kg)

M_{Waf} = mass of waste after frying due to sieving (kg)

M_{Cf} = mass of Charcoal used for frying (kg)

M_L= moisture loss (%)

M_{Nfg} = Net mass of fried gari (kg)

M/RF = Rate of frying per mass (kg/s)

T_f = Resilience time for frying (kg)

PARAMETERS EVALUATION

$$mass\ of\ charcoal\ pot = 2.3kg$$

$$mass\ of\ charcoal\ pot + charcoal\ = 9.4kg$$

$$Total\ mass\ of\ charcoal\ pot = 9.4 - 2.3 = 7.1kg\ (before\ burnt$$

Initial inner temperature was 54^0C

Cooking temperature was 77^0C

$$mass\ of\ charcoal\ pot + charcoal = 4.45kg\ (after\ burnt)$$

$$mass\ of\ charcoal\ = 4.45 - 2.3 = 2.15kg$$

$$total\ mass\ of\ charcoal\ used = mass\ before\ burnt - mass\ after\ burnt$$

$$total\ mass\ of\ charcoal\ \ used = 7.1 - 2.15 = 4.95kg$$

Mass of charcoal (M_{Cf}) used per sample with respect to time

Sample 1

$$\frac{8}{48.1} \times 4.95 = 0.82kg$$

Sample 2

$$\frac{7.5}{48.1} \times 4.95 = 0.77kg$$

Sample 3

$$\frac{7.5}{48.1} \times 4.94 = 0.72kg$$

Sample 4

$$\frac{6.9}{48.1} \times 4.95 = 0.72kg$$

Sample 5

$$\frac{6.5}{48.1} \times 4.95 = 0.67kg$$

Sample 6

$$\frac{6.2}{48.1} \times 4.95 = 0.64kg$$

Sample 7

$$\frac{6}{48.1} \times 4.95 = 6.62kg$$

$$Total = 04.5kg$$

Calculation of % Moisture loss (M_L)

$$\%\, \boldsymbol{Moisture\ loss} = \frac{M_{bf} - M_{bf}}{M_{bf}} \times 100$$

Sample 1

$$= \frac{3-2}{3} \times 100 = 33\%$$

Sample 2

$$\frac{3-2.22}{3} \times 100 = 0.3kg$$

Sample 3

$$\frac{7.5}{48.1} \times 0.81 = 0.028kg$$

Sample 4

$$\frac{7.0}{48.1} \times 0.18 = 0.027kg$$

Sample 5

$$\frac{6.9}{48.1} \times 0.18 = 0.026kg$$

Sample 6

$$\frac{6.5}{48.1} \times 0.18 = 0.024kg$$

Sample 7

$$\frac{6.2}{48.1} \times 0.18 = 0.023kg$$

Sample 8

$$\frac{6}{48.1} \times 0.18 = 0.022kg$$

Mass of waste after frying (M_{Waf}) for each sample

The total waste, M_{waf}, = 0.68kg

Sample 1

$$\frac{2}{17.8.} \times 0.68 = 0.08kg$$

Sample 2

$$\frac{2.2}{3} \times 100 = 27\%$$

Sample 3

$$\frac{3-2.35}{3} \times 100 = 22\%$$

Sample 4

$$\frac{3-2.60}{3} \times 100 = 13\%$$

Sample 5

$$\frac{3-2.65}{3} \times 100 = 12\%$$

Sample 6

$$\frac{3-2.68}{3} \times 100 = 11\%$$

Sample 7

$$\frac{3-2.7}{3} \times 100 = 10\%$$

Formula Used For Other Calculated Parameters

$M_{Laf} = M_{bf - M_{bf}}$

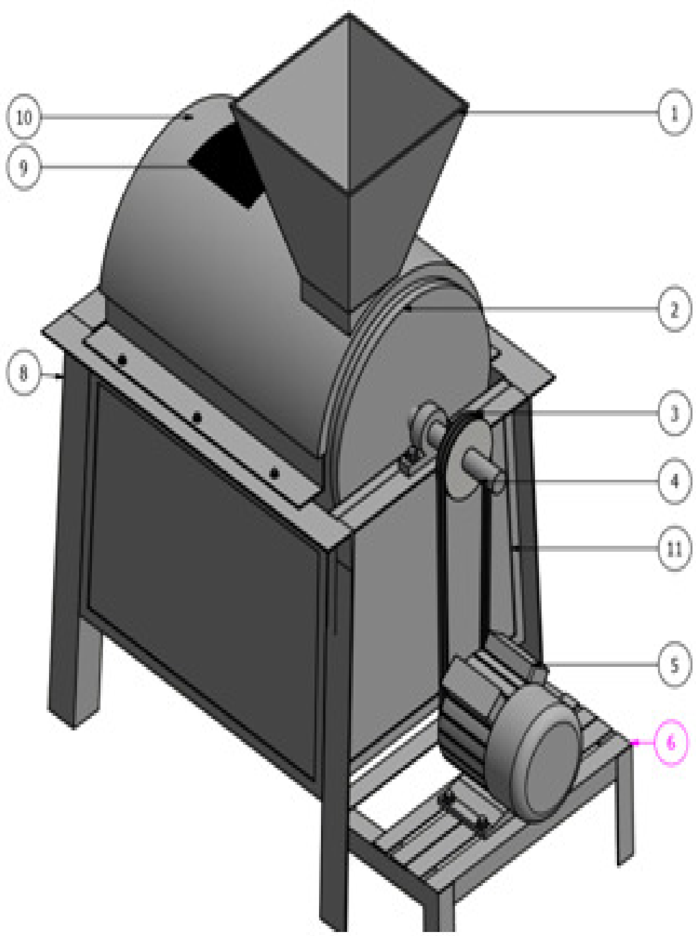
$$M_L = \left(\frac{M_{bf} - M_{bf}}{M_{bf}} (\times 100\right)\%$$

$M_{Naf} = M_{af - M_{Waf}}$

Rate of frying, RF = $\frac{M_{bf}}{T_f}$

Table 1: Result of the performance of the machine on the samples

SAMPLES	MASS OF SAMPLE BEFORE FRYING (kg)	MASS OF SAMPLE AFTER FRYING (kg)	TIME SPENT TO FRYING *(min)*	RATE OF FRYING *(kg/min)*	FRYING EFFICIENCY (%)	CAPACITY OF THE SAMPLE *(tonne/hr)*
1	3	2	8	0.36	66.7	0.022
2	3	2.2	7.5	0.40	73.33	0.024
3	3	2.35	7	0.43	78.33	0.026
4	3	2.60	6.9	0.43	86.67	0.026
5	3	2.65	6.5	0.46	88.37	0.028
6	3	2.68	6.2	0.48	89.33	0.029
7	3	2.7	6.0	0.50	90	0.030



PART NO	ITEM	DESCRIPTION	MATERIAL	QTY
13	PADDLE	LAGGED SIDE COVER	Stainless Steel	10
12	FRONT & BACK LAGGED COVER	730 X 710 X 460		2
11	LAGGED SIDE COVER	575 X 518 X 460		2
10	FRYING DRUM	Ø 455	Stainless Steel	1
9	VENT			1
8	FRAME	890 X 610 X 765	Mild Steel	1
7	CHARCOAL POT	750 X 320 X 100	Mild Steel	1
6	ELECTRIC MOTOR SEAT	580 X 400 X 200		1
5	ELECTRIC MOTOR	5hp		1
4	DRIVE SHAFT	Ø 40	Stainless Steel	4
3	DRIVEN PULLEY	Ø 300	Mild Steel	1
2	DRUM COVER	Ø 455 X 20	Stainless Steel	1
1	HOPPER	350 X 350 X 330	Stainless Steel	1

BILL OF MATERIALS

Fig. 1: An Assembled Machine.

V. Statistical Analysis of the Results

Statistical analysis involves the collection, and scrutinizing of a set of data in order to come to a conclusion on the implications and general overview of the data. Confidence Interval has been employed in the analysis of the data collected from the samples. The analyses are presented in tables 2 to 5. In order to determine the confidence interval, the mean,$\bar{x}$, the standard deviation, σ, the standard error, and the margin of error are calculated through Eqs.6 - 9.The parameters of interest include the moisture content, sieving rate, sieving efficiency, and the capacity of the machine.

$$Mean, \bar{x} = \frac{\sum x_a}{n} \quad (6)$$

$$\text{Standard deviation, } \sigma = \sqrt{\frac{\sum(x_a - \bar{x})^2}{n}} \quad (7)$$

$$Standard\ error = \frac{\sigma}{\sqrt{n}} \quad (8)$$

$$\text{Confidence interval} = \bar{x} - t_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}} \quad (9)$$

Moisture Content

Table 2: Table showing statistical analysis of Moisture Content of samples

SAMPLES	MOISTURE CONTENT REMAINING (%) x_a	$x_a - \bar{x}$	$(x_a - \bar{x})^2$
1	38.2	6.2	38.44
2	36.2	4.2	17.64
3	34.7	2.7	7.29
4	33.4	1.4	1.96
5	32.4	0.4	0.16
6	31.2	−0.8	0.64
7	30.2	−1.8	3.24
8	29.2	−2.8	7.84
9	27.8	−4.2	17.64
10	26.7	−5.3	28.09
	$\sum x_a = 320$		$\sum(x_a - \bar{x})^2 = 122.94$

$$\bar{x} = \frac{\sum x_a}{n} = \frac{320}{10} = 32\%$$

$$\sigma^2 = \frac{\sum(x_a - \bar{x})^2}{n} = \frac{122.94}{10} = 12.294$$

$$\sigma = \sqrt{12.294} = 3.506$$

$$\bar{x} - t_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}}$$

The value of t is given as 2.09 *from statistical table.*

$$32 - 2.09\frac{3.506}{\sqrt{10}} < \mu < 32 + 2.09\frac{3.506}{\sqrt{10}}$$

$$32 - 2.3172 < \mu < 32 + 2.3172$$

$$29.683 < \mu < 34.317$$

Therefore the percentage moisture content remaining in the cassava mash is between the intervals 29.683% and 34.317%, since raw cassava contains 68.20% moisture.

Table 3: Statistical Table of Frying Rate.

SAMPLES	Rate of frying $(kg/secs$ x_r	$x_r - \bar{x}$	$(x_r - \bar{x})^2 10^{-3}$
1	0.36	-0.077	5.929
2	0.40	-0.037	1.369
3	0.43	-0.007	0.049
4	0.43	-0.007	0.049
5	0.46	-0.023	0.529
6	0.48	-0.043	1.849
7	0.50	-0.063	03.969
	$\sum x_r = 3.06$		$\sum(x_r - \bar{x})^2 = 13.743 \times 10^{-3}$

$$\bar{x} = \frac{\sum x_r}{n} = \frac{3.06}{7} = 0.437$$

$$\sigma^2 = \frac{\sum(x_a - \bar{x})^2}{n} = \frac{13.743 \times 10^{-3}}{7} = 1.963 \times 10^{-3}$$

$$\sigma = \sqrt{1.963 \times 10^{-3}} = 0.044$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

$Thevalueoftisgivenas\ 2.09\ fromstatisticaltable.$

$$0.437 - 2.09 \frac{0.044}{\sqrt{7}} < \mu < 0.437 + 2.09 \frac{0.044}{\sqrt{10}}$$

$$0.437 - 0.03476 < \mu < 0.437 - 0.03476$$

$$0.402 < \mu < 0.472.$$

Therefore, it implies that the minimum rate of fry cannot be less than $0.402kg/min$, this is when the cassava mash did not loss any water at all while the maximum rate of sieve when the cassava mash is completely dewatered cannot be more than $0.472kg/min$. This is to notify that the frying rate of the machine is between the intervals $0.402kg/min$ and $0.472kg/min$.

Table 4: Statistical Table of Frying Efficiency

SAMPLES	FRYING EFFICIENCY (%) x_S	$x_S - \bar{x}$	$(x_S - \bar{x})^2$
1	66.67	-14.93	222.90
2	73.33	-8.27	68.39
3	78.33	-3.27	10.69
4	86.67	5.07	25..70
5	88.37	6.77	45.83
6	89.33	7.73	59.75
7	90	8.4	70.56
	$\sum x_s = 572.7$		$\sum (x_s - \bar{x})^2 = 503.82$

$$\bar{x} = \frac{\sum x_s}{n} = \frac{572.7}{7} = 81.6$$

$$\sigma^2 = \frac{\sum (x_s - \bar{x})^2}{n} = \frac{503.82}{7} = 71.57$$

$$\sigma = \sqrt{71.57} = 8.459$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

$The\ value\ of\ t\ is\ given\ as\ 2.09\ from\ statistical\ table.$

$$81.6 - 2.09 \frac{8.459}{\sqrt{7}} < \mu < 81.6 - 2.09 \frac{8.459}{\sqrt{7}}$$

$$88.6 - 6.662 < \mu < 81.6 + 6.662$$

$$74.94 < \mu < 88.26$$

It implies that the least frying efficiency that can be obtained from the dewatered cassava mash is 74.94% while the maximum frying efficiency that can be obtained is 88.26%, that is when the cassava mash is well dewatered and moderate cooking steam is generated. Therefore the percentage frying efficiency of the machine is between the intervals 744.94% and 88.26%.

Table 5: Statistical table of capacity of machine.

SAMPLES	CAPACITY 0F MACHINE $tonne/hr\ x_c$	$x_c - \bar{x}$	$(x_c - \bar{x})^2 \times 10^{-5}$
1	0.022	-0.004	25.60
2	0.24	-0.002	1.60
3	0.026	-0.000	0.40
4	0.026	-0.000	0.00
5	0.028	-0.002	0.00
6	0.029	-0.003	0.9
7	0.030	-0.004	1.6
	$\sum x_c = 0.185$		$\sum (x_c - \bar{x})^2 = 4.9 \times 10^{-5}$

$$\bar{x} = \frac{\sum x_c}{n} = \frac{0.185}{7} = 0.026$$

$$\sigma^2 = \frac{\sum (x_c - \bar{x})^2}{n} = \frac{4.9 \times 10^{-5}}{10} = 7 \times 10^{-6}$$

$$\sigma = \sqrt{7 \times 10^{-6}} = 0.00265$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

$$The\ value\ of\ t\ is\ given\ as\ 2.09\ from\ statistical\ table.$$

$$0.026 - 2.09\frac{0.00265}{\sqrt{7}} < \mu < 0.026 - 2.09\frac{0.00265}{\sqrt{7}}$$

$$0.026 - 0.0021 < \mu < 0.026 + 0.0021$$

$$0.0258 < \mu < 0.0262$$

The above value gives the range at which the machine is capable of producing per hour. From the value, it can be seen that the minimum amount of gari (product) the machine can produced is 0.0258tonnes/hr while the maximum amount of product is 0.0262tonnes/hr.

6.1 CONCLUSION

This machine has successfully turned dewatered sieved cassava mash into fried gari product by cooking and frying action. The operation of this machine has undoubtedly reduced the maximum production of gari at a minimum cost, this type of machine is more efficient since the conditions for withstanding rotation, vibrations and prevention against corrosion were considered during the design and construction of the machine.

After considering the mass before frying, mass of charcoal used for frying, moisture loss, mass of net gari fried, time for frying, moisture loss, mass of gari net gari fried, time for frying and rate of frying, the machine has an efficiency of 90%.

The machine can be used for small and large scale industries.

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