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Performance Evaluation of an Egusi-melon Washing Machine

Traditionally, woven basket in the flowing water stream with heaps of melon balls at the washing site is being employed in washing of Egusi-melon seeds in most local settings in Nigeria. This traditional melon washing method was observed to be associated with high level of drudgery ranging from the famers developing pains all over the body, infection with water-borne diseases and low washing output. In this study, Egusi-melon washing machine was fabricated in the Department of Agricultural and Bio-Environmental Engineering of Auchi Polytechnic, Auchi, Nigeria.The machine after construction was evaluated using a factorial experiment in a Randomized Complete Block Design (RCBD) involving three levels of speed (1008, 1482 and 1901rpm), three levels of feedrate (2.6, 3.3, and 3.9kg) and three levels of sieve size (6.0, 7.5 and 10.5) in three replications. The result obtained was statistically analyzed using SPSS 19.0 software and Duncan's New Multiple Range Test (DNMRT) to determine the level of significant among the treatment factors. However, the performance parameters considered for measurement are Washing Efficiency and Washing Capacity. Washing Efficiency and Washing Capacity of 80% and 1.16kg/min respectively was obtainedat Speed of 1008 rpm, Feedrate of 2.6kg/min and sieve size of 7.5mm. Also, the result of the statistical analysis shows that the machine speed, federate, sieve size and the interactions between them are all significant factors on the Washing Capacity and Washing Efficiency of the machine at 5% confidence level.

Keywords: *Egusi-melon, feedrate, washing efficiency, washing capacity, sieve size*

1. Introduction

Egusi-melon (*citrulluslantus*) belongs to the family of (*cucurbitaceae*), the melon with small fruits that are generally bitter and mainly grown for its seeds called Egusi in Yoruba language in the south-west of Nigeria.A tendril climbing herbaceous annual crop that grows better in some parts of the savannah belt region of Nigeria (Fursa, 1981; Mohr, 1986; Vaughan and Geissier, 1997; Sanders, *et al.,* 1999). It is cultivated widely in Africa, Middle East and West Asia like India, China and Japan (Zhang, 1996). It is extremely grown in West Africa, Namibia, Botswana, Sudan and Egypt (Kolo, 1995). However, West Africa and Central Africa are the largest producers of Egusi-melon seeds (Ladipo, *et al.,* 2000; Oyolu, 1977).

The World production records of egusi-melon seeds in 2002 were 576,000tons, harvested from 608,000ha of land. Production in Nigeria for the same year amount to (347,000tons) from 361,000ha, Cameroon produced (57,000tons), Sudan (46,0000tons), DR Congo (40,000tons), Central Africa Republic (23,000tons) and Chad (20,000tons) and China (25,000tons) (FOS, 1998 and 2003). By the above statistics, Nigeria alone produced more than half of the World production of egusi melon. Hence, melon is one of the agricultural products that can boost the Gross Domestic Product (GDP) of Nigerianif it is mass producedby mechanizing all stages of its production. Egusi-melon is largely produced and consumed by the large population of Nigeria and Africa (Iwuoha and Ike, 1996). The egusi seeds become a delicacy after it has been depodded, washed, shelled, dried, ground into coarse, whitish meal and made into pulp to cook soup called "egusi soup"(Anochili, 1978). Also, the egusi pulp when fermented is used to produced a sweetener locally called "*Ogiri*" in western Nigeria (Oyolu, 1977). In addition, quality vegetable oil that is being used for cooking, for cosmetic purposes, for soap making and of great value for pharmaceutical industries is extracted from the egusi-melon seeds. The residue from egusi-melon after the oil has been extracted can be rolled into balls and fried to produced a local snack called "*robo*" in western Nigeria or used as livestock feed (Anochili, 1978; Denton, *et al.,* 2004).

Despite all these enormous usage of the egusi-melon seed, its depodding, washing and shelling makes it difficult to process. The reason being that these operations are yet to be effectively mechanized. However, Fig. 1 shows the processing flow chart of egusi-melon seed. It requires about two to three weeks, depending on climatic condition of the area for egusi-melon balls to ferment and ready for depodding and washing respectively. The washing of egusi melon is full of drudgery, time consuming and required a lot of water and washing skills. Presently, over 95% of the egusi melon seeds produced in Nigerian markets is processed using traditional methods (Okolo, *et al.*, 2002; Adewumi, 1999; Makanjuola, 1972). This in turns has direct effect on the quantity, quality and price of the egusi-melon seeds in the market at any point in time. To ensure availability of clean egusi-melon seeds in sufficient quantities in Nigeria and World markets at all times, there is need for fabricating affordable and portable egusi melon washing machine using indigenous technology and available materials in our locality.

2. Materials and methods

2.1 Description of the Egusi-melonWashing Machine

The orthographic and isometric views of the egusi-melon washing machine are as shown on the Figure 2 and Figure 3 respectively.The machine has three main chambers; the washing, rinsing and power chambers. The various chambers and their functions are described as follows:

(i) The Washing Chamber

This is the compartment where the fermented melon pulp with the seeds is washed with the aim of separating the pulp from the seeds. The washing compartments (figure 4) were designed to accommodate a rotating circular disk and a rectangular washing sieve that does the separation.

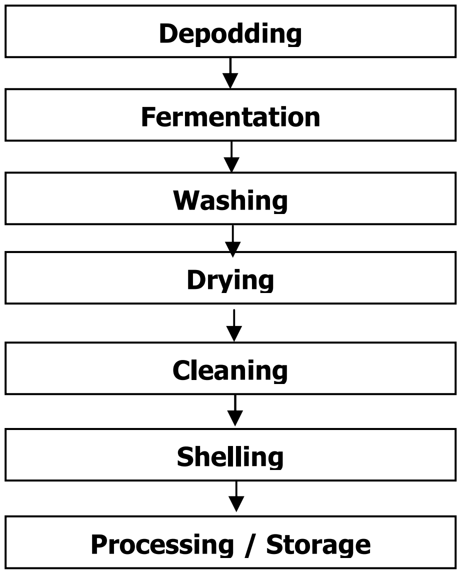

Figure 1. Flow chat of post harvest processing egusi melon seed
Source: (Anochili, 1978)

(ii) The Rinsing Chamber

The washed melon-seeds are transferred into the rinsing chamber where the melon-seeds are further washed and rinsed in a pool of water with the aim of obtaining clean melon-seeds. This compartment was designed to further agitate the melon-seeds in the pool of water to ensure the final cleaning of the egusi-melon seeds. The rinsing chamber has the same features and working principles with the washing chamber,except that it has a sieve that ensures the remover of the finest dirt from the Egusi-melon seeds.

(iii) The Power Chamber

This is the powerhouse of the washing machine. It housed the electric motor and other power transmitting elements of the machine like the pulleys, shafts, belts and bearings.A 7kw electric motor was used to power the rotors in the two chambers.

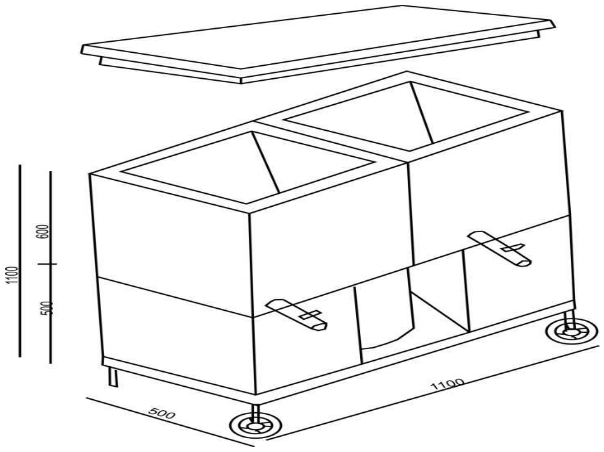

Figure 2. Orthographic views of Melon-seed washing machine

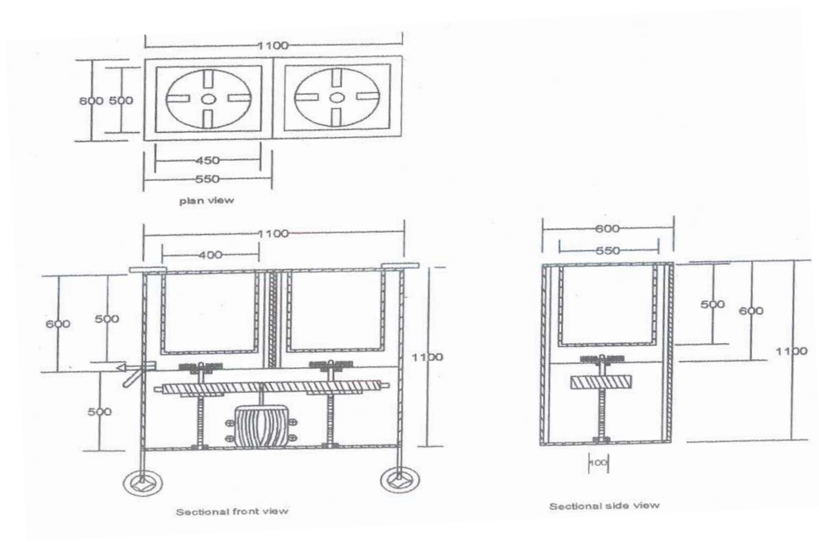

Figure 3. Isometric views of Melon-seed washing machine

(a) 6.0mm washing basket in operation (b) 7.5mm resin basket in operation

Figure 4. Showing the views of washing baskets with egusi-melon washing machine in operation

2.2. The Performance procedure

Among the required gadget for the operation of this machine is the overhead plastic water tank with minimum capacity of 5000 liters. The overhead water tank is positioned at certain height to enable free flow of water into the machine chambers by gravity. This arrangement imitates free flow of water in stream or river as it was in the traditional melon washing method. The sieves with different screen sizes replace the use of local baskets in traditional washing method. The two sieves are submerged inside the pool of water in the washing and rinsing chambers. The washing machine was switched-on for 2 – 3 minutes and then switched-off. The rotor generates turbulence as it rotates under the sieve of the washing machine. The prolong agitation of the fermented melon pulp with the seeds in the sieve of the washing and rinsing chambers separate the melon-seeds from the pulp-fibers, thereby making the two to float differently in the pool of water in the chambers. The sieves in the chambers sift away the melon pulp-fibers and retains the clean melon-seeds as shown in Fig. 4 (a & b). After the machine had been used to wash 2-3 batches of some quantities of melon-pulp, the dirty water with the sludge is drained away through the water outlet valves into a channel that drains away the slurry from the washing sites. This machine washes in batches with the aim of maximizing the available water.

Three operating factors and five performance parameters were used for the evaluation of the egusi-melon washing machine. The three operating factors are; Operating speed at three levels (i.e.1008rpm,1482rpm and 1901rpm), Feedrate at three levels (i.e.2.6kg/min, 3.3kg/min, and 3.9kg/min) at three different Sieve sizes (i.e.6.0mm, 7.5mm and10.5mm). The performance parameters considered are:the Melon-seed washing efficiency(%),Percentage of melon-seed losses(%)and Capacity of melon-seed washing machine (kg/min). The data obtained were statistically analyzed using SPSS 16.0 software for analysis of variance (ANOVA) and Duncan's New Multiple Range Test (DNMRT).

2.3. The Performance Evaluation Equations

The performance evaluating equations used for estimating the performance parameters of both the Melon-seed washing machine and the Traditional method of washing melon-seeds are stated as follows in Equations (1) - (3):

$$\eta_W = \frac{m_{fc}}{m_{fc} + m_L} \times 100\% \quad (1)$$

$$\eta_L = \frac{m_L}{m_{fc} + m_L} \times 100\% \quad (2)$$

$$C_W = \frac{m_{fc}}{T_{OP}} \times 100\% \quad (3)$$

Where, η_W = Melon-seed washing efficiency (%)

η_L = Percentage of melon-seed losses (%)
C_W = Capacity of melon-seed washing machine (kg/min)

3. Results and discussion

The data generated for the calculated average values of washing capacity and washing efficiency at different speeds, federates and sieve sizes is as shown on Tables 1, 2 and 3. The data was then analyzed statistically for Analysis of Variance (ANOVA) and Duncan's New Multiple Range Test (DNMRT) using SPSS 19.0 software.

Table 1. Average values of washing capacity and washing efficiency for 6.0mm sieve size at different speeds, federates

Speed (rpm)	Feedrate (kg/min)		
	2.6	3.3	3.9
a. Washing Capacity (kg/hr)			
1008	0.127±0.006	0.887±0.006	0.850±0.010
1482	0.550±0.010	0.907±0.006	1.030±0.010
1901	0.430±0.010	0.603±0.006	0.630±0.010
b. Washing Efficiency (%)			
1008	85.0±0.10	74.0±0.06	70.3±0.58
1482	70.0±1.00	67.0±0.10	67.3±0.58
1901	66.0±0.10	60.0±1.00	61.7±0.58

**Each value is the mean of triplicate ± Standard deviation of Washing Capacity and Washing Efficiency at different speeds and feedrates*

Table 2. Average value of Washing Capacity and Washing Efficiency for 7.5mm Sieve size at Different Speeds, Federates

Speed (rpm)	Feedrate (kg/min)		
	2.6	3.3	3.9
a. Washing Capacity (kg/hr)			
1008	0.170±0.010	0.373±0.006	0.743±0.006
1482	0.853±0.006	1.067±0.006	1.283±0.006
1901	0.353±0.006	0.603±0.006	1.453±0.006
b. Washing Efficiency (%)			
1008	80.3±0.58	74.7±0.58	84.7±0.58
1482	60.3±0.58	60.0±1.00	63.3±0.58
1901	57.3±0.58	54.0±1.00	58.3±0.58

**Each value is the mean of triplicate ± Standard deviation of Washing Capacity and Washing Efficiency at different speeds and feedrates*

Table 3. Average value of Washing Capacity and Washing Efficiency for 10.5mm Sieve size at Different Speeds, Federates

Speed (rpm)	Feedrate (kg/min)		
	2.6	3.3	3.9
a. Washing Capacity (kg/hr)			
1008	0.247±0.006	0.307±0.006	1.327±0.006
1482	0.273±0.006	0.343±0.006	0.383±0.006
1901	0.177±0.006	0.317±0.006	0.333±0.006
b. Washing Efficiency (%)			
1008	32.3±0.58	33.0±0.058	21.3±0.58
1482	26.8±0.29	32.7±0.58	25.7±0.58
1901	20.2±0.76	31.0±0.00	26.3±0.58

**Each value is the mean of triplicate ± Standard deviation of Washing Capacity and Washing Efficiency at different speeds and feedrates*

3.1. The Analysis of Variance (ANOVA)

The data were subjected to statistical analysis by considering the experiment as a 3×3×3×3 factorial design with three factors being investigated the speed and feedrate while the sieve size was considered as the blocking factor. The analysis of variance for the effect of speed, federate and sieve size on the washing capacity and washing efficiency of the Egusi melon washing machine is as shown on Table 4 and 5 respectively. The analysis shows the significance effects of the factors as well as the interaction effects.

Table 4. Analysis of Variance (ANOVA) for the Effects of Speed, Feedrate and Sieve size on the Washing Capacity of the Machine

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	11.213[a]	26	.431	8957.521	.000*
Intercept	30.840	1	30.840	640512.923	.000*
Speed	.647	2	.324	6722.538	.000*
Feedrate	3.872	2	1.936	40210.462	.000*
Sieve size	1.848	2	.924	19192.923	.000*
speed * feedrate	.528	4	.132	2741.846	.000*
speed * sieve size	2.224	4	.556	11549.038	.000*
Feed rate * sieve size	.597	4	.149	3097.423	.000*
speed * feedrate * sieve size	1.497	8	.187	3886.308	.000*
Error	.003	54	4.815E-005		
Total	42.056	81			
Corrected Total	11.216	80			

*Significant at $p \leq 0.05$

The Tables show that the factors (i.e speed, federate and sieve size) and interactions between them are all significant on the washing capacity and washing efficiency of the machine at $p \leq 0.05$. Further analysis of the result using Dunce's New Multiple Range Test (Table 6) was carried out to know the level of significant among the treatment factors.

Table 5. Analysis of Variance (ANOVA) for the Effects of Speed, Feedrate and Sieve size on the Washing Efficiency of the Machine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	33411.651[a]	26	1285.063	3985.074	.000*
Intercept	238024.726	1	238024.726	738131.807	.000*
Speed	2543.000	2	1271.500	3943.013	.000*
Feedrate	63.541	2	31.770	98.523	.000*
Sieve size	28593.474	2	14296.737	44335.211	.000*
speed * feedrate	193.012	4	48.253	149.636	.000*
speed * sieve size	1131.525	4	282.881	877.235	.000*
feedrate * sieve size	676.149	4	169.037	524.196	.000*

speed * feedrate * sieve size	210.950	8	26.369	81.771	.000*
Error	17.413	54	.322		
Total	271453.790	81			
Corrected Total	33429.064	80			
*Significant at p ≤ 0.05					

Table 6. Duncan's New Multiple Range Test (DNMRT) on the Effects of Speed, Feedrate and sieve size on the washing Capacity and washing Efficiency of the machine

Parameters	Feedrate(kg/min)			Speed (rpm)			Sieve size (mm)		
	2.6	3.3	3.9	1008	1482	1901	6.0	7.5	10.5
Washing Capacity (kg/hr)	0.3578^{a}	0.6007^{b}	0.8925^{c}	10.5489^{c}	0.5589^{b}	0.7433^{a}	0.4119^{c}	0.6682^{b}	0.7711^{a}
Washing Efficiency (%)	53.222^{c}	54.033^{b}	55.370	48.311^{c}	52.574^{b}	61.741^{c}	27.700^{c}	65.889^{b}	69.037^{a}

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

The Duncan,s New Multiple Range Test (DNMRT) shows the degree of significance differences in each of the factors. It can be observed from the table that the washing capacity and washing efficiency obtained at different levels of speeds, feedrates and sieve sizes are significantly different from one another.

3.2. Effect of Operating Factors on the Washing Capacity of the Machine

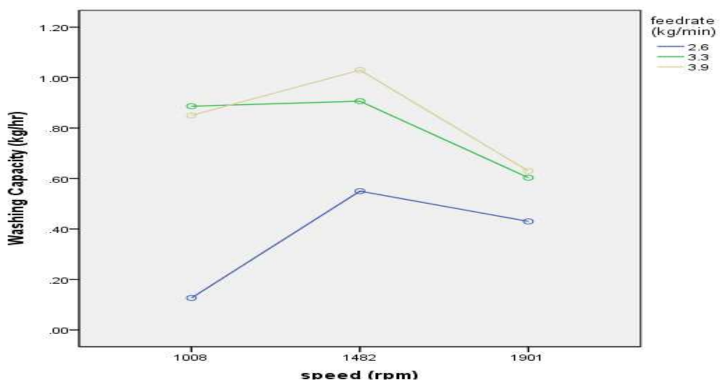

Figure 6.a. Effect of Washing Speed and Feedrate on the Washing Capacity of the Machine at 6.0mm Sieve size

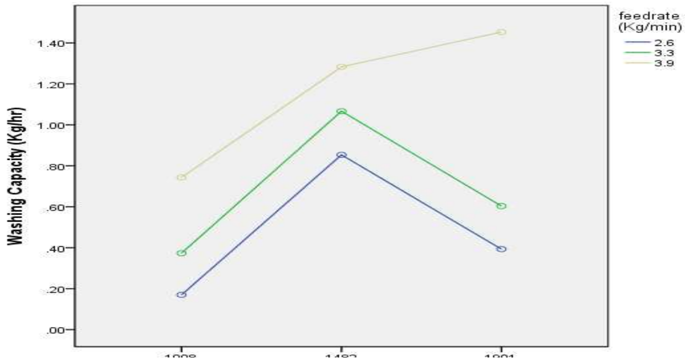

Figure 6.b. Effect of Washing Speed and Feedrate on the Washing Capacity of the Machine at 7.5mm Sieve size

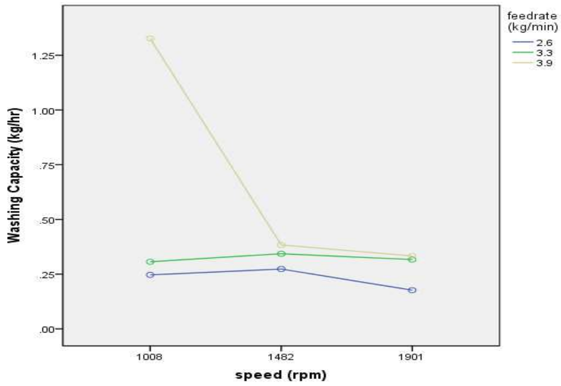

Figure 6.c. Effect of Washing Speed and Feedrate on the Washing Capacity of the Machine at 10.5mm Sieve size

3.3. Effect of Operating Factors on the Washing Efficiency of the Machine

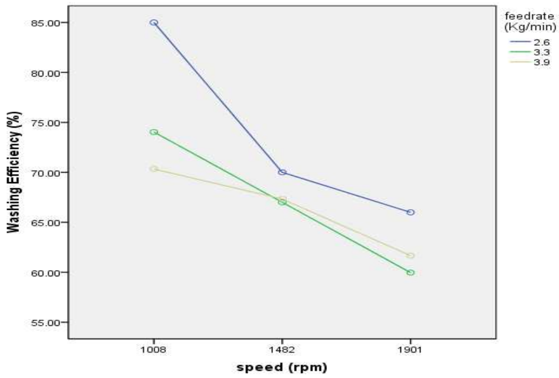

Figure 7.a. Effect of Washing Speed and Feedrate on the Washing Efficiency of the Machine at 6.0mm Sieve size

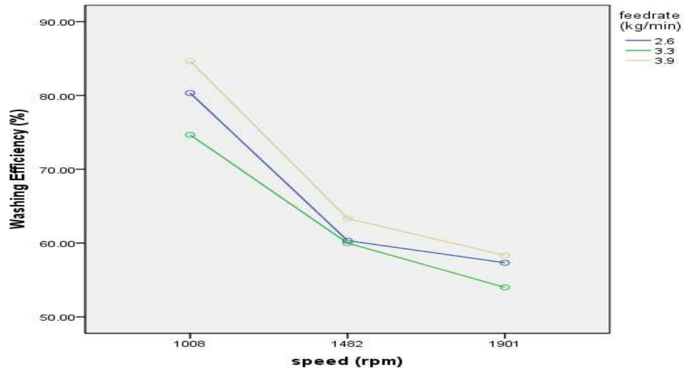

Figure 7.b. Effect of Washing Speed and Feedrate on the Washing Efficiency of the Machine at 7.5mm Sieve size

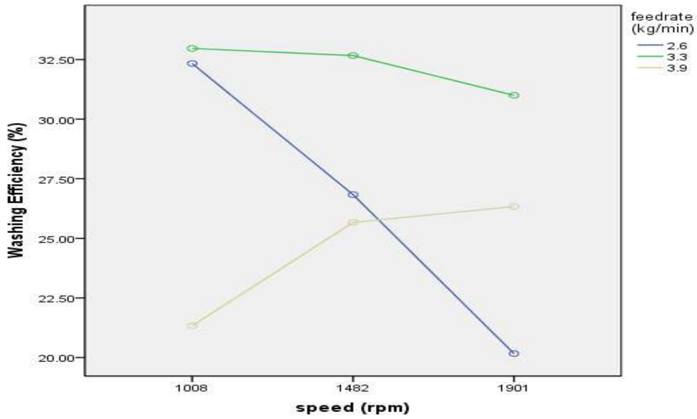

Figure 7.c. Effect of Washing Speed and Feedrate on the Washing Efficiency of the Machine at 10.5mm Sieve size

4.Conclusion

In conclusion, the various investigations made in this study shows that there is good interaction between the performance parameters of the melon washing machine and that of the investigated operating factors. The summary of the evaluation results obtained during the study shows that the optimum washing efficiency of the machine was estimated to be about 80% at the operating speed of 1008rpm with 2.6kg/minfederate.Although, the traditional washing method was rated higher with washing efficiency 90%, characterized with a lot of melon seed losses (i.e 28%).

Hence, for optimum performance of this melon washing machine, operating conditionsof 1008rpm, federate of 2.6kg/min and sieve size of 7.5mm is recommended for higher washing efficiency of 80% and washing capacity 1.16kg/min with little or no melon-seed losses.

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