Journal of Postharvest Technology
2021, **09**(4): 39-52
www.jpht.in

RESEARCH ARTICLE

Evaluation of mean shelling efficiency of Bambara nut at different speed levels and moisture contents using shelling machine

Donatus Asua Kogh[1], Simon V. Irtwange[2], Bill Anaka[3], James Flomo Gaydaybu[4], Daniel Momngu Tiough[1]

[1] Department of Vocational and Technical Education, Benue State University, Makurdi, Nigeria
[2] Agricultural and Environmental. Engineering, Fed. University of Agriculture, Makurdi, Nigeria
[3] No. 26 Iorchia Ayu Road, Wurukum, Mkd. P.O. Box 949, Makurdi,, Nigeria
[4] Bong County Technical College, Gbarnga City, Liberia

Received: 21.08.2021 Accepted: 08.10.2021

ABSTRACT

Studies have shown that Bambara nut has not received maximum attention in area of research as it is the third most important grain after ground nut and cowpea. Cracking this nut requires a cracker since the manual means requires a lot of human efforts but the cracker works better and more effective when the shelling efficiency are achieved at different moisture content. This study therefore was on evaluation of mean shelling efficiency of Bambara nut at different speed levels and moisture content using a modern Sheller. Between group design was used as a design for this study and the data was collected at different stages that is categories of shelling efficiency which are completely shelled, partially shelled, completely shelled and broken and not shelled with the respective weight of bambara nut loaded on the machine, the weight of seeds obtained after shelling. One way analysis of variance was used to test the significant difference and the result indicated that there was a significant difference in the performance of the machine based on the shelling efficiency. Findings further shows the independent effect of speed, moisture content and shelling efficiency on the performance of the machine. On the interaction effect, speed*moisture content, speed*shelling efficiency, moisture content*shelling efficiency and speed*moisture content*shelling efficiency were also considered. The finding showed that the speed level of 275 RPM with the 7% moisture content has the highest level of shelling efficiency with the mean of 97.8 (SD = 6.85) while the least shelling efficiency is found when you have 300 RPM with 9% moisture content with an average completely shelled 4.10 (SD = .78). It was recommended among others that in using this modern cracker, Bambara nut should be shelled at 7% moisture content and at the speed of 275 RMP.

Keywords: Moisture content, speed, shelling efficiency, shelling and grains

Citation: Kogh, D. A., Irtwange S. V., Anaka, B., Gaydaybu, J. F., Tiough, D. M. 2021. Drying rate analysis of three fish species dried using an amendedbiomass (charcoal) dryer. *Journal of Postharvest Technology*, **9**(4): 39-52.

INTRODUCTION

As an underutilized crop, Bambara nut has not received sustained research. Bambara nut is the third most important grain after Ground nut and cowpea (Ezeaku, 1994). In Nigeria, Bambara nut is widely produced in Borno, Anambra, Plateau, Taraba, Sokoto, Bauchi, Benue, Kano, Yobe, Adamawa and Gombe States, (Ezue, 1977; Atiku, 2000). The entire plant is known for soil improvement because of nitrogen fixation. In West Africa, the nuts are used for food and beverage because of its high protein

* *For correspondence:* J. F. Gaydaybu (Email: jfgaydaybu@gmail.com)

ISSN2348-4330

content and for digestive system applications. It can be eaten as a snack, roasted and salted, or as a meal, boiled similar to other beans (Data sheet *Vignasubterranean*, 2011).

The gross energy value of Bambara nut is reported to be greater than Cowpea, Ground nut and Pigeon peas (Goli, 1997). Bambara nut is an underutilized Africa legume which provides security for many farmers as it shows considerable drought resistance.

Bambara nut is grown for its edible seeds. Matured seeds are very hard to cook, so have to be soaked in water to soften before cooking. Un dehulled seeds are mixed with roots and tubers such as yams, cocoyam and sweet potatoes and cooked into a pottage with the addition of oil, salt, pepper and other spices (Enwere and Hung,1996). The medicinal role of Bambara nut is mainly based on information obtained from communities in several parts of Africa, where this crop is reportedly responsible and useful for treatment of various ailments. As a treatment for diarrhea, a mixture of Bambara nut and water from boiled maize are consumed. Raw Bambara nut seeds are chewed and swallowed by pregnant women to alleviate the nausea associated with pregnancy (Enwere and Hung, 1996).

The pods are harvested by pulling or lifting the plant manually, sometimes the support of a hoe may be needed. Alternatively, a single furrow ox plough can be used to achieve the same purpose. The pods are manually separated from the vines. After which the pods are washed, used fresh or can be sun dried and stored at a safe storage moisture content between 8 to 12 %moisture content, wet basis. (Goli, 1997). The seed contains about 63% carbohydrate, 19% protein and 6.5% oil. The haul can be used for livestock feed (Tanimu and Aliyu, 1996). However, the shelling of pods to obtain clean seed is one of the most tedious operations in Bambara nut processing. As a result, it has constituted a bottle- neck to the large scale production and processing of this important proteinous crop (Atiku, Aviara and Haque, 2004). One of the Researchers having been born and brought up in Turan, Kwande Local Government Area, Benue State, Nigeria, where Bambara nut is cultivated in large quantities, has experienced the tediousness and the difficulties encountered by local Bambara nut farmers in shelling Bambara nut pods. This therefore triggered this research to reduce the suffering faced by the people. Specifically this study tested and checked the mean shelling efficiency of the Reciprocating Cracker.

MATERIALS AND METHODS

To conduct a performance test, the first pulley was fixed to the shaft; the two discharge chutes of the hopper were closed using the flow rate control device. The power supply was switched on to run the diesel engine and to put the working components of the machine in operation.

First, the machine was test run using unconditioned bambara nut pods to eliminate machine material loss which could affect the evaluation of performance indicators. After which, a full hopper equivalent to 10 kg of Bambara nut pods at specified moisture content were fed into the first section of the hopper. The vibration of the machine enhanced by reciprocating mechanism (hanger) on which the hopper was suspended made the pods to sieve into the predetermined (three) categories of pod (Small, Medium and large) sizes. The small size pods were allowed to fall directly into the shelling zone ahead of the large and medium size pods. This was done to optimize the power required to drive the shelling drum. After size sorting of the pods was achieved, the flow rate control devices for large and medium pods were opened and the pods were discharged freely under the influence of gravity and vibration into their respective shelling chamber. The pods were shelled until the shelling chamber was emptied. The average time for batch operation of the machine at the various run was noted to be 2min.

The weight of pods that was completely shelled and unbroken (A), weight of completely shelled but broken (B), weight of partially shelled pods (C) and the weight of unshelled pods (D), the quantity of shells that was cleaned out was collected. The quantity of shells that was not cleaned but collected with the seeds was separated. This was calculated using the data collected prior to analysis.

Data collected

N_T = total weight of Bambara nut pods fed into the hopper of the machine = 10kg

N_{CT} = total weight of Bambara nut pods clogged into the screen after machine operation = 0.02kg

A = weight of completely shelled and unbroken seed =9.78kg

B = weight of completely shelled and broken (damage) seed = 0.09kg

C = weight of partially shelled pods = 0.02 kg

D = weight of completely unshelled pods = 0.09 kg

Therefore,

Percentage of completely shelled and unbroken seed $p_{CS} = \left(\frac{A}{N_T - N_{CT}}\right) \times 100\ \%$

$$p_{CS} = \left(\frac{9.78kg}{10kg - 0.02kg}\right) \times 100$$

$p_{CS} = 97.9\%$

Percentage of completely shelled and broken seed $p_{CB} = \left(\frac{B}{N_T - N_{CT}}\right) \times 100\ \%$

$$p_{CB} = \left(\frac{0.09kg}{10kg - 0.02kg}\right) \times 100\ \%$$

$p_{CS} = .9\ \%$

Percentage of partially shelled and unbroken seed $p_{PS} = \left(\frac{C}{N_T - N_{CT}}\right) \times 100\ \%$

$$p_{PS} = \left(\frac{0.02kg}{10kg - 0.02kg}\right) \times 100\ \%$$

$p_{PS} = .2\%$

Percentage of completely unshelled $p_{CU} = \left(\frac{D}{N_T - N_{CT}}\right) \times 100\ \%$

$$p_{CU} = \left(\frac{0.09kg}{9.98kg}\right) \times 10$$

$p_{CS} = .9\%$

Shelling efficiency of the machine, $E_S = \left(\frac{A+B+C}{N_T - N_{CT}}\right) \times 100\ \%$

$$E_S = \left(\frac{9.78kg + 0.09kg + 0.02kg}{10kg - 0.02kg}\right) \times 100$$

$$E_S = 97.8\ \%$$

Performance test of the shelling machine

The performance test was done using experimental design for the statistical analyses for the fabricated Shelling Machine. The experiment followed a four-treatment effect (speed level, moisture content and sorting efficiency) in a Randomized Complete Block Design (RCBD) involving three observations per experimental unit. The experimental unit comprises three factors; three speed levels in each of the three levels of moisture contents and sorting efficiency giving a nine treatment combinations between speed level and moisture content and another nine treatment combination between speed level and sorting efficiency giving a twenty-seven observations for the experiment between speed and moisture content as well as speed and sorting efficiency to determine the performance efficiency in terms of shelling (ie those that are completely shelled, completely shelled and broken, partially shell, completely unshelled, clean shell and unclean shells. All data recorded was subjected to Analysis of Variance to determine the extent to which speed level, moisture content and sorting efficiency affects the machine performance indicators at 95% confidence level using SPSS version 20.

Table 1: Data for determination of shelling efficiency

Shelling efficiency	weight of Bambara nut pods loaded on the machine (kg)	weight of seed obtained after shelling (kg)
Completely shelled	10	9.78
Partially shelled	10	2.80
Completely shelled and broken	10	1.60
Not shelled	10	8.40

Results in Table 1 show the four categories of shelling efficiency which are completely shelled, partially shelled, completely shelled and broken and not shelled with the respective weight of bambara nut loaded on the machine, the weight of seeds obtained after shelling. One way analysis of variance was used to test the significant difference and the result is presented in table 6.

Table 2: Summary of one Way ANOVA for shelling efficiency of the Shelling Machine

Source	Mean	SD	df	F	P	Remarks
Completely shelled	6.33	1.61	3, 32	18.162	.000	Sig
Partially shelled	2.18	2.78				
Completely shelled and broken	.67	.62				
Not shelled	.98	1.05				
Total	2.43	2.77				

Results in Table 2 show that, there is a significant difference in the performance of the machine based on the shelling efficiency($p<.001$). From the result on the Table1 it can be observed that the machine has a very high shelling efficiency particularly in terms of completely shelled which carried the highest mean score of 6.33 (SD = 1.61). Other shelling efficiencies which include partially shelled (Mean = 2.18; SD = 2.78), completely shelled and broken (Mean = .67; SD = .62) and not shelled (Mean = .98; SD = 1.05) were also significantly different as completely shelled was followed by partially shelled which was followed by not shelled and lastly completely shelled and broken. This gives the machine a very high shelling efficiency as completely shelled stood out clearly among the categories of shelling efficiency. Figure 1 is the graphical representation of the shelling efficiencies as grouped and presented in the table;

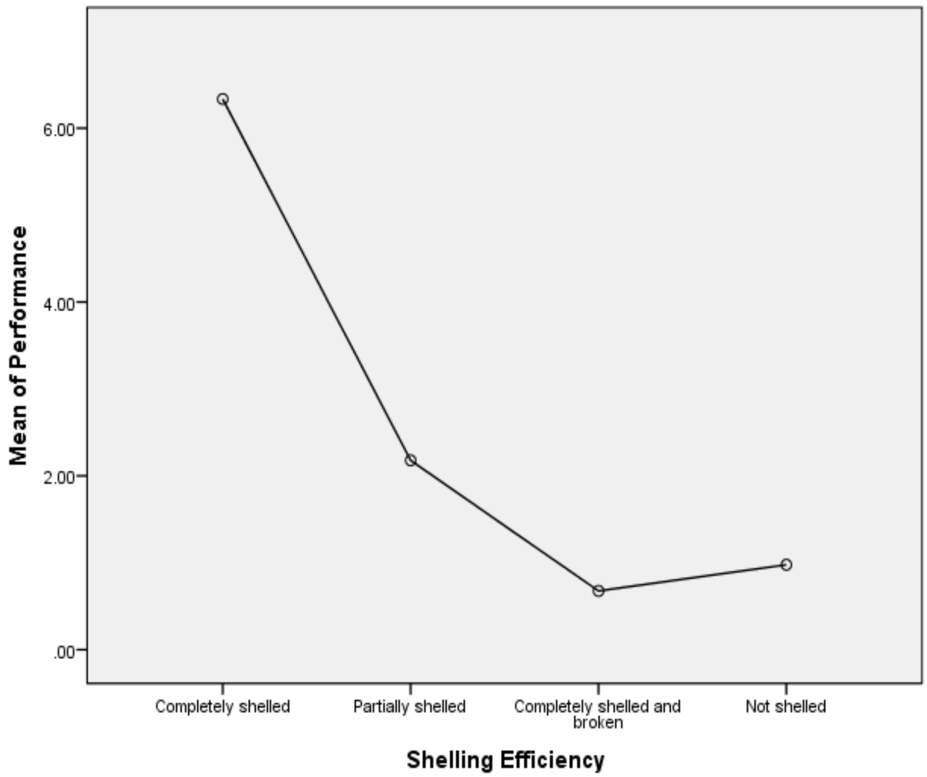

Figure 1: Shelling efficiency of the Reciprocating Cracker

To further check the efficiency of the modified machine, it was important to determine the best shelling efficiency that can be obtained in terms of completely shelled, partially shelled, completely shelled and broken and not shelled. To test this, a comparative analysis of variance was conducted coupled with multiple comparism using data presented in Table 3;

Table 3: Data for determination of speed, moisture content and shelling efficiency

Speed	Moisture content	Shelling efficiency	weight (kg) of seeds obtained after shelling
250 RPM	5% moisture content	completely shelled	8
250 RPM	5% moisture content	partially shelled	1.2
250 RPM	5% moisture content	completely shelled and broken	.20
250 RPM	5% moisture content	not shelled	.30
250 RPM	7% moisture content	completely shelled	7.9
250 RPM	7% moisture content	partially shelled	1.3
250 RPM	7% moisture content	completely shelled and broken	.10

250 RPM	7% moisture content	not shelled	.20
250 RPM	9% moisture content	completely shelled	5.50
250 RPM	9% moisture content	partially shelled	.90
250 RPM	9% moisture content	completely shelled and broken	1.00
250 RPM	9% moisture content	not shelled	2.20
275 RPM	5% moisture content	completely shelled	6.50
275 RPM	5% moisture content	partially shelled	2.80
275 RPM	5% moisture content	completely shelled and broken	.36
275 RPM	5% moisture content	not shelled	.30
275 RPM	7% moisture content	completely shelled	9.78
275 RPM	7% moisture content	partially shelled	.09
275 RPM	7% moisture content	completely shelled and broken	.02
275 RPM	7% moisture content	not shelled	.09
275 RPM	9% moisture content	completely shelled	5.38
275 RPM	9% moisture content	partially shelled	1.10
275 RPM	9% moisture content	completely shelled and broken	1.20
275 RPM	9% moisture content	not shelled	2.00
300 RPM	5% moisture content	completely shelled	4.90
300 RPM	5% moisture content	partially shelled	2.40
300 RPM	5% moisture content	completely shelled and broken	1.60
300 RPM	5% moisture content	not shelled	.06
300 RPM	7% moisture content	completely shelled	8.40
300 RPM	7% moisture content	partially shelled	1.01
300 RPM	7% moisture content	completely shelled and broken	.20
300 RPM	7% moisture content	not shelled	.30
300 RPM	9% moisture content	completely shelled	4.10
300 RPM	9% moisture content	partially shelled	1.20
300 RPM	9% moisture content	not shelled	1.40
300 RPM	9% moisture content	completely shelled and broken	2.80

Table 3 presents the scores from which interaction effect of speed (250 RPM, 275 RPM and 300 RPM), moisture content (5%, 7% and 9%) and shelling efficiency (completely shelled, partially shelled, completely shelled and broken and not shelled) was tested. In this Table 3, 250 RPM was tested against 5% and completely shelled, 250RPM against 5% moisture content and partially shelled, 250RPM against 5% moisture content and completely shelled and broken as well as 250RPM with 5% moisture content with not shelled. This was done on all the speed levels with respective moisture content as well as shelling efficiency and the number of seeds obtained after shelling was collected and recorded in Table 3 which was subsequently used to test the best speed under a particular moisture content that gives the best result tested and presented in Table 4 – Table 6.

Table 4: Univariate Analysis of Variance showing the Interaction between Speed, Moisture Content and Shelling Efficiency of the Modified Machine between-subjects Factors

Subjects	Value label	Mean	SD
Speed	250 RPM	2.40 2.24 2.40	2.98 3.14 2.39
	270 RPM		
	300 RPM		
Moisture content	5 % moisture content	2.03	2.66
	7 % moisture content	2.85	3.81
	9 % moisture content	2.40	1.69
Shelling efficiency	Completely shelled	6.34	1.61
	Partially shelled	2.17	2.78
	Completely shelled and broken	.68	.62
	Not shelled	.98	1.05

Table 4 shows the descriptive statistics on the univariate analysis conducted to determine the main and interactive effect of speed, moisture content and shelling efficiency. The three variables under consideration which are the speed, moisture content and shelling efficiency have been presented with their categories along with the mean and standard deviation values for each of the categories. On the basis of speed, 250 RPM had the mean of 2.40 (SD = 2.98), 270 RPM had the mean of 2.24 (SD = 3.14) and 300 RPM had the mean of 2.40 (SD = 2.39). On the basis of moisture content, 5 % moisture content had the mean of 2.03 (SD = 2.66), 7 % moisture content had the mean of 2.85 (SD = 3.81) while 9 % moisture content had the mean of 2.40 (SD = 1.69). On the basis of shelling efficiency, completely shelled had the mean of 6.34 (SD = 1.61), partially shelled had the mean of 2.17 (SD = 2.78), completely shelled and broken had the mean of .68 (SD = .62) while not shelled had the mean of .98 (SD = 1.05)

Table 5: Summary of Univariate analysis of Variance showing Speed, Moisture Content and Shelling Efficiency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	221.843a	34	6.525	.139	.989	.825
Intercept	219.695	1	219.695	4.680	.276	.824
Speed	126.345	2	12.673	9.014	.030	.028
Moisture content	130.760	2	130.380	8.008	.012	.016
Shelling efficiency	175.876	3	58.625	1.249	.563	.789
Speed * Moisture content	2.059	4	.515	.011	.999	.042
Speed * Shelling efficiency	8.759	6	1.460	.031	.999	.157
Moisture content * Shelling efficiency	26.859	6	4.476	.095	.982	.364
Speed * Moisture content * Shelling efficiency	8.183	11	.744	10.084	.030	.148
Error	46.948	33	46.948			
Total	480.639	36				

R^2 = .825; Adjusted R^2 = -5.113

Table 5 presents the summary of the interaction between speed, moisture content and shelling efficiency. The results show the independent effect of speed p<0.05, moisture content(p<0.05) and shelling efficiency(p>0.05) on the performance of the machine. On the interaction effect, speed*moisture content (p>0.05), speed*shelling efficiency(p>0.05), moisture content*shelling efficiency (p>0.05) and speed*moisture content*shelling efficiency (p<0.05) were also considered.

To further interpret the result in ascertaining the best speed combined with moisture content that can ensure the best shelling efficiency, post-hoc analysis was conducted and the result is presented in the Table 6;

Table 6: Post-hoc and multiple comparison for the variables and their categories

Variable Categories	**Mean**	**Standard Deviation**
250 RPM * 5% moisture content*completely shelled	8.00	1.55
250 RPM*5% moisture content*partially shelled	1.20	.83
250 RPM*5% moisture content*completely shelled and broken	.200	.77
250 RPM*5% moisture content*not shelled	.30	.17
250 RPM*7% moisture content*completely shelled	7.90	.35
250 RPM*7% moisture content*partially shelled	1.30	4.52

250 RPM*7% moisture content*completely shelled and broken	.10	.09
250 RPM*7% moisture content*not shelled	.20	.11
250 RPM*9% moisture content*completely shelled	5.50	.78
250 RPM*9% moisture content*partially shelled	.90	.15
250 RPM*9% moisture content*completely shelled and broken	1.00	.20
250 RPM*9% moisture content*not shelled	2.20	.42
275 RPM*5% moisture content*completely shelled	6.50	1.55
275 RPM*5% moisture content*partially shelled	2.8	.83
275 RPM*5% moisture content*completely shelled and broken	.36	.77
275 RPM*5% moisture content*not shelled	.30	.17
275 RPM*7% moisture content*completely shelled	97.8	6.85
275 RPM*7% moisture content*partially shelled	.20	4.51
275 RPM*7% moisture content*completely shelled and broken	.09	.09
275 RPM*7% moisture content*not shelled	.02	.02
275 RPM*9% moisture content*completely shelled	5.38	.78
275 RPM*9% moisture content*partially shelled	1.10	.15
275 RPM*9% moisture content*completely shelled and broken	1.2	.20
275 RPM*9% moisture content*not shelled	2.00	.42
300 RPM*5% moisture content*completely shelled	4.90	1.55
300 RPM*5% moisture content*partially shelled	2.4	.83
300 RPM*5% moisture content*completely shelled and broken	1.6	.77
300 RPM*5% moisture content*not shelled	.60	.17
300 RPM*7% moisture content*completely shelled	4.93	.35
300 RPM*7% moisture content*partially shelled	1.01	4.52
300 RPM*7% moisture content*completely shelled and broken	.20	.09

300 RPM*7% moisture content*not shelled	.30	.11
300 RPM*9% moisture content*completely shelled	4.10	.78
300 RPM*9% moisture content*partially shelled	1.20	.15
300 RPM*9% moisture content*completely shelled and broken	1.4	.200
300 RPM*9% moisture content*not shelled	2.80	.42

Results in the Table 6show the mean difference in the shelling efficiency across different speed and moisture content. The table shows that at the speed level of 250 RPM with 5% moisture content, completely shelled efficiency had the mean of 8.00 (SD = 1.55), partially shelled had the mean of 1.20 (SD = .83), completely shelled and broken had the mean of .200 (SD = .77) and not shelled had the mean of .30 (SD = .17). Also, at 250 RPM with 7% moisture content, completely shelled had the mean of 7.90 (SD = .35), partially shelled was 1.30 (SD = 4.52), completely shelled and broken had the mean of .10 (SD = .09) and not shelled had the mean of .20 (SD = .11). In the same vein, at 250 RPM with 9% moisture content, completely shelled had the mean of 5.50 (SD = .78), partially shelled had the mean of .90 (SD = .15), completely shelled and broken had the mean of 1.00 (SD = .20) while not shelled had 2.20 (SD = 42).

Also, at 275 RPM with 5% moisture content, completely shelled had the mean of 6.50 (SD = 1.55), partially shelled had the mean of 2.8(SD = .83), completely shelled and broken had .36 (SD = .77) while not shelled had the mean of .30 (SD = .17). In the same vein, 275 RPM with 7% moisture content, completely shelled had the mean of 97.8 (SD = 6.85), partially shelled had the mean of .20(SD = 4.51), completely shelled and broken had the mean of .09 (SD = .09) while not shelled had the mean of .02 (SD = .02). Furthermore, at the speed of 275 RPM with 9% moisture content, completely shelled had the mean of 5.38 (SD = .78), partially shelled had the mean of 1.10 (SD = .15), completely shelled and broken had the mean of 1.2 (SD = .20) while not shelled had the mean of 2.00 (SD =.17).

Moreover, at the speed of 300 RPM with 5% moisture content, completely shelled had the mean of 4.90 (SD = 1.55), partially shelled had the mean of 2.4 (SD = .83), completely shelled and broken had the mean of 1.6 (SD = .77) while not shelled had the mean of .60 (SD = .17). At the speed of 300 RPM with 7% moisture content, completely shelled had the mean of 4.93 (SD = .35), partially shelled had the mean of 1.01 (SD = 4.52), completely shelled and broken had the mean of .20 (SD = .90) while not shelled had the mean of .30 (SD = .11). Also, at the speed level of 300 RPM with 9% moisture content, completely shelled had the mean of 4.10 (SD = .78), partially shelled had the mean of 1.20 (SD = .15), completely shelled and broken had the mean of 1.4 (SD = .200) while not shelled has the mean of 2.80 (SD = .42).

Looking at the table generally, the speed level of 275 RPM with the 7% moisture content has the highest level of shelling efficiency with the mean of 97.8 (SD = 6.85) while the least shelling efficiency is found when you have 300 RPM with 9% moisture content with an average completely shelled 4.10 (SD = .78). On the basis of partially shelled, speed level of 275 RPM with 5% moisture content had the highest rate of partially shelled efficiency with average of 2.8 (SD = .83) while speed 275 RPM with 7% moisture content has the leas number of partially shelled with an average of .20 (SD = 4.51). Moreover, speed 300 RPM with 5% moisture content has the highest number of completely shelled and broken with average of 1.6 (SD = .77) while speed of 275 RPM with 7% moisture content has the least number of completely shelled and broken with average of .09 (SD = .09). Lastly, in terms of not shelled, speed of 300 RPM with 9% moisture content had the highest number of not shelled with average of 2.80 (SD =.42) while speed 275 RPM with 7% moisture content has the lowest number of not shelled with average of .02 (SD =.02).

Figure 2, Figure 3 and Figure 4 are graphical representations of the interpretation carried out and enlisted above to determine the comparison of the results particularly in terms of speed, moisture content as well as shelling efficiency.

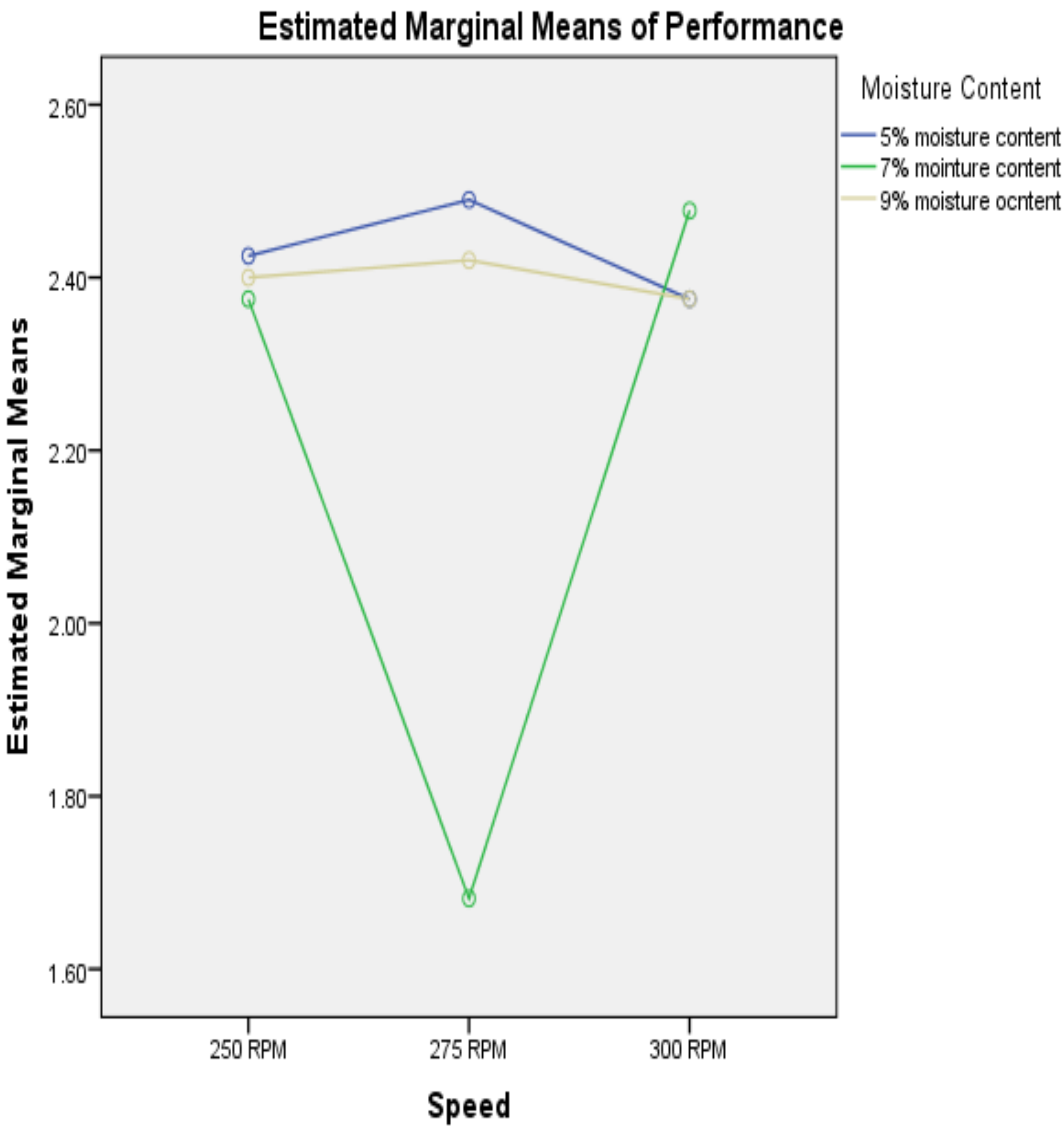

Figure 2: Interaction between speed and moisture content

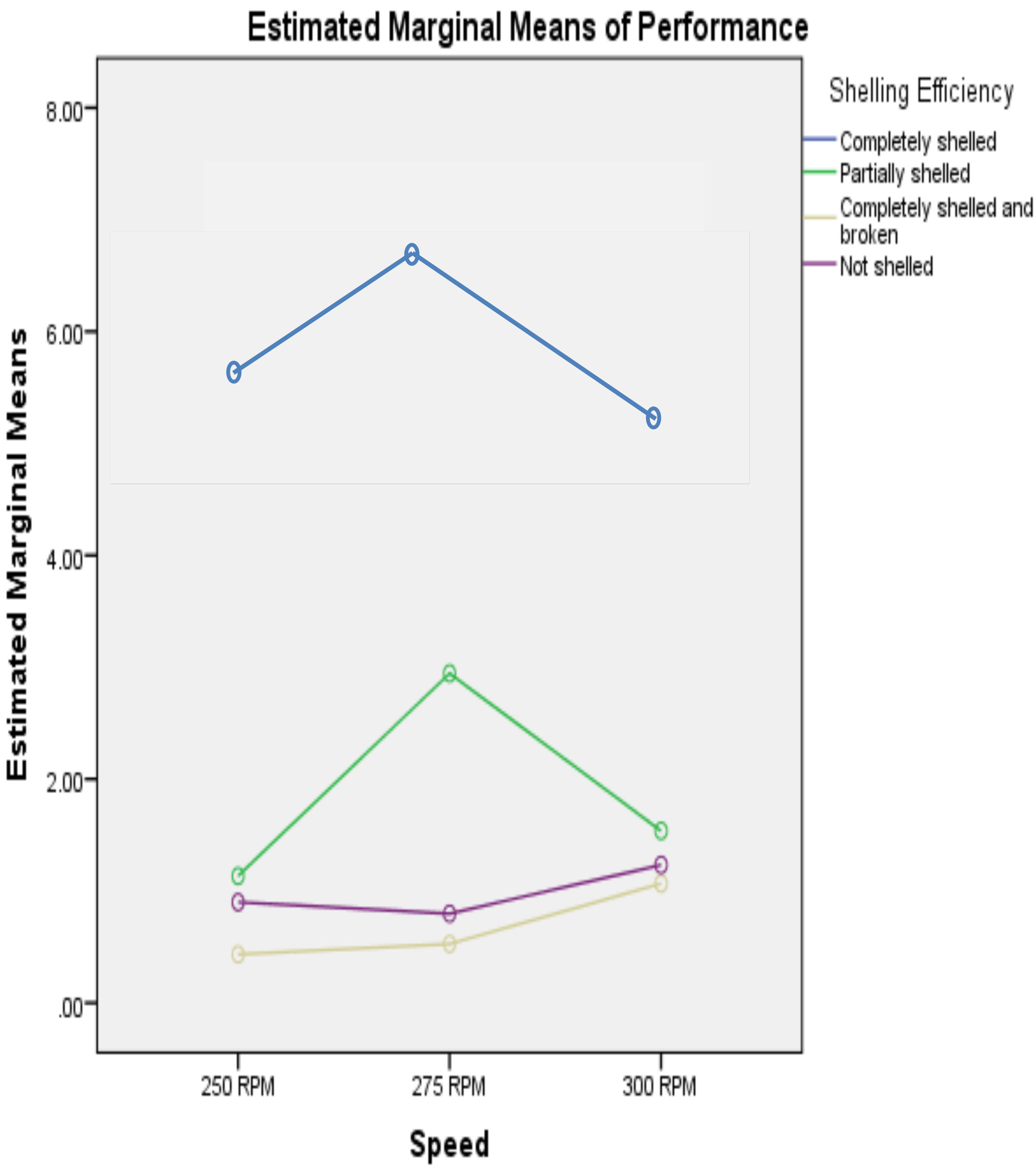

Figure 3: Comparison between speed and shelling efficiency of the machine

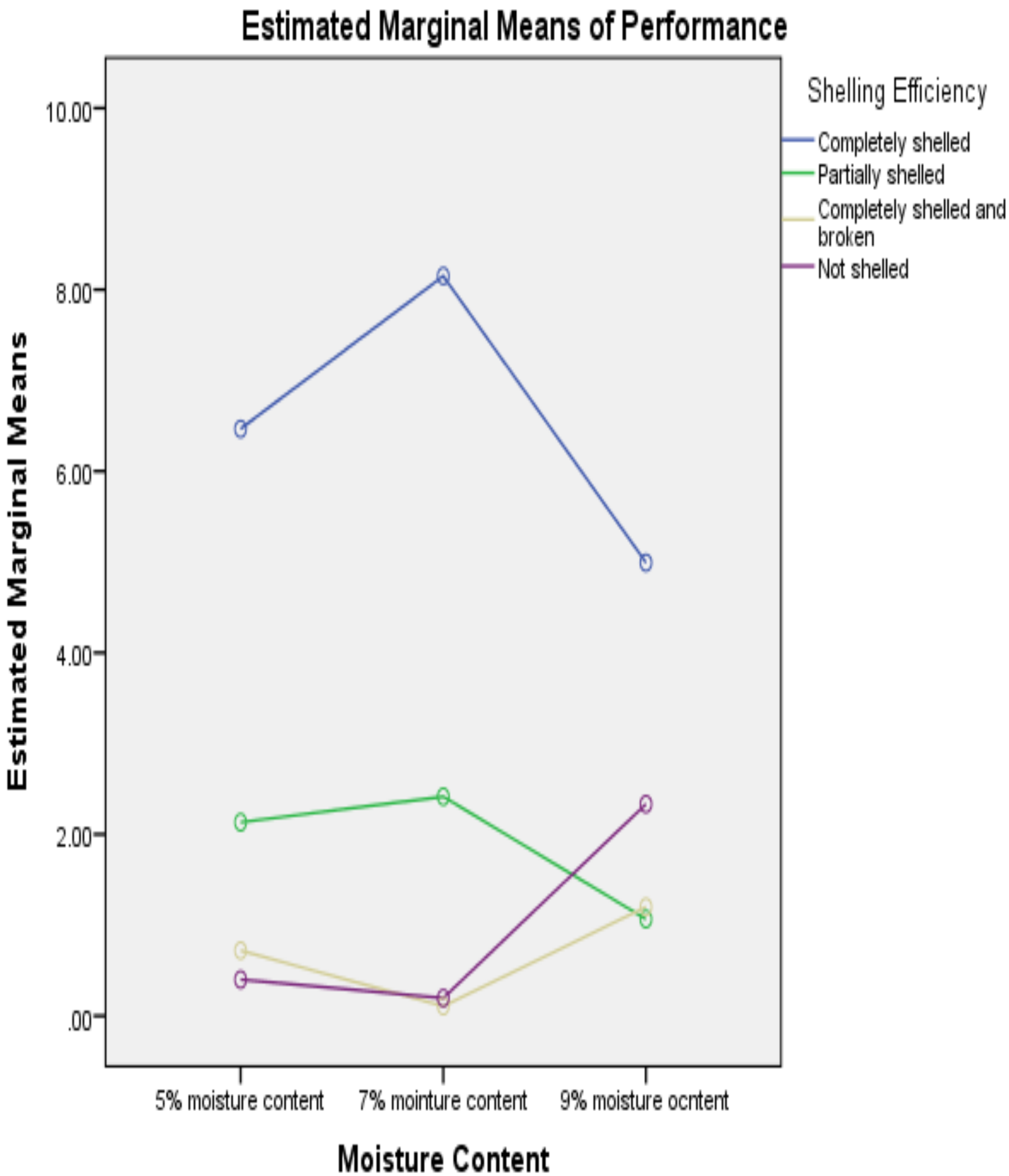

Figure 4: Interaction between moisture content and shelling efficiency of the machine

CONCLUSION

Based on the finding of this study, it was concluded that among the three levels of speed which was 250 RPM, 275 RPM and 300 RPM, the best of the speed that gives ultimate performance was 275 RPM (Mean = 8.40 (SD = 6.85). In terms of moisture content, the study showed that, there was a significant difference between levels of moisture content and the performance of the machine (p<.05). The result further shows through observation of the mean difference that 7% moisture content (Mean = 2.85; SD = 3.81) was the best moisture content that produced the desired result. There was a significant difference in the performance of the machine based on the shelling efficiency (p<.001). The machine has a very high shelling efficiency particularly in terms of completely shelled seed which carried the highest mean score of 6.33 (SD = 1.61).The Researchers recommended that in using the Shelling Machine Bambara nut should be shelled at 7% moisture content and at the speed of 275 RMP. Also, government should encourage the production of Bambara nut by making Reciprocating Crackers available to Bambara nut producing villages.

REFERENCES

Arena, B., Daggett, N., Gawlak, A. andGomes,J. 2012. Design of a low-cost solar food dryer. Retrieved on November 9, 2018, from (https://www.mie.neu.edu/ME%202010%2012%20Design%20Low%20Cost%20Food.

Axtell, B. 2002. Drying food for profit: A guide for small businesses. London, UK:Practical Action Publishing Limited.

Bassey, M.W. 1989. Development and use of solar drying technologies. *Nigeria Journal of Solar Energy*, (8) 133-164.

Dipak, D. A. 2013. Design and development of biomass-based forced convective drying system(Master thesis). Department of Renewable Energy Engineering, College of Technology and Engineering, MaharanaPratap University of Agriculture and Technology, India.

Engineering Toolbox, 2003. Specific heat of food and foodstuff. Retrieved on November 14, 2018 from https://www.engineeringtoolbox.com/specific-heat-capacity-food-d 295.

Green, M. G. and Schwarz, D. 2001. Solar drying equipment. Retrieved on November 1, 2018, from http://www.gtz.de/gate.

Kituu G.M., Shitanda,D., Kanali, C. L., Mailutha, J.T., Njoroge, C. K. and Silayo, V. K. 2010. Thin-layer drying model for simulating the drying of tilapia fish (*Oreochromis niloticus*) in a solar tunnel dryer.*Journal of food engineering,* 98(3), 325-331.

Olayemi, F. F. 2012. Shelf-life and quality characteristics of smoked catfish (*clariasgariepinus*) stored in composite packaging materials (PhD. Dissertation). Retrieved on July 18, 2019, from http://ir.library.ui.edu.ng.

Tertsegha, M. 2019. Design, construction and performance evaluation of an indirect – passive solar tomato dehydrator with a charcoal – fire heater unit (Unpublished Master Dissertation). Benue State University, Makurdi, Nigeria.

Tibebu, T. B. 2015. Design, construction, and evaluation of the performance of solar dryer for drying fruit (Master Thesis). Kumasi, KNUST, Ghana.