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Optimization of Water Absorption Capacity of Two Varieties (Tvsu-1659 and Tvsu-711) of Bambara Groundnut

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ABSTRACT

This research work examines the optimization of water absorption capacity of twoselected varieties (TVSU-711)and TVSU -1659)of Bambara groundnuts.Hexagonal design was used to optimize temperature (30 – 55 ^{0}C) and time (10 – 40 mins) for the optimization of water absorption capacity of the selected groundnuts. The result obtained from the water absorption shows that the optimum moisture absorption capacity of TVSU 1659 is 0.736%, at 31.68^{0}C for 32.5min while the optimum condition moisture absorption capacity of TVS711 is 0.867%, at 53.3 ^{0}C an d 32.5 min. The R^2, and Adj $R^2$for TVSU-1659, are 0.8594 and 0.6837 respectively, while theR^2, and Adj $R^2$for TVSU-711 are 0.8745 and 0.7177 respectively. The final empirical model in terms of coded factors for the moisture absorbed by TVSU-1659 and TVSU-711 are $(moisture\ absorbed)^{\frac{1}{2}} = +0.13 + 0.071 + 0.084 + 0.051 + 0.24 - 0.17AB$ and $(moisture\ absorbed)^{\frac{1}{2}} = +0.018 + 0.065A + 0.074B + 4.346E - 003A^2 + 0.37B^2 + 0.15AB$ respectively. Conclusively, TVSU-711 has the higher water absorption capacitythan TVSU-1659 which implies that TVSU-711 has ability to absorb water than TVSU-1659. TVSU-711.

Keywords: Underutilized, Bambara groundnut,Hexagonal design, Water absorption capacity.

Aims Research Journal Reference Format:
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1. INTRODUCTION

Water absorption can be defined as the amount of water absorbed by a composite material when immersed in water for a period of time or as the ratio of the weight of water absorbed by a material, to the weight of the dry materials (Antwi, 2011). Water absorption through soaking is the most common preliminary process applied to cereals, legumes and grains during the production of various cereals, legumes and grains based food product such as thin porridge pap (ogi) (Apena *et al.,*2006).

The amount of water absorbed by seeds during soaking is affected by different factors such as the initial moisture content, variety of the seeds, soaking duration, and temperature and acidity level of the water (Karapantsios *et al.,* 2002; Laria *et al.,* 2005). Dried products need to be soaked before consumption or further processing (Nayak *et al.,* 2006). During the soaking of food materials, liquid water is progressively absorbed .Tunde- Akintunde, (2010) studied effect of soaking water temperature and time on some rehydration characteristics and nutrient loss in dried bell pepper. He reported that at higher soaking water temperatures, larger amounts of vitamin C leached into soaking water. Researchers have demonstrated that increasing the temperature of the soaking medium is an effective way to accelerate water uptake by various seeds and hence, shorten the soaking time (Afolabi, 2014).

Bambara groundnut (*Vigna subterranea* L.) Verdc is grown extensively in Nigeria but it is one of the lesser utilized legumes in Nigeria (Olapade and Adetuyi, 2007). In Nigeria, Bambara groundnut is known in Hausa as *gujiya* and *kwaruru*, while in Ibo it is known as *okpa* and in Yoruba as *epiroro*. It iscultivated by farmers as a "famineculture" crop because it has several naturalagronomic advantages including high nutritional *value* and drought tolerance *(Arachid hypogea)* (Anchirinah *et al*., 2001; Azam-Ali *et al*., 2001). Bambara groundnut is an annual legume. The pod is verysmall (1.5cm long), round or slightly oval shaped and wrinkled with mostly one or sometimes two seeds. The unripe pod is yellowish green, while the mature pods may be yellowish green or purple. After fertilization the flower stem elongates .The sepal enlarges and the fruit develops above below the soil surface Bambara take 7 to 15 days to germinate. The seed stored for about 12 months germinate well. Flowering starts 30 to 35 days after sowing and may continue until the end of the plant's life. A growth period of 110 to 150 days is required for the crop to develop, an average day. Bambara can grow on any well drained soil. Planting date is sown during October and November after good rains (Wihad and Omer, 2006).

The fodders of Bambara groundnut are used to feed animals (Brink *et al*., 2006). In some communities like Ibos in Nigeria, this plant is used for medicinal purpose, leaves serve as anti-vomiting when eaten in row (Minka, 2000). In Nigeria, the freshly harvested pods are cooked, shelled and eaten as a vegetable snack, while dry seeds are either roasted and eaten as a snack in a manner similar to boiled peanuts or milled into flour and used in preparation of moin-moin (Olapade et al., 2005), Poulter and Caygill (2006) also reported that it could be used for milk making. Other reports, by Akani *et al*., 2000 and Atiku*et al.,*(2004), stated that the seed of Bambara groundnut can be used for baby food, human consumption, industrial products and animal feed. In fact, Bambara Groundnut has the potential in addressing the energy protein malnutrition problem in developing countries because it is a proteinous food with a high amount of carbohydrate (Chinedu and Nyinyi, 2012; Mazahibet *et al.,* 2013).

After drying of these varieties of Bambara groundnut seeds ,they need to be reabsorbed in water for use, but soaking takes time ,therefore there is need to know the optimum time and temperature that will facilitate efficient water absorption. In this study two varieties were considered and were subjected to water absorption capacity. The optimum conditions of the selected factors will be determined with the use of design of experiment software (Design Expert 6.08).

2. METHODOLOGY

2.1 Raw materials and preparation

Two varieties of varieties of Bambara groundnut with accession number TVSU-1659 and TVSU-711 were collected from International Institute of Tropical agricultural (IITA) in Ibadan, Nigeria. The broken nuts and external materials have been eliminated from the source and the nuts are of uniform and medium sizes thus abolish the effect of nut size on the soaking trials. The seeds were kept in a clean nylon and effectively labeled. Apparatus and equipment used include oven, desiccators, aluminum dish, stop watch, electronic balance, thermometer, measuring cylinder, Beaker and filter paper. A Reagent used is Distilled water.

2.2 Soaking Treatment

The nuts of the two selected varieties of Bambara groundnut beans were used for the water absorption process. The water absorption experiment was done by using the method used of Seyed and Amin (2014). In water absorption process, 5 g of seed was weighed on electronic weighing balance and place in 100mL of distilled water in beakers of 250 ml, under temperatures of 30 and 55 °C, with three repetitions for each temperature. The amount of water absorption by various seeds was controlled by digital chronometer at duration of 10 and 40 minutes. To know the amount of water absorption, samples was weighed periodically, after reaching a fixed sampling time; the samples was removed from beaker. The excess water on the samples was drained by wipers. The soaked samples that had been cleaned with dried baby wipes was weighed again to know the water uptake by the samples. The data from this experiment was used to calculate water absorption capacity for the varieties of the samples use according to equation (1).

$$\text{WAC } \% = \frac{W_2 - W_1}{W_2 - W_0} X100\ \% \qquad 1$$

WAC is the Water absorption capacity$(d.b\%)$, W_2 is the weight of the sample after immersion, W_1 is the weight of the empty pan with the sample and W_0 is weight of the empty pan.

2.3 Optimization of Water Absorption at Optimum Condition

Process factors such as temperature and time were optimized using Hexagonal design under the Response Surface Methodology of the Design of Experiment (DOE) software (6.0.8). Selected time ranges are 10 and 40 minutes while the selected ranges of temperature are 30- 55 ^{0} C for this research work are stated in (Table 1). Ten experimental runs are proposed and this was conducted in triplicate. The procedure was conducted for the two varieties of Bambara groundnut and the experimental conditions that gave maximum water absorption capacity from varieties of Bambara groundnut were recorded.

Table 1: Factors and levels of variables

Factors	Units	Level	
		Low	High
Temperature	^{0}C	30	55
Time	Min	10	40

3. RESULTS AND DISCUSSIONS

3.1. Design Summary for the Water absorption from TVSU-1659 and TVSU-711

The study type used for experimental design for the water absorption from TVSU-1659 and TVSU-711 was Response surface. The initial design suggested by the software (Design Expert 6.08) was the Hexagonal Design .Two factors interaction was used as the design model. The factors considered were time (min) and temperature (^{0}C) while the response is the amount of moisture absorbed. The design generated ten (10) runs and the results obtained showed that the transformation that was done for the response considered for TVSU-1659 and TVSU-711 is Power. Also, for TVSU-1659 and TVSU-711 the model obtained for moisture content considered was quadratic.

Table 2: Design Summary for the Water absorption from TVSU-1659 and TVSU-711

Response	Name	Units	Trans	Model
Y1	TVSU-1659	%	Power	Quadratic
Y2	TVSU-711	%	Power	Quadratic

Table 3: Responses from Experimental Data

	Factors		RESPONSE (%)	
RUN	TIME(min)	TEMP (0C)	TVSU-711	TVSU-1659
1	32.5	31.675	0.735	0.736
2	17.5	31.675	0.734	0.467
3	32.5	53.325	0.867	0.733
4	25	42.5	0.601	0.467
5	25	42.5	0.468	0.600
6	17.5	53.325	0.734	0.734
7	25	42.5	0.667	0.534
8	10	42.5	0.533	0.534
9	40	42.5	0.600	0.600
10	25	42.5	0.468	0.401

The experimental result for the optimization of water absorption capacity of two varieties (TVSU-1659 and TVSU-711) of Bambara groundnut using Hexagonal deign is shown in Table 3.From the above Table 3, it can be inferred that for TVSU-1659, the highest amount of moisture absorbed was obtained when water absorption capacity was 0.736%, at experimental run 1,when time was 32.5min and temperature was 31.7^0C and the lowest amount of moisture absorbed was gotten when water absorption capacity was 0.401%, time was 25 min and temperature was42.5^0C at experimental run 10 respectively while for TVSU-711, the highest amount of moisture absorbed was obtained when water absorption capacity was 0.867%, time was 32.5min and temperature was 53.3 ^{0}C at experimental run 3 and the lowest amount of moisture absorbed was gotten when water absorption capacity was 0.468% at experimental run 10 when time was 25min and temperature was 42.5% respectively.

Table 4 ANOVA of water absorption for TVSU-1659 and TVSU-711.

TVSU-1659						TVSU-711				
Source	Sum of squares	DF	Mean Square	F Value	Prob > F	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	0.13	5	0.027	4.89	0.0746*	0.23	5	0.046	5.58	0.0604*
A	*0.015*	1	0.015	*2.75*	*0.1729*	*0.012*	1	*0.012*	*1.50*	*0.2877*
B	*0.021*	1	*0.021*	*3.88*	*0.1203*	0.016	1	*0.016*	1.96	*0.2339*
A^2	*3.428E-003*	1	*3.428E-003*	*0.63*	*0.4715*	*2.519E-005*	1	*2.519E-005*	*3.029E-003*	*0.9587*
B^2	*0.074*	1	*0.074*	*13.57*	*0.0211**	*0.18*	1	*0.18*	*22.25*	*0.0092**
AB	*0.022*	1	*0.022*	4.11	0.*1125*	*0.016*	1	*0.016*	1.94	*0.2359*
Residual	0.022	4	5.434E-003			0.033	4	8.313E-003		
Lack of Fit	*8.794E-003*	1	*8.794E-003*	*2.04*	*0.2487*	*6.158E-003*	1	*6.158E-003*	*0.68*	*0.4695*
Pure Error	*0.013*	3	*4.314E-003*			*0.027*	3	*9.032E-003*		
Cor Total	0.15	9				0.27	9			

Level of significance *(P>0.10)

For TVSU-711the R-Squared=0.8745, Adj R-Squared = 0.7177, Pred R-Squared = -0.0183

For TVSU-1659 , the R-Squared= 0.8594, Adj R-Squared = 0.6837, Pred R-Squared = -1.1960

The final empirical model in terms of coded factors for the moisture absorbed is given as:

$$((TVSU-1659))^3 = +0.13 + 0.071\text{A} + 0.084B + 0.051A^2 + 0.24B^2 - 0.17AB2$$

$$((TVSU-711^3)) = +0.18 + 0.065A + 0.074B + 4.346E-003A^2 + 0.37B^2 + 0.15AB3$$

From the coded factors , it can be seen that for TVSU-711 and TVSU-1659, A,B,AB,A^2 and B^2 has positive coefficients which indicates that they affect the moisture absorbed positively. That is the factors are directly proportional to the moisture absorbed by the samples. The result of statistical analysis of variance (ANOVA) carried out for the response evaluated to obtain quadratic model is shown in Table 4.The "Model F-value" obtained for the moisture absorbed from TVSU-1659 was 4.89. The model F-value implied that the model was significant and there was only a 7.46% chance could occurs due to noise. From Table 4 for TVSU-711, the model Fand p- value of 5.58 and 0.0604 respectively is an indication that the model is very significant.The larger the magnitudeof the F-values and the smaller p values, the more significant is the corrresponding coefficients .The model Fvalueimplied that the model was significant and there was o nly a 6.04% chance could occur due to noise. Values of "Prob < F" less than 0.10 indicate model terms are significan t. For TVSU -711,the fit of the model was checked by the determination coefficient ($R^{2)}$. A negative "Pred R-Squared" implies that the overall mean is a better predictor of theresponse than the current model.Significant lacks of fit and high value of the coefficient of variation were found.Probability values (greater than 0.10) indicated that some of the model terms are not significant .TVSU-711has the closest R^2 and adjusted R^2 close to 1.

In this case B^2 are significant modelterms.Values greater than 0.1000 indicate the model terms are not significant. It also shows that B^2 has highest influence in the regression model with F-value of 22.25 followed by A^2 (sample) with F-value3.029E-003. This implies that B^2 plays a significant role in the developed model followed by A^2.The significance of the model was further tested by the evaluation of R^2 value.The R^2 obtained was 0.8745. Akintunde *et al.,* 2015 stated that the goodness of fit of a model is determine by the coefficient of determination (R^2) and the value should not b less than 0.80. When the values of probability >Fis less than 0.1000 indicates that model terms are siginificant .In this case $B^2$is a significant model term while if the values are greater than 0.1000 it is an indication that the model terms are not significant in ths case A,B,AB and A^2.are not significant model terms The result revealed that both temperaure and time shows a significant inluence on moisture absorbed by TVSU-711.

For TVSU1659, the model F and pvalue of 4.89 implies the model is very significant.Values of "Prob < F" less than 0.10 indicate model terms are significant. In this case B^2 are significant model terms.Values greater than 0.1000 indicate the model terms are not significant. In this case $B^2$are significant model terms. It also shows that B^2 has highest influence in the regression model with F-value of *13.57*25 followed by A^2 (sample) with F-value of 0.63. This implies that B^2 plays a significant role in the developed model followed by A^2. The significance of the model was further tested by the evaluation of R2 value. The R2 obtained was 0.8594. A negative "Pred R Squared"implies that the overall mean is a better predictor of the response than the current model. Probabilityvalue (greater than 0.10) indicated that some of the models are not significant. In this case B2 is a significant model term while if the values are greater than 0.1000 it is an indication that the model terms are not significant in ths case A,B,AB and A2 are not significant model.The result revealed that both temperature and time shows a significant influence on the moisture absorbed by the TVSU-1659.The P-values lower than 0.10 in TVSU -711 and TVSU-1659 indicate that in the case of moisture absorbed response model terms B2 are significant.

For TVSU -711, the predicted R-squared of -0.0183 is not as close to the Adj R-squared of 0.7177 as one might normally expect. Also, for TVSU 1659 Pred RSquare of 1.1960 is not as close to the Adj Rsquared of 0.6837 as one might normally expect. For TVSU-711, the "Lack of Fit F-value" of 0.68 implies the lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good because we want the model to fit. And for TVSU-1659,the "Lack of Fit F-value" of 2.04 implies the Lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good because we want the model to fit.

3.3 Diagnostic Case Studies

3.3.1. Diagnostics Case Studies for Bambara groundnut seeds

Table 5, shows the result of the diagnostic case studies for the moisture absorbed Bambara groundnut seeds.Experi mental runs 2,4,6,7 and 10 shows a negative residual for TVSU-1659 and experimental runs 1,3,5,8 and 9 shows a positive residual. For TVSU-711, experimental runs 2,4,6,7 and 8 shows a negative residual while experimental runs 1,3,5,9 and 10 shows a positive residual. The residual shows the closeness of the actual values to the predicted value. Negative value of the residual indicates that the actual value is greater than the predicted value while a positive value implies that the predicted value is greater than the actual value, and a predicted value of zeros means no net difference between the actual value and predicted value.

Table 5: Diagnostic Case Studies for Bambara groundnut seeds

Diagnostics Case Statistics			TVSU-1659		Diagnostics Case Statistics	TVSU-711	
Standard Order	Actual Value	Predicted Value	Residual	Run Order	Actual Value	Predicted Value	Residual
1	0.15	0.11	0.038	8	0.15	0.12	0.032
2	0.40	0.44	-0.038	6	0.40	0.43	-0.032
3	0.40	0.36	0.038	3	0.65	0.62	0.032
4	0.22	0.26	-0.038	9	0.22	0.25	-0.032
5	0.40	0.36	0.038	1	0.40	0.37	0.032
6	0.10	0.14	-0.038	2	0.40	0.43	-0.032
7	0.069	0.13	-0.069	10	0.10	0.18	-0.077
8	0.22	0.13	0.083	5	0.10	0.18	-0.077
9	0.15	0.13	0.018	7	0.30	0.18	0.117
10	0.10	0.13	-0.032	4	0.22	0.18	0.037

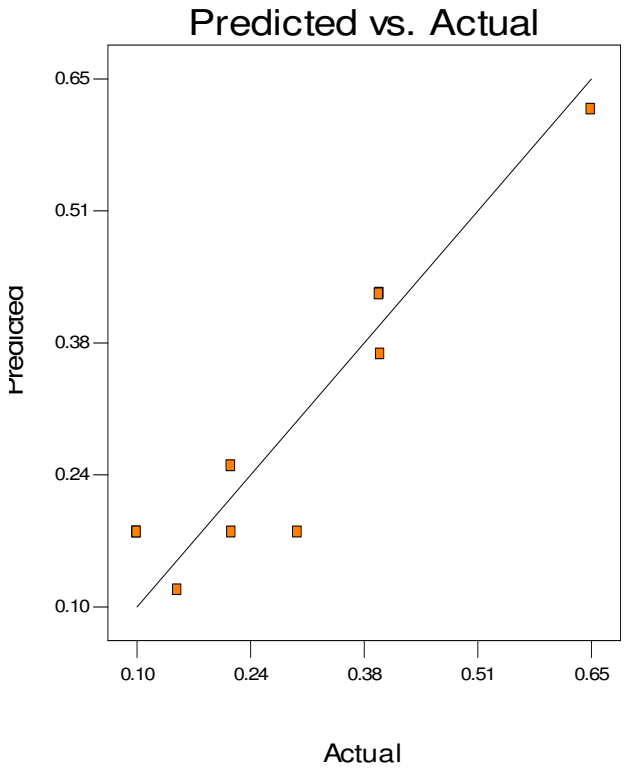

Fig 1a: Plot of predicted value against actual values of moisture absorbed from TVSU-711.

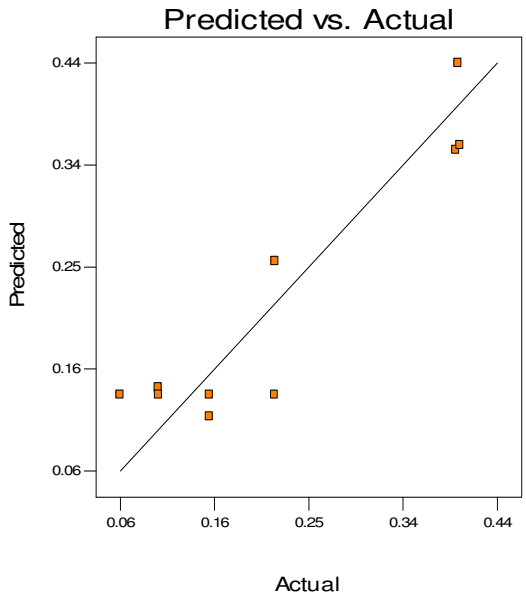

Fig 1b: Plot of predicted value against actual values of moisture absorbed from TVSU-1659.

The points on fig 1a and 1b diverge very well from the straight line. The 3-dimensional (3D) model graphs (figures 2a-b) show the effects of the interaction between (a) time and temperature as well as (b) temperature and time on moisture absorbed from TVSU-1659 and TVSU-711.The effect of changes in the time on the moisture absorbed is more pronounced in both figures and this support a natural development that more moisture absorbed are obtainable as the mass of Bambara groundnut seeds increases. From the result the absorption time is shown to be the most important that affects the moisture with respect to moisture aborption temperature.Increase in temperature and time results to more moisture absorbed by the samples,

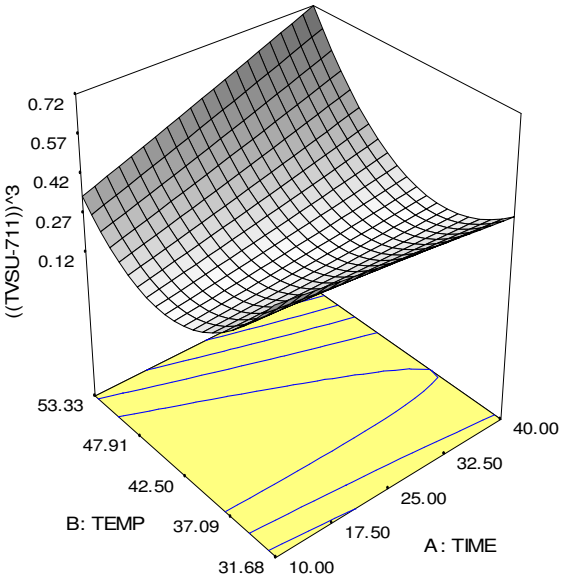

Fig 2a:3D Plot of the effect of Time and Temperature on the moisture absorbed from TVSU-711.

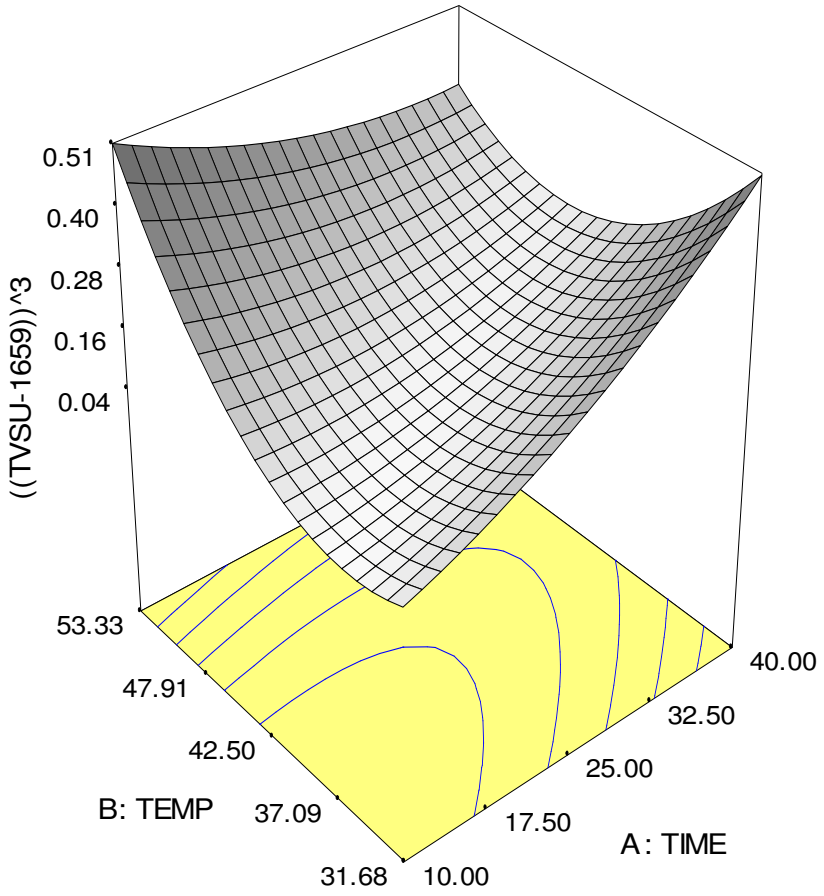

Fig 2b:3D Plot of the effect of Time and Temperature on the moisture absorbed from TVSU-1659.

3.4. Process Optimization and Validation

One of the main objectives of this study was to find the optimum process parameters which the TVSU-711 and TVSU-1659 absorbed moistures should have in order to achieve moisture absorbed. The function of desirability was applied using Design Expert software version 6.08(STAT-EASE Inc., Minneapolis, USA) in order to compromise between the response. In the optimization analysis, the target criteria for time and temperature were set as minimum, in range and maximum. TVSU-711 and TVSU-1659 has the desirability to be 1.00.The amount of moisture absorbed was validated using the data generated from the experiment .The evaluation parameters are also presented in Table 6.The predicted and experimental value is presented in Table 6 with the percentage errors for TVSU-1659 and TVSU-711 are 2% and 11.32%.

Table 6: The optimum conditions for the moisture absorbed from TVSU-1659 and TVSU-711 and the percentage error of the predicted and experimental results for TVSU-1659 and TVSU-711.

Optimum conditions for moisture absorbed				Amount of moisture absorbed		
	Time(min)	Temp(0C)	Predicted	Experimental	Error	
TVSU-711	31.99	54.63	1.244	1.4019	2	
TVSU-1659	38.1	31.43	1.117	1.4727	11.3	

4. CONCLUSIONS

Conclusively, the result obtained shows thatTVSU-711 has highest water absorption capacity followed by TVSU-1659.Which implies that TVSU-711 has ability to absorb water than TVSU-1659during the optimization of the two varieties of Bambara groundnut. Also, TVSU-711 has the highest R-Squared. whlile TVSU-1659 has the highest Adj R-Squared.The TVSU-711 has R-Squared close to 1.0 than TVSU-1659.This study clearly shows that the response surface methodology is one of the suitable methods to optimize the best operating conditions to maximize the moisture absorbed.The percentage errors between predicted and experimental results of moisture absorbed at optimim condition were found to be 2% and 11.32%.The exprimental values were in good agreement with the model predicted values.

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REFERENCES

1. Akani, A.O., Ohanwe, C.N., and Omoniyi, I.O., (2000).Determination of optimum impact for decortications of Bambara groundnut. Proc. Nigerian Soc. *Agricultural Engineering.* 22:87-89.
2. Akintunde, A.M., Ajala, S.O and Betiku, E. (2015).Optimization of Bauhinia monandra seed oil extraction viaartificial neural network and response surface methodology: Apotential biofuel candidate .*Industrial Crops and Products* .67:387-394.
3. Anchirinah, V.M, Yiridoe, E.K., and Bennett- Lartey, S.O. (2001). Enhancing sustainable production and genetic resource conservation of Bambara groundnut: A survey of indigenous agricultural knowledge systems. *Outlook on Agric* .30:281-8.
4. Antwi, G.I. (2011).Water Diffusion Coefficients of Selected Cereals and Legumes grown. In Ghana As Affected By Temperature And Variety. Kwame Nkrumah University of science and technology Kumasi Faculty of Agricultural and Mechanical Engineering Department of Agricultural Engineering. pp. 1-99.
5. Apena, A., Chinweike-Umeh, S.N., and Abaelu, A.M. (2006). Evaluation of improved Ogi (Apik) with potential for the control of diarrhea. *Nigerian Food Journal*. 24: 180-185.
6. Atiku, A.A. (2000). Bambara groundnut processing storage practicing in North Eastern Nigeria. Postgraduate Seminar paper, Dept. Agric., Eng., University of Maiduguri Press, Maiduguri, Nigeria.
7. Azam-Ali, S.N., Sesay, A., Karikari, K.S., Massawe, F.J, Aguilar-Manjarrez, J., Bannayan, M., and Hampson, K.J. (2001). Assessing the potential of an underutilized crop - a case study using Bambara groundnut. *Exp Agric*.37:433–72.
8. Brink, M., Ramolemana, G.M., and Sibuga, K.P. (*Vigna subterranean* (L.) Verde in Brink. M. & Belay. G. (2006) (éditeurs) PROTAI cereals and pulses/cereals et legumes secs. (CD-Room). PROTA, Wageningen, PaysBas.
9. Chinedu, S.N., and Nyinyi C.O (2012). Proximate analysis of sphenostylisoterocorpa and voandzeia substebanean consumed in South East Nigeria. *Journal of Agriculture Expansion and Rural Development*.10(3):57-62.
10. Karapantsios, T.D., Sakonidou, E.P., and Raphaelides, S.N. (2002).Water dispersion kinetics during starch gelatinization. *Carbohydrate Polymers.* 49(4): 479–490.
11. Kashiri, M., Kashaninejad, M., and Aghajani, N. (2010). Modeling water absorption of sorghum during soaking. *Latin American Applied Research*. 40(4): 383-388.
12. Khazaei, J., and Mohammadi, N. (2009). Effect of temperature on hydration kinetics of sesame seeds (*Sesamum indicum L.*). *Journal of Food Engineering. 91*.
13. Laria, J., Meza, E., Mondragon, M., Silva, R.., and Pena, J.L. (2005).Comparison of overall water uptake by corn kernel with and without calcium hydroxide at room temperature. *Journal of Food +Engineering.* 67(4):451-456.
14. Mazahibet, A.M., Nuha, M.O., Salawa, I.S., and Babiker, E.E. (2013). Some nutritional attributes of Bambara groundnut as influenced by domestic processes. *International Food Research Journal.* 20(3). 1165-1171.
15. Minka, S.R., and Bruneteau, M. (2000). Partial chemical composition of Bambara pea (*Vigna subterranean (L. Verde*). Food Chemistry. 68: 273-276.
16. Nayak, C.A., Suguna, K., and Rastogi, N.K. (2006). Combined Effect of Gamma-Irradiation and Osmotic Treatment on Mass Transfer during Rehydration of Carrots. *Journal of Food Engineering* 74(1): 134-142.
17. Olapade, A.A., Ozumba, A.U., Solomon, H.M., Olatunji, O., and Adelaja, S.O. (2005). Rheological properties and consumer acceptance of moin-moin premix. *Nigerian Food Journal* 23: 144-147.
18. Poulter, N.H., and Caygill, J.C. (2006). Vegetable milk processing and rehydration characteristics of Bambara groundnut [*Voandzeia subterranean* (L.) thouars]. *Journal of Science Food Agricultural*. 31:1158-63.
19. Resio, A.C., Aguerre, R. J., and Suarez, C. (2006). Hydration kinetics of amaranth grain. *Food Engineering*. 72(3): 247-253.
20. Tunde-Akintunde, T.Y. (2010).Water absorption characteristics of Nigerian Acha (*Digitariaexilis*). *International Journal of Food Engineering.* 6: 1-10.
21. Wihad, M., and Omer, E. (2010).NutritiveValue of Newly Developed Bambara Groundnut (*Vigna subterranea L.*) Lines. Department of Food Science and Technology Faculty of Agriculture University of Khartoum. Pg 4-6.