Impact of Processing Techniques and Packaging Materials on some Functional Properties of Soybean Flour.

[1]Bosede A. Orhevba
Department of Agricultural and Bioresources Engineering,
Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria
Email: bosede.orhevba@futminna.edu.ng

Anehi A. Dauda and Peter A. Obasa
Department of Agricultural and Bioresources Engineering,
Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria
Email: {arddyedee@gmail.com, peter.obasa@futminna.edu.ng}

ABSTRACT

This study investigated some functional properties of soya bean flour produced from steeping and gelatinization techniques and stored in different packaging materials. The freshly harvested soya bean seeds used for the study were cleaned and soaked for five different durations (6, 9, 12, 15, and 18 hours); cooked at five different cooking times (20, 25, 30, 35 and 40mins); packaged in five different materials (paper bag, low density polythene bag, composite bag, high density polythene bag and plastic) and stored for five different periods (20, 40, 60, 80 and 100 days). A Response Surface Methodology, Central Composite Experimental Design was used. The samples of flour were then subjected to functional analysis. All experiments were carried out in triplicates. Data obtained was analyzed using Design Expert 11.0 statistical software tool; the Analysis of Variance (ANOVA) was conducted and empirical models developed. Statistical analysis shows that the gelatinization duration, and packaging materials had significant effect ($P \leq 0.05$) on the oil absorption capacity of the flour sample at P-value of 0.044 for gelatinization duration, 0.012 for packaging material, and water absorption capacity of the flour samples was significant with effect to storage duration P= 0.001, packaging material of 0.015 p-value. Bulk density of the processed flour was not significantly affected by processing techniques, packaging materials and storage duration employed in this study. Numerical optimization conducted on the experimental factors shows best desirability constraint of 0.60 point at steeping and gelatinization duration of 13.03 minutes and 25minutes respectively.

Key words: Bulk density; Central composite design; Soya bean flour; Steeping; Oil absorption; Water absorption.

Manuscript received January 3, 2020; revised April 30, 2020.

1.0 INTRODUCTION

Soybean (*Glycine max*) is a legume that originated from Eastern Asia (www.fao.org), it was introduced into Nigeria in 1908 (Omotayo *et al.*, 2007). According to Ajayi *et al.*, (2011), soya bean is being acknowledged as a viable and essentially nutritious crop with numerous health benefits. The crop has also been identified as a major raw material for many domestic and industrial products. Soybean has a great demand due to its versatility; it has found many applications in the formulation of both human and animal foods, pharmaceutical and confectionery industries and other industrial uses (Omotayo *et al.*, 2007). It is utilized in many forms like bean, meal, cake and oil. The industrial demand and domestic supply level for soybean was estimated to be about 634,000 metric tons and 386,864 metric tons respectively (Omotayo *et al.*, 2007).

Soybean flours can be obtained by grinding full-fat dehulled soybeans or defatted flakes made from dehulled soybeans; they are then allowed to pass through a 100-mesh standard screen (www.fao.org). Steeping and gelatinization techniques are used in the processing of soybean to flour so as to minimise the anti-nutritional properties (Bibianalgbabul and Sule, 2013). Functional properties of soybean flour play an important role in the manufacturing of products as it determines the application and use of food materials for various food products (Adeleke and Odedeji, 2010).

Water absorption capacity is the ability of the flour to absorb water and swell for improved consistency, a high absorption capacity may assure product cohesiveness (Houson and Ayenor, 2002). It is desirable in food systems to improve yield and consistency and give body to food. Oil absorption capacity acts as flavour retainer and increases the mouth feel of foods, it also improves the palatability and extension of the shelf life particularly in bakery were fat absorption are desired (Aremu *et al.*,2007).

Packaging has become part of our daily lives. Packaged products are found all over the world. The global packaging market is currently valued at $597 billion and is estimated to reach $820 billion by 2016 (Silayoi and Speece, 2004). Consumers are increasingly demanding higher quality packaging for products which has in turn increased the role of packaging in the sale of goods and services (Institute of Packaging Ghana, IOPG, 2014). Packages come in such forms as packaged foods, canned drinks, and bottled water. Packaging helps consumers know the contents of products, and serve as instruction guides. Manufacturing and expiry dates, warning symbols, net weight, country of origin, recyclable symbol, company's address and nutritional facts are all very essential facts that, through packaging are provided to the consumers. Best packaging material for soybean flour, gives aesthetic delight and satisfaction, and also tactile pleasure (Soroka, 2002).

The objective of storage is to preserve the properties of the flour present after it has been processed, thereby making it possible to obtain and market sub-products with satisfactory quality. Vitality of the product can be preserved and the grinding quality and nutritive properties of the food can be maintained (Brooker *et al*., 1992; Adejumo *et al*., 2018).

Most soya products are made out of soya flour, thus there is a high demand for the flour in commercial quantity. The knowledge of a suitable processing technique and packaging material for soybean flour will go a long way to meeting this demand.

The losses incurred in soybean production can be reduced by processing it into flour. The use of better packaging materials for soybean flour will reduce losses during transportation and storage.

This research therefore finds relevance in the establishment of the best packaging materials and storage conditions for soybean flour that will serve as baseline for confectionary industries.

2. 0 MATERIALS AND METHODS

2.1 Materials

Freshly harvested soybean (*Glycine max*) seeds that were used in producing the flour were obtained from a commercial farmer in Lapai, Niger State, Nigeria. The chemicals and reagents that were used were obtained from the Food Science Laboratory, School of Agricultural Technology, Federal University of Technology Minna, Niger State, Nigeria.

2.2 Methods

2.2.1 Sample Preparation

The flour was prepared according to the method described by Bibianalgbabul and Sule (2013). The grains were manually cleaned by separating all foreign materials, such as sticks, dirt, husk, chaff and other extraneous materials from the soybeans. The soybeans were washed in clean water and soaked for 6 hrs. This method was repeated for soaking times of 9, 12, 15 and 18 hrs. The soaked soybeans were poured in boiling water, and boiled for 20, 25, 30, 35 and 40 mins. The soybeans were washed and the coats removed and separated from the beans in cold water. The beans were dried at 65^0C, grinded into flour, sieved, packaged and stored for 100 days. The experimental design employed in this study is the Central Composite Design giving twenty-five runs as shown in Table 1.

2.2.2 Packaging

Electronic weighing balance was used to measure 200 grams of the flour and packaged in paper bag, low density polythene bag, composite (mixed), high density polythene bag and plastic as shown in Plate I.



Paper bag Low density polythene bag Composite


High density polythene bag Plastic

Plate I: Soybeans flour in different packaging materials.

2.2.3 Storage

The packaged soybean flour was stored for a period of 100 days. The functional properties were determined every 20 days so as to assess the effect of the packaging materials on them during storage.

2.2.4 Functional Properties

Functional properties determined include; water absorption capacity, oil absorption capacity and bulk density. Water absorption capacity was determined by the method described by Aremu *et al.,* (2007) and in accordance with the method reported by Sathe and Salunkhe (1981). Oil absorption capacity was determined according to the method described by Claver *et al;* (2010).
The bulk density of soybean flour was determined according to the method described by Appiah *et al*., (2011).

2.3 Statistical Analysis

All experiments were carried out in triplicates. Data obtained were analyzed using Design Expert 11; Analysis of Variance (ANOVA) was conducted and empirical models were developed 3D surface response plot was developed. The experimental design is shown in Table 1.

Table 1: Response Surface Methodology Central Composite Experimental Design Matrix

Run	Sample	X_1(mins)	X_2(hrs)	X_3(days)	X_4(materials)
1	A	-1(9)	-1(25)	-1(40)	-1(LDPE)
2	B	+1(15)	-1(25)	-1(40)	-1(LDPE)
3	C	-1(9)	+1(35)	-1(40)	-1(LDPE)
4	D	+1(15)	+1(35)	-1(40)	-1(LDPE)
5	E	-1(9)	-1(25)	+1(80)	-1(LDPE)
6	F	+1(15)	-1(25)	+1(80)	-1(LDPE)
7	G	-1(9)	+1(35)	+1(80)	-1(LDPE)
8	H	+1(15)	+1(35)	+1(80)	-1(LDPE)
9	I	-1(9)	-1(25)	-1(40)	+1(HDPE)
10	J	+1(15)	-1(25)	-1(40)	+1(HDPE)
11	K	-1(9)	+1(35)	-1(40)	+1(HDPE)
12	L	+1(15)	+1(35)	-1(40)	+1(HDPE)
13	M	-1(9)	-1(25)	+1(80)	+1(HDPE)
14	N	+1(15)	-1(25)	+1(80)	+1(HDPE)
15	O	-1(9)	+1(35)	+1(80)	+1(HDPE)
16	P	+1(15)	+1(35)	+1(80)	+1(HDPE)
17	Q	-α(6)	0(30)	0(60)	0(Composite)
18	R	+α(18)	0(30)	0(60)	0(Composite)
19	S	0(12)	-α(20)	0(60)	0(Composite)
20	T	0(12)	+α(40)	0(60)	0(Composite)
21	U	0(12)	0(30)	-α(20)	0(Composite)
22	V	0(12)	0(30)	+α(100)	0(Composite)
23	W	0(12)	0(30)	0(60)	-α(Paper)
24	X	0(12)	0(30)	0(60)	+α(Plastic)
25	Y	0(12)	0(30)	0(60)	0(Composite)

X_1= Steeping duration, X_2= Gelatinization duration, X_3= Storage duration,
X_4= Packaging materials

3.0 RESULTS AND DISCUSSION

3.1 Results

The mean of the replicated results obtained for functional properties from the study is presented in Table 2.

Table 2: Functional Properties of Soybean Flour				
Run	Sample	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Bulk Density (g/cm^3)
1	A	220	160	0.56
2	B	220	150	0.57
3	C	240	160	0.56
4	D	240	150	0.57
5	E	220	130	0.57
6	F	220	160	0.57
7	G	240	170	0.57
8	H	240	170	0.56
9	I	220	140	0.57
10	J	220	170	0.56
11	K	240	170	0.57
12	L	230	150	0.58
13	M	220	170	0.57
14	N	220	160	0.57
15	O	240	170	0.57
16	P	230	150	0.57
17	Q	220	170	0.58
18	R	200	190	0.59
19	S	240	160	0.58
20	T	220	190	0.6
21	U	200	130	0.57
22	V	240	170	0.59
23	W	240	170	0.59
24	X	250	170	0.58
25	Y	240	160	0.59

X_1 = Steeping duration, X_2 = Gelatinization duration, X_3 = Storage duration, X_4= Packaging Material

3.2 Discussion

3.2.1 The Impact of Processing Parameters and Packaging Materials on the Functional Properties of Soybean Flour

The results for four factors of response surface methodology, central composite experimental design of functional properties of soybean flour samples are shown in Table 2.

3.2.1.1 Water Absorption Capacity of Soybean Flour

The ANOVA result (Table 3) showed that the developed linear model of water absorption capacity was found to be significant. The processing parameters were all found to have insignificant effect on water absorption capacity of the soybeans flour samples while thee package materials and storage duration effect was significant on the soybeans flour at p-value of 0.015 and 0.017 respectively. The actual model revealed positive effect on the water absorption capacity of the flour as shown in the model equation (1). Figures 1 and 2 shows the contour and 3D effect of variables view of steeping duration, Gelatinization duration and storage duration at 60days and package code value (0) composite material on water absorption capacity of soybeans flour. The value was high at gelatinization duration above 31 along all the steeping durations.

Table 3: ANOVA for Linear model of Water Absorption Capacity of Soybean Flour

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	3416.67	4	854.17	5.55	0.0036
A-Steeping duration	66.67	1	66.67	0.4333	0.5179
B-Gelatinization duration	266.67	1	266.67	1.73	0.2029
C-Storage duration	2016.67	1	2016.67	13.11	0.0017
D-Packaging Material	1066.67	1	1066.67	6.93	0.0159
Residual	3077.33	20	153.87		
Cor Total	6494	24			

*Response 1: Water Absorption Capacity **
***** Values of "Prob > F" less than 0.05 indicate model terms are significant. X_1 = Steeping duration, X_2 = Gelatinization duration, X_3 = Storage duration, X_4= Packaging Material

Final equation in terms of Actual factors

$$Water\ Absorption\ Capacity = 179.03 + 0.055X_1 + 0.0666X_2 + 0.045X_3 + 0.66X_4 \quad 1$$

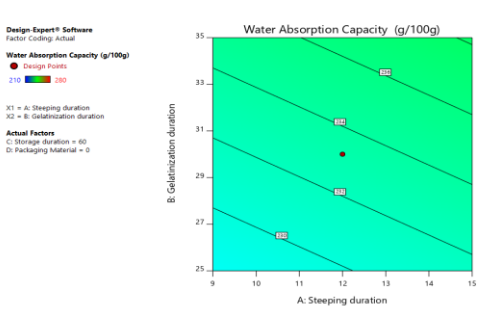

Fig. 1: Water Absorption Capacity Contour Plot

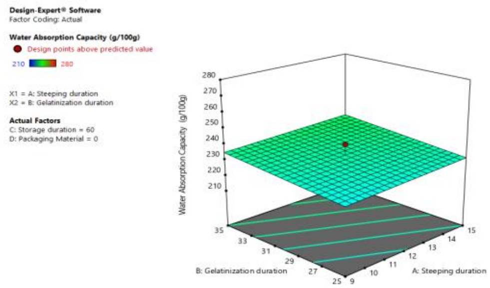

Fig. 2: Three-Dimensional Surface response plot of Water Absorption Capacity

3.2.1.2 Oil Absorption Capacity of Soybean Flour

The statistical analysis showed that the oil absorption capacity of soybean flour is significantly influenced by the processing parameters and packaging materials. The developed linear model was found significant (p-value = 0.013) as shown in the ANOVA result presented in Table 4. All the process factors contributed positively on the oil absorption capacity of the flour as shown in the model equation (2). Figures 3 and 4 shows the 3D surface response view and contour to that shows the boundary effect of variables on oil absorption capacity of the flour with relation to process parameters and storage medium. The linear model ANOVA shows that Gelatinization duration and packaging material has significant effect on the oil Absorption capacity at ($P \leq 0.05$) probability level with boundary region of 29 minutes above within all the steeping duration used in this study.

Table 4: ANOVA for Linear model of Oil Absorption Capacity of Soybean Flour

**Response 2: Oil Absorption Capacity **

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	3350	4	837.5	4.12	0.013 sig
A-Steeping duration	204.1	1	204.17	1	0.32
B-Gelatinization duration	937.5	1	937.5	4.61	0.044
C-Storage duration	704.1	1	704.17	3.46	0.077
D-Packaging Material	1504	1	1504.1	7.4	0.013
Residual	4066	20	203.3		

***** Values of "Prob > F" less than 0.05 indicate model terms are significant
X_1 = Steeping duration, X_2 = Gelatinization duration, X_3 = Storage duration,
X_4= Packaging Material

Final equation in terms of Actual factors

$$Oil\ Absorption\ Capacity = 98.983 + 0.97X_1 + 1.25X_2 + 0.27X_3 + 7.91X_4 \quad \mathbf{2}$$

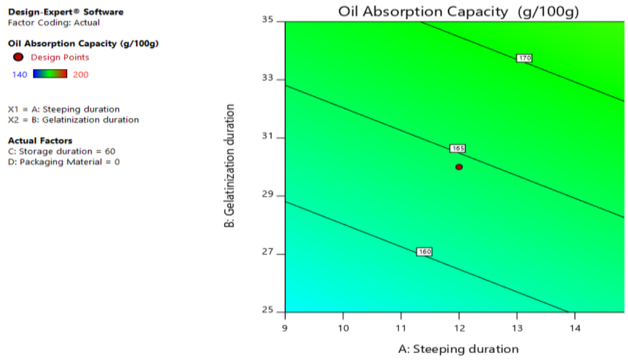

Fig. 3: Oil Absorption Capacity Contour Plot

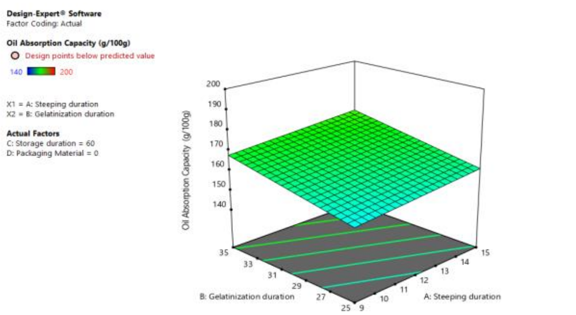

Fig. 4: Three-Dimensional Surface response Plot of Oil Absorption Capacity Model

3.2.1.3 Bulk Density of Soybean Flour

The statistical analysis showed that bulk density was not influenced by the processing parameters, steeping duration, gelatinization duration, storage duration and packaging materials, because their P-values were more than 0.05. The soybean flour bulk density linear model was insignificant but the quadratic model showed significant model at p-value =0.012 because quadratic model p-value is less than $P \leq 0.05$ as presented in the ANOVA result (Table 5). The steeping duration, gelatinization duration, storage duration, package material and interactions between the steeping duration and gelatinization duration; gelatinization duration and package material all had positive effect on the bulk density of the flour as shown in the quadratic model equation (3). The 3D surface respond plots showing the effect of variables on bulk density are shown in Figures 5 and 6.

Table 5: ANOVA for Quadratic model of the Bulk Density of Soybean Flour

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.0075	14	0.0005	4.33	0.0124	sig
A-Steeping duration	0.0003	1	0.0003	2.72	0.1302	
B-Gelatinization duration	0.0002	1	0.0002	1.64	0.2287	
C-Storage duration	0.0007	1	0.0007	5.67	0.0385	
D-Packaging Material	0	1	0	0.302	0.5947	
AB	0.0001	1	0.0001	0.453	0.5162	
AC	6.25E-06	1	6.25E-06	0.0503	0.827	
AD	0.0008	1	0.0008	6.09	0.0332	
BC	0.0001	1	0.0001	0.453	0.5162	
BD	0.0001	1	0.0001	0.453	0.5162	
CD	0.0001	1	0.0001	0.453	0.5162	
A^2	0.0001	1	0.0001	0.4353	0.5243	
B^2	9.93E-06	1	9.93E-06	0.0799	0.7831	
C^2	0.0008	1	0.0008	6.48	0.0291	
D^2	0.0029	1	0.0029	23.1	0.0007	
Residual	0.0012	10	0.0001			
Cor Total	0.0088	24				

* Values of "Prob > F" less than 0.05 indicate model terms are significant, X_1 = Steeping duration, X_2 = Gelatinization duration, X_3 = Storage duration, X_4= Packaging Material

Final equation in terms of Actual factors

$$Bulk\ Density = 0.552 + 0.0027X_1 - 0.0009X_2 + 0.0015X_3 + 0.000231X_4 + 0.0001X_1X_2 + 0.0075X_1X_3 - 0.00225X_1X_4 + 0.00019X_2X_3 + 0.00035X_2X_4 - 0.00094X_3X_4 \quad (3)$$

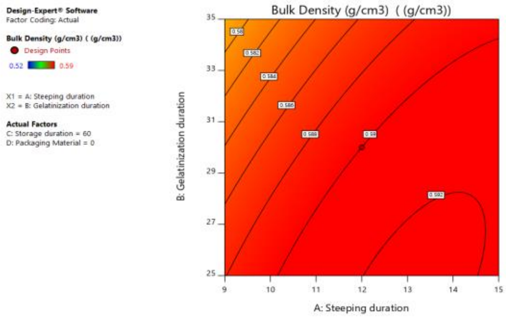

Fig. 5: Bulk Density Contour Plot

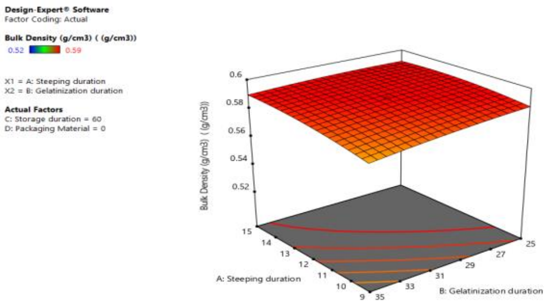

Fig. 6: Three-Dimensional Surface response Plot of Bulk Density Model

Conclusions

It can therefore be concluded that the gelatinization duration, storage duration and packaging materials had significant effect ($P \leq 0.05$) on the water absorption and oil absorption capacity of the soybean flour samples, bulk density of the flour samples was not significantly affected by processing techniques employed in this study. The optimization tool using desirability condition at 0.61 given 45solution points and best optimal techniques conditions to be 13.032 minutes steeping duration and gelatinization time of 25 minutes with storage duration of 69.60 days with the use of composite packaging material.

REFFERENCES

Adeleke R.O and Odedeji J.O. Functional Property of Wheat and Sweet Potato Flour Blends. *Pakistan Journal of Nutrition*, 2010*;* 9(6): 535-538.

Adejumo, B. A.; Sadiq, I. A.; & Obasa, P. A. (2018). Microbiological Quality of Packaged Moringa Oleifera Leaves Powder in storage. *Journal of Science, Technology, Mathematics and Education (JOSTMED)*, volume 14(2).

Ajayi, I. A, Ajibade, O, Oderinde, R. A. Preliminary Phytochemical Analysis of some Plant Seeds. Res. J. Chem. Sci. 2011; 1(3):58-62.

Appiah, F, Asibuo, J.Y and Kumah, P. Physical and functional properties of bean flours of three cowpea (*Vigna unguiculata L. walp*) varieties in Ghana. *African Journal of Food Science*, 2011; 5(2): 100-104.

Aremu, M.O., Olaofe, O., and Akintaye, E.T. (2007). Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. *Journal of Food Technology*, 2007; *5(2): 109-115*.

Bibianalgbabul, D. A. and Sule, S. Proximate composition, functions and sensory properties of Banbara nut (*Voandzeia Subterranean*), Cassava (*Manihot esculentus*) and soybean (*Glycine max*) flour blends for Akpekpa production. Department of Food Science and Technology, University of Agriculture Markurdi, Nigeria, 2013.

Brooker, D.B.; Bakker-Arkema, F.W. and Hall, C.W. *Drying and storage of grains and oilseeds, Springer*, 1992. ISBN 0442205155, New York, United States.

Claver, I.P, Zhang H, Li Q, Zhu K, Zhou H. Impact of the soak and the malt on the physicochemical properties of the sorghum starches. *International Journal of Molecular Science*, 2010; 11:3002–3015.

Houson, P. and G.S. Ayenor. Appropriate processing and food functional properties of maize flour. *African Journal of Science Technology*, 2002; *3:126-131*.

IOPG. Ghana. Institute of Packaging Ghana, Situational Analysis Report, January 2014.

Omotayo, A. M., Olowe, V. I. O, Fabusoro, E, Babajide, J.M, Ojo, D. K and Adegbite, D. A. Commercial Demand for Soybean in Nigeria. Report of a Survey Commissioned by Propcom (Promoting Pro-Poor Opportunities in the Commodity and Service Market). Monograph Series # 29, 2007.

Sathe, S.K. and Salunkhe, D.K. (1981). Functional properties of Great Northern bean Phaseolus vulgaris). *Journal of Food Science* 46:71-75.

Silayoi, P. and Speece, M. (2004). Packaging and Purchase Decisions, *British Food Journal*, 2004; 106(8): 607-628.

Soroka, W. Fundamentals of Packaging Technology, Institute of Packaging Professionals, Naperville, Illinois, USA, 2002.

www.fao.org. Technology of Production

of Edible Flours and Protein Products from Soybeans, FAO AGRICULTURAL SERVICES BULLETIN No. 97, 1992.

Authors contribution

Orhevba, B. A and Anehi, A.D conducted the research; Obasa, P. A analyzed the data; Orhevba, B. A wrote the paper. All authors approved the final version of the paper.

Acknowledgements

The authors will like to thank Laboratory Technologists of the Department of Food Science and Department of Agricultural and Bioresources Engineering, Federal University of Technology Minna, Niger State, Nigeria.

Conflict of Interest

The authors declare no conflict of interest.

Biography of Engr. Dr B. A. Orhevba

Dr. B. A. Orhevba is an Associate Professor of Agricultural Engineering. Her area of specialization is crop processing and storage, food packaging, storage stability of packaged foods, extraction and characterization of oil from underutilized seeds, development of product from underutilized seeds and development of crop processing equipment. She is a registered member of ASABE (The American Society of Agricultural and Biological **Engineers),** COREN (Council for the regulation of Engineering in Nigeria), NSE (Nigerian Society of Engineers) among others. She lectures at the Federal University of technology, Minna, Nigeria. She has many undergraduate and post graduate supervisions to her credit and has published many papers in highly reputable National and International Journals.