International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-12 Issue-8, July 2023

Effect of Varied Pulleys on A Centrifugal Palm Kernel Cracker

Oladebeye, Dayo Hephzibah, Adefidipe, Ebenezer Rotimi, Abodunrin, David Olumuyiwa, Maliki, Omeiza Bayode

Abstract: ***This paper is based on the performance evaluation of centrifugal palm kernel cracker for small, medium and large scale firms that deals with the cracking of palm kernel nut to meet market requirement. The cracking machine has hopper, the cracking chamber which incorporates the shaft and flange, the outlet, electric motor, belt and pulleys. The performance of the machine was evaluated by considering the cracking time and the shaft speed. The machine was modified by introducing four pulleys with diameters of 200mm, 250mm, 300mm, and 350mm, which produced rotor speeds of 936rpm, 749rpm, 624rpm and 535rpm respectively. The rotor speeds were then used to test the designed machine and its efficiency were evaluated. The machine has cracking chamber, which flap the palm kernel nuts on the stationary hard surface. The designed machine was operated by 15hp electric motor. The result showed that the cracking efficiency was highest at 936rpm with efficiency of 53% for a time taken of 38sec to crack effectively.***

Keywords: Cracking Chamber, Cracking Time, Shaft Speed, Cracking Efficiency, Rotor Speed.

I. INTRODUCTION

Centrifugal Palm kernel cracker refers to the method in which palm kernel nuts are cracked using centrifugal force to flap the palm kernel nuts on the stationary hard surface. According to [1] palm kernel and the shell was stated as the very important wealth creating farm product in Nigeria which the kernels and shells have application in numerous industries such as; soap making, cosmetics, livestock feeds (agriculture), medicine, foundry, civil works, even as a means of energy etc. Local farmers in nearly every part of southern Nigeria are faced with the problems of how easily and quickly their palm kernel nut can be cracked and as well separate the shell from the kernels without exerting much energy and time at relatively cheap cost. The economic importance of palm kernel is indicated by its wide use as food, traditional medicines and in industries [2].

Manuscript received on 20 December 2022 | Revised Manuscript received on 01 July 2023 | Manuscript Accepted on 15 July 2023 | Manuscript published on 30 July 2023.

*****Correspondence Author(s)

Oladebeye Dayo Hephzibah, Department of Mechanical Engineering, The Federal Polytechnic, Ado-Ekiti, Nigeria. E-mail: dayobeye@yahoo.com, ORCID ID: 0000-0002-7431-688X

Adefidipe Ebenezer Rotimi*, Olusegun Obasanjo Centre for Engineering Innovation, The Federal Polytechnic, Ado-Ekiti, Nigeria. E-mail: mailto:eecl2013@gmail.com, ORCID ID:0009-0000-2199-0988

Abodunrin David Olumuyiwa, Department of Agricultural Science and Technology, College of Technology, Bamidele Olumilua University of Education, Science and Technology, Ikere Ekiti. Nigeria. E-mail: muyiwaabodunrin@gmail.com, ORCID ID: 0000-0001-7360-9288

Maliki Omeiza Bayode, Department of Mechanical Engineering, The Federal Polytechnic, Ado-Ekiti, Nigeria. E-mail: maliki_ob@fedpolyado.edu.ng, ORCID ID: 0009-0000-1234-8619

Palm kernels are cracked in the local mills for the extraction of palm kernel oil and kernel cake, the kernel oil is used for the production of glycerin, margarine, edible oil, confectionery, candle, soap, oil paint and medicines and the kernel cake is used as an ingredient for livestock feeds in the livestock industries [3].

In the recent past, cracking is done by placing the nut on the top of the stone and striking it with another stone with an impact force, causing the shell to split. However, the industries and local farmers need palm kernel machine to aid their production in order to meet the market requirement (Patrick, *et al.*, 2004) [10]. Due to technological advancement, palm kernel machines were developed for cracking palm kernel to remove the shell from the nut. It was discovered that the palm kernel used are for rural areas and local farmers and not designed for industrial sectors. One of the devices that can produce this requirement of the industrial sectors is called a centrifugal palm kernel cracker [4].

Centrifugal palm kernel cracker comprises of some basic component like the hopper through which the palm kernel nut is fed into the machine, to the chamber which consist of the flange which flap the palm kernel nut on the hard surface with the use of impact force, then the shaft rotate. The pulley is driven by the electric motor which then makes the shaft to rotate [5]. Oluwole *et al.*, (2016) investigated on the dynamics of vertical axis centrifugal nut cracker. The cracker consists of a feed hopper with a flow rate control device, cracking unit, separating unit and power system which consists of a single phase 3hp, 1500-rpm electric motor with belt and pulley system. The cracking unit consists of impeller with four vanes mounted on a vertical shaft and an impeller casing which served as the cracking surface. The working principle of the cracker is similar to that of centrifugal pump. The nuts to be cracked are rotated and pushed by the vanes of the impeller in the direction of the vanes motion, thereby imparting mechanical energy to the nuts. [6]

When leaving the impeller, the nuts gain kinetic (velocity) energy and the velocity components are studied graphically by means of velocity vectors. The results of the analysis showed that the radial velocity is 0.66 m/s, tangential velocity is 15.71 m/s, resultant velocity is 15.72 m/s, while the cracking velocity is 10.41 m/s which gave an impact (cracking) energy of 0.55 J. The cracker was evaluated using sheanut at four moisture levels of 6, 13, 22.7 and 27.9% (db) and nut feed rates of 11.4, 15.5, 23.1 and 45.2 kg/h. Furthermore the study showed that at nut moisture content of 22.7% (db) and feed rate of 11.4 kg/h, the cracking efficiency of 100% was achieved. [7].

Ndukwu *et al.*, (2017) evaluated the functional performance of a vertical-shaft centrifugal palm nut cracker.
In the research, the cracker efficiency and kernel breakage ratio are some of the most important parameters used for evaluating the cracker performance. The result indicated that for the lowest speed of 1,650 r/min, and the highest feed rate of 880 kg/h and for all moisture contents, the cracking efficiency was not up to 65%. Therefore; the obtained result showed that the efficiency increases with an increase in machine speed and a decrease in feed rate. Furthermore, the kernel breakage ratio ranged from 0–0.18 (0–18%) for all feed rates and moisture contents.
Oke, (2007) worked on the development and performance evaluation of indigenous palm kernel dual processing machine. In the work, the machine was tested to ascertain its performance. The result from the research showed it has efficiency of 98% with processing rate of 95nuts per second with just one 4hp electric motor which is an improvement over existing ordinary palm kernel cracking machine that has 90% efficiency of cracking with processing rate of 89nuts per second without separation. [8]
Udo *et al.*, (2012) carried out research on performance evaluation of a palm kernel nut cracking machine. The aim of this research work was to assess the performance of the developed mobile palm kernel nut cracking machine. So total sample of four thousand (4,000) palm kernel nuts were divided into five groups of eight hundred palm kernel nuts and each group was further divided into four sub-groups of two hundred (200) palm kernel nuts. The research work showed that the cracking efficiencies at speeds of 1200, 1800, 2200 and 2400 rpm were 98±0.3, 98.5±0.08, and 98.5±0.01 and 99±0.04%respectively. Also, the performance efficiencies of the developed machine were 93, 94, 95, 94.5 and 94% while the overall efficiencies were 90.86, 92.12, 93.58, 93.08 and93.06% for the set speeds. It may therefore be concluded that the overall performance of this developed palm nut kernel cracking machine were effective because it fell within the range of between 90 to 98% overall efficiency. [9]

II. METHODS

Palm nuts are fed into the feed hopper with the discharge control plate closed. The machine is then powered through a Vee-belt drive arrangement between an electric motor and pulley keyed to the cracking disc shaft. The machine is allowed to attain a steady speed for about five (5) minutes, before the feed control plate is open to allow nuts to fall into the cracking chamber. As the palm nuts enter into the chamber, they are then rotated. The impact force between the palm nut and the chamber casing causes it to crack, thus releasing the kernels and shell nuts that are then discharge through the outlet provided at the machine unto an option collection sack. Four pulleys with the diameters of 200mm, 250mm, 300mm and 350mm were used respectively. The pulleys were then used to test the efficiency of the machine and the results were evaluated. The curve casing that leads the palm kernels to the cracking chamber was introduced in order to prevent splashing or flying back of palm kernels during cracking.

III. TEST RESULTS

Table 1: Result for 30kg Palm Kernel Cracked with a pulley of 200mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	29.6kg
Time taken to crack the palm kernel	38sec
Weight of the palm kernel cracked	15.9kg
Un- cracked palm kernel	1.3kg
Weight of the kernel shell	12.4kg

Table 2: Result for 30kg Palm Kernel Cracked with a pulley of 250mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	29.3kg
Time taken to crack the palm kernel	1min
Weight of the palm kernel cracked	14.3kg
Un- cracked palm kernel	2.1kg
Weight of the kernel shell	12.9kg

Table 3: Result for 30kg Palm Kernel Cracked with a pulley of 300mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	29.3kg
Time taken to crack the palm kernel	1min 37sec
Weight of the palm kernel cracked	13.8kg
Un-cracked palm kernel	2.9kg
Weight of the kernel shell	12.3kg

Table 4: Result for 30kg Palm Kernel Cracked with a pulley of 350mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	28.7kg
Time taken to crack the palm kernel	2mins 29sec
Weight of the palm kernel cracked	12.6kg
Un -cracked palm kernel	4.2kg
Weight of the kernel shell	11.9kg

Table 5: Shows the Result for the Time taken to Crack the Palm Kernel at Different Speed of (936r.p.m, 749r.p.m, 624r.p.m and 535r.p.m)

Speed (rev/min)	Time taken to Crack the Palm Kernel
936r.p.m	38sec
749r.p.m	1min
624r.p.m	1min 37sec
535r.p.m	2mins 29sec

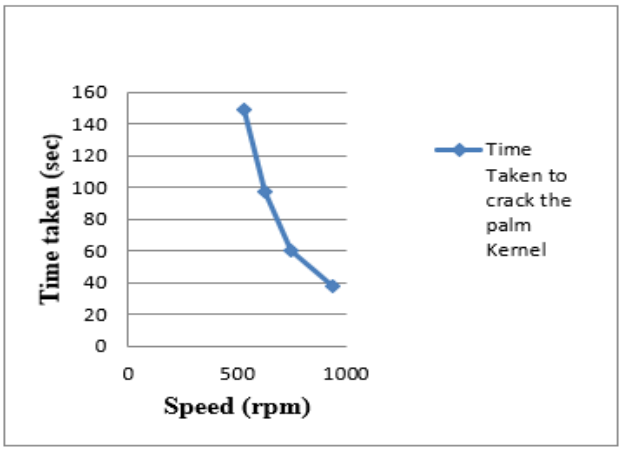


Fig 1: Time taken to crack the palm Kernel

From Figure 1 above, it was deduced that as the speed reduces, the time taken to crack the palm kernel increase.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Table 6: Shows the Result for the Weight of Cracked Palm Kernel at Different Speed of (936r.p.m, 749r.p.m, 624r.p.m and 535r.p.m).

Speed (rev/min)	Weight of Cracked Palm Kernel
936r.p.m	15.9kg
749r.p.m	14.3kg
624r.p.m	13.8kg
535r.p.m	12.6kg

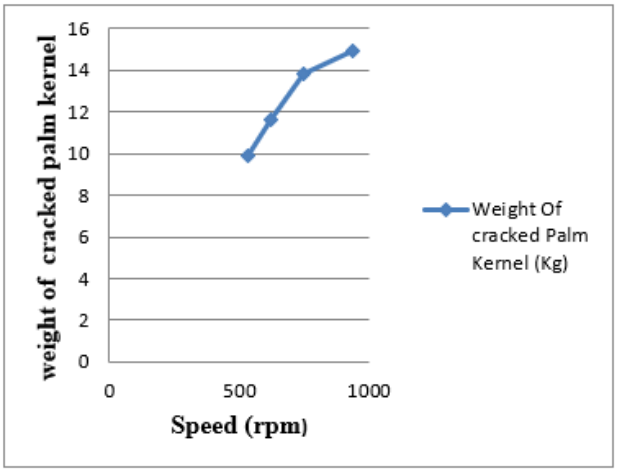


Fig 2: Weight of Cracked Palm Kernel

Figure 2 above shows the result of weight of cracked palm kernel at different speed. It was observed that the weight of the cracked palm kernel reduces as the speed also reduces which implies that the higher the diameter of the pulley the lower the speed and the higher the torque.

Table 7: Shows the Result for the weight of Un - Cracked Palm Kernel at Different Speed of (936r.p.m, 749r.p.m, 624r.p.m, and 535r.p.m)

Speed (rev/min)	Un- cracked palm kernel (kg)
936r.p.m	1.3kg
749r.p.m	2.1kg
624r.p.m	2.9kg
535r.p.m	4.2kg

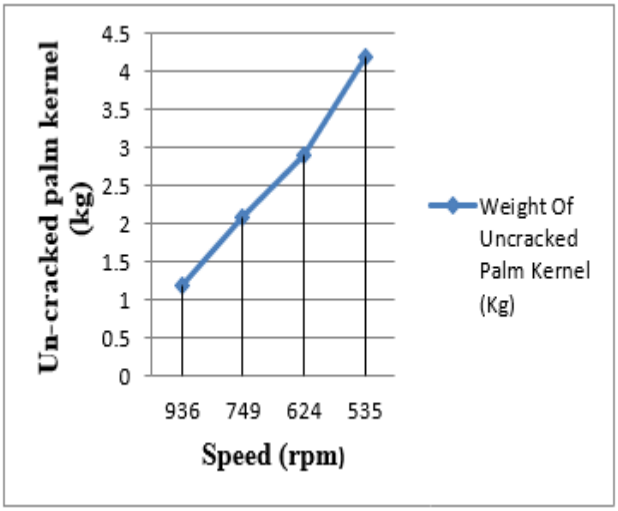


Fig 3: Weight of Un - Cracked Palm Kernel (Kg)

Figure 3 above shows the result of the weight of the un-cracked palm kernel. It was observed that the weight of the un-cracked palm kernel increases as the as the speed reduces.

Table 8: Shows the Comparative Analysis of the Result for the performance evaluation.

Speed(rpm)	Weight of cracked palm kernel(kg)	Weight of un-cracked palm kernel(kg)	Weight of Kernel shell (kg)	Time taken (sec)	Weight after cracking
936	15.9	1.3	12.4	38	29.6
749	14.3	2.1	12.9	60	29.3
624	13.8	2.9	12.3	97	29.0
535	12.6	4.2	11.9	149	28.7

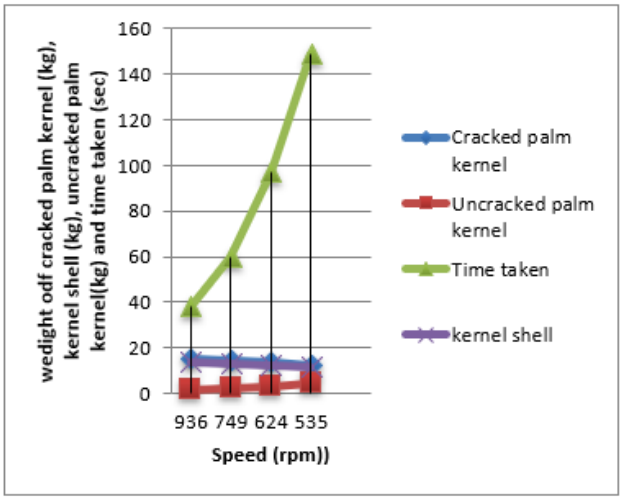


Fig 4: Comparative analysis of the result

Figure 4 above is a graphical representation of the comparison between the volumes of the cracked and un - cracked palm kernel with the time taken to crack at different speed. The graphical representation implies that as the speed reduces, the un-cracked palm kernel increases, the palm kernel shell reduces and the weight of palm kernel after cracking reduces while the time taken increases.

A. Result:

(i) Cracking rate:

$$\frac{Total\ palm\ kernel\ fed\ into\ the\ machine\ (kg)}{Total\ time\ of\ cracking\ (sec)}$$

$$= \frac{30+30+30+30\ (kg)}{129+97+68+56\ (s)}$$

$$\frac{= 120\ kg}{350\ s}$$

$$= 0.34\ \text{kg/s}$$

(ii) Efficiency: $\frac{Work\ Input}{Work\ Input}$ x 100

Work Input

- At Speed of 936r.p.m
  Work Output = 15.9kg
  Work Input = 30kg
  Therefore; $\frac{=15.9\ kg}{30kg}$ x 100
  = 53.0%
- At Speed of 749 r.p.m
  Work Output = 14.3kg
  Work Input = 30kg

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Therefore; $\frac{=14.3kg}{30kg}$ x 100

= 47.6%

- At Speed of 624 r.p.m
  Work Output = 13.8kg
  Work Input = 30kg
  Therefore; $\frac{=13.8kg}{30kg}$ x 100
  = 46.0%
- At Speed of 535 r.p.m
  Work Output = 12.6kg
  Work Input = 30kg
  Therefore; $\frac{=12.6\ kg}{30kg}$ x 100
  = 42.0%

Table 9: Shows the result of the efficiency of the machine at different speed (936rpm, 749rpm, 624rpm, and 535rpm respectively)

Speed (rpm)	Efficiency (%)
936	53.0
749	47.6
624	46.0
535	42.0

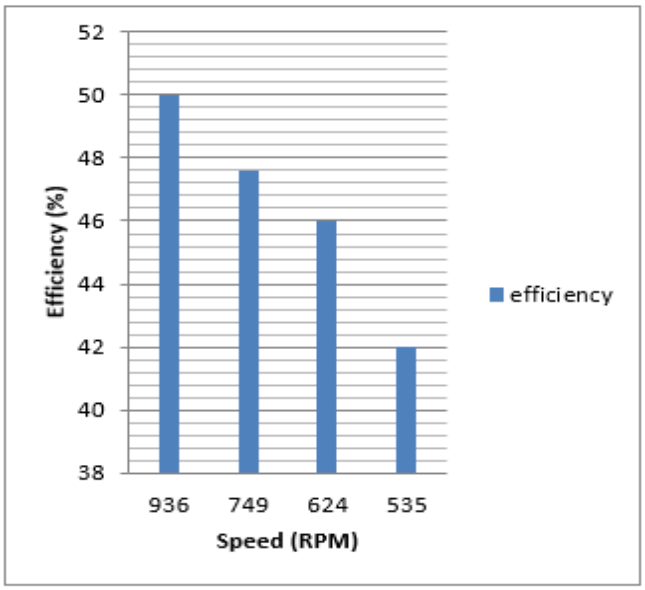


Fig 5: Shows the efficiency of the machine at different speed.

Table 10 Sample Size of Palm Kernel

S/N	1	2	3	4	5	6	7	8	9	10	TOTAL
DIAMETER (MM)	19	21	15	22	12	25	19	12	11	15	171

Mean diameter of palm kernel nut = $\frac{Total\ diameter}{No\ of\ palm\ kernel}$

= $\frac{171}{10}$ = 17.1mm

IV. CONCLUSION

From the above study, it was concluded that performance evaluation was carried out on palm kernel cracker to know the effectiveness of the machine. From the test carried out on the machine, it was deduced that as the speed reduces, the uncracked increases and the palm kernel shell reduces while the time taken increases. That means the cracking efficiency has the highest output at 936rpm with efficiency of 50.0% at a time taken of 38sec to crack effectively.

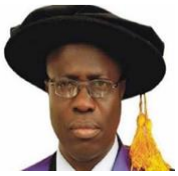
DECLARATION

Funding/ Grants/ Financial Support	No, we did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors having equal contribution for this article.

REFERENCES

1. H. M. A. A. R. M. a. M. I. Norlida, "Blending of palm oil, palm stearin and palm kernel oil in the preparation of table and pastry margarine," Food and Agriculture Organisation of the United Nations, 1996.
2. Koya O. A. and Faborode M. O, "Mathematical modelling of palm fruit cracking based on Hertzs Theory," Biosystems Engineering, vol. 9, no. 4, pp. 1-7, 2005. [CrossRef]
3. A. A. Adebayo, "Development and Performance Evaluation of a Motorized Palm Nut Cracking Machine.," in Proceeding of the Annual Conference of the Nigerian Institution of Agricultural Engineers., 2004.
4. Koya, O. A. and Faborode, M. O., "Separation Theory for Palm Kernel and Shell Mixture on a Spinning Disc," Biosystems engineering , 2006. [CrossRef]
5. Ihediwa, Victor E. and Ndukwu, Macmanus C., "Properties, machines and processes for industrial extraction processes for industrial extraction and refining of palm kernel oil: a brief guide and refining of palm kernel oil: a brief guide," in Proceedings of 18th International Conference and 38th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE), Umudike, , 2017.
6. F. A. Oluwole, M. Ben Oumarou, Garba M. Ngala, "Dynamics of Centrifugal Impact Nut Cracker," International Journal of Research Studies in Science, Engineering and Technology, vol. 16, no. 1, pp. 1-7, 2016.
7. Oluwole Oniya, Fatai Akande, Kazeem Oriola and Gbolahan Bolaji., "Level of Oil Palm Production Mechanization in Selected Local Government Areas of Oyo and Osun States, Nigeria.," in 2nd International Conference on Engineering and Technology Research, 2013.
8. P. K. Oke, "Development and performance evaluation of indigenous palm kernel dual processing machine.," Journal of Engineering and Applied Sciences, vol. 2, no. 4, pp. 701-705, 2007.
9. I. U. E. S. B. a. N. C. B. Udo, "Determination of optimum inclusion level of some plant and animal protein-rich feed ingredients in least-cost ration for African catfish (Clarias gariepinus) fingerlings using linear programming technique," Int. J. Oceanogra. Marine. Ecol. Sys., vol. 1, no. 1, pp. 24-35, 2012. [CrossRef]
10. Patrick D. O., Yusup S., Osman N. B., Zabiri H., Uemura Y. and Shahbaz M., "Development and Performance Evaluation of a Motorized Palm Nut Cracking Machine," in Proceeding of the Annual Conference of the Nigerian Institution of Agricultural Engineers, 2004.

AUTHOR'S PROFILE



Oladebeye, Dayo Hephzibah, holds a Doctor of Philosophy in Mechanical Engineering. He is a Chief Lecturer at the Department of Mechanical Engineering and currently the Rector of The Federal Polytechnic, Ado Ekiti. He is a COREN registered Engineer and fellow of several professional associations including the Nigerian Society of Engineers (NSE), Member of Nigerian Institution of Mechanical Engineers (NIMechE) and Nigerian Institution of Engineering Management (NIEM)etc. He has to his credit several researched published articles in international peer reviewed journals.

Adefidipe, Ebenezer Rotimi, is a PhD research candidate in Production and Materials Engineering. He is the Director of Olusegun Obasanjo Centre for Engineering Innovation, The Federal Polytechnic, Ado Ekiti, Nigeria. He is a COREN registered Engineer and member of professional associations such as the Nigerian Institution of Mechanical Engineers (NIMechE), Institute of Appraisers and Cost Engineers (IACE), and the Nigerian Society of Engineers (NSE).
Engr. Adefidipe specializes in the design, fabrication, installation, and performance evaluation of food processing and industrial machines. He has publications in various international peer reviewed journals.

Abodunrin David Olumuyiwa is a Master of Engineering Degree Candidate. He is currently an Assistant Chief Agricultural Superintendent at Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Nigeria He is a COREN registered Engineer. His research interest includes Agricultural and Bio-Environmental Engineering, He has published in several international peer reviewed journals.

Maliki Omeiza Bayode holds a Master degree in Engineering. He is Lecturer I at the Department of Mechanical Engineering. He is currently the Head of Production Unit of the Department of Mechanical Engineering, The Federal Polytechnic, Ado-Ekiti. He is a COREN registered Engineer and a member of Nigerian Association of Technologist in Engineering. He has to his Credit several researched published articles in international peer reviewed journals.