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Content

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The Comparative Study of Gompertz Exponential Distribution and other three Parameter Distributions of Exponential Class

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***Abstract*:** Statistical distributions are very useful in describing and predicting real world phenomena. In this paper, a new continuous model called Gompertz exponential distribution is defined and studied. Its resulting densities and statistical properties were carefully derived and the method of maximum likelihood was proposed in estimating the model parameters. A simulation on R was done to assess the performance of the parameters of the new model. Gompertz exponential distribution was illustrated with an application to real life data. The result shows that Gompertz exponential distribution performs better than other three-parameter distributions such as Kumaraswamy–exponential distribution, Generalized Gompertz distribution and Three-Parameter Lindley distribution.
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Keywords: MLE, GOMPERTZ-exponential, replication, Log Likelihood and AIC

1.0 Introduction

Statistical distributions and their properties are used in modeling naturally occurring phenomena. A large number of distributions have been defined and studied in the literature, which are found to be applicable in the real life. The normal distribution addresses real-valued variables that tend to cluster at a single mean value. The Poisson distribution models discrete rare events. [1] studied the Gompertz distribution and calculated the moment generating function in terms of incomplete or complete gamma functions, and their results are either approximate or left in an integral form. The development of new compound distributions that are more flexible than existing distributions is an important new trend in distribution. For instance, the beta-Gompertz distribution [2] and the generalized Gompertz distribution (GGD) [3] were both introduced to take care of skewed data; while the Exponentiated Generalized Weibul-Gompertz distribution and the Gompertz- Lomax distribution (which extends the Lomax distribution using the Gompertz family of distributions) were introduced to take care of non-normal data [4].

The exponential distribution is perhaps the most widely applied statistical distribution for problems in reliability. The exponentiated Gompertz distribution defined and studied by [5] is generated from Gompertz random variable by raising the cdf of the Gompertz distribution to a parameter θ.

The current paper focuses on extending the Exponential distribution using the Gompertz family of distributions. The method of Maximum Likelihood Estimator (MLE) for estimating the parameters of the distribution is proposed. A simulation method is used to assess the performance of the parameters of the Gompertz exponential distribution, and an application to real life data sets was provided to assess the potentials of the newly derived distribution. The results obtained are compared with those from Generalized Gompertz distribution, and the proposed distribution is shown to have better performance.

To start with, the cumulative distribution function (cdf) and probability density function (pdf) of the exponential distribution with parameter λ are given by

$$G(x) = 1 - e^{-\lambda x}, \qquad \lambda > 0$$

$$g(x) = \lambda e^{-\lambda x}, \qquad \lambda > 0$$

respectively where λ is referred to as the rate parameter.

According to [6] the cdf and pdf of the Gompertz generalized family of distributions are given by

$$F(x) = 1 - e^{\left(\frac{\theta}{\gamma}\right)\{1-[1-G(x)]^{-\gamma}\}} \qquad ; \theta > 0, \gamma > 0$$

$$f(x) = \theta g(x)[1 - G(x)]^{-\gamma-1} e^{\left(\frac{\theta}{\gamma}\right)\{1-[1-G(x)]^{-\gamma}\}} \qquad ; \theta > 0, \gamma > 0$$

Where θ and γ are additional shape parameters whose role is to vary tail weights. $G(x)$ and $g(x)$ are the cdf and pdf of the parent (or baseline) distribution respectively. The pdf of Gompertz-Exponential distribution is derived by inserting the densities in (1) and (2) into (4)

$$f(x) = \theta \lambda e^{\lambda x \gamma} e^{\left(\frac{\theta}{\gamma}\right)[1-e^{\lambda x \gamma}]}, \qquad x > 0, \theta > 0, \gamma > 0, \lambda > 0$$

where θ and γ are scale parameters while λ is rate parameter.

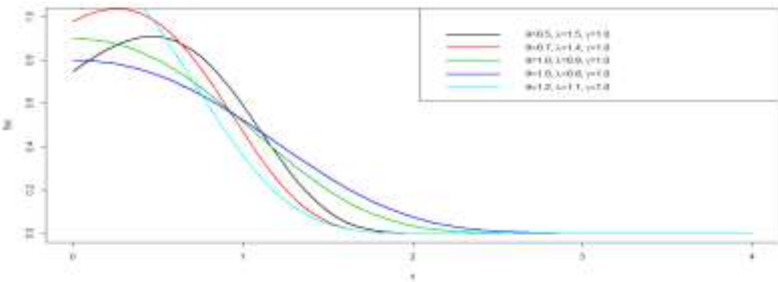

Figure 1: Graph of pdf of GoEp distribution at various parameters.

The cdf of Gompertz-Exponential distribution is derived by inserting the density in (1) into (3),

$$F(x) = 1 - e^{\left(\frac{\theta}{\gamma}\right)[\,1-e^{\lambda x \gamma}]} \quad ,\theta > 0\,,\gamma > 0\,,\lambda > 0 \qquad (6)$$

where θ and γ are scale parameters while λ is rate parameter.

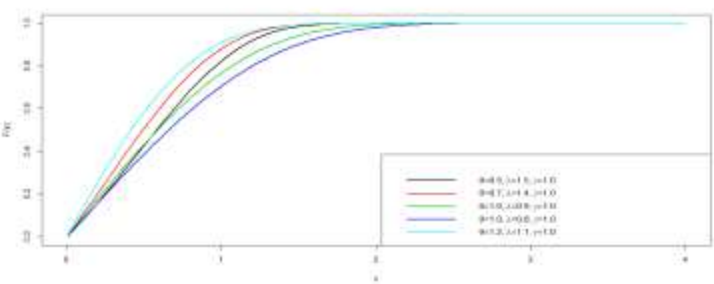

Figure 2: Graph of CDF of GoEp distribution at various parameters.

The Mean and Variance of Gompertz Exponential distribution is obtained thus:

$$E(X) = \int_0^\infty x f(x) dx$$

Using (5) for *f*(*x*), we obtain

$$E(x) = \int_0^\infty x\theta\lambda e^{\lambda x \gamma} e^{\left(\frac{\theta}{\gamma}\right)[\,1-e^{\lambda x\gamma}]} dx$$

Let $t = \lambda\gamma, p = \theta\lambda \; and \; z = \frac{\theta}{\gamma}$

$$E(x) = \int_0^\infty xpe^z \, e^{tx} e^{-ze^{tx}} \, dx$$

Let $s = pe^z$

$$E(x) = \int_0^\infty xs \, e^{tx} e^{-ze^{tx}} \, dx \qquad (7)$$

Let $= ze^{tx}$, therefore, $e^{tx} = \frac{u}{z}$

$$du = zte^{tx} dx, \qquad dx = \frac{du}{zte^{tx}} = \frac{du}{tu}$$

When $x = 0, u = ze^{tx} = ze^{t(0)} = ze^0 = z$

When $x = \infty, u = ze^{tx} = ze^{t(\infty)} = ze^\infty = \infty$

From (7), $E(x) = \int_0^\infty xs \, e^{tx} e^{-ze^{tx}} \, dx$

$$E(x) = \int_z^\infty xs \frac{u}{z} e^{-u} \frac{du}{tu}$$

$$E(x) = \int_z^\infty \frac{s}{zt} xe^{-u} du = \frac{s}{zt} \int_z^\infty xe^{-u} \, du$$

But u $= ze^{tx}$, $e^{tx} = \frac{u}{z}$, $tx = ln\frac{u}{z}$, $x = \frac{1}{t} ln\frac{u}{z}$

Recall that $(x) = \frac{s}{zt} \int_z^\infty xe^{-u} \, du$, therefore, $E(x) = \frac{s}{zt} \int_z^\infty \frac{1}{t} ln \frac{u}{z} e^{-u} du$

$$E(x) = \frac{s}{zt^2} \int_z^\infty ln\frac{u}{z} e^{-u} du$$

$$E(x) = \frac{s}{zt^2} \int_z^\infty ln\frac{u}{z} e^{-u} du = \frac{pe^z}{\frac{\theta}{\gamma}\lambda^2 \gamma^2} \int_z^\infty ln\frac{u}{z} e^{-u} du = \frac{\theta\lambda e^{\theta/\gamma}}{\frac{\theta}{\gamma}\lambda^2 \gamma^2} \int_z^\infty ln\frac{u}{z} e^{-u} du = \frac{e^{\theta/\gamma}}{\lambda\gamma} \int_z^\infty ln\frac{u}{z} e^{-u} du$$

The mean of GOMPERTZ exponential distribution is hereby derived in a integral form as given below,

$$E(x) = \frac{e^{\frac{\theta}{\gamma}}}{\lambda\gamma} \int_z^\infty ln\frac{u}{z} e^{-u} du$$

$where\ \ z = \frac{\theta}{\gamma}\ , t = \lambda\gamma, u = ze^{tx} = \frac{\theta}{\gamma}e^{\lambda\gamma x}$

$Recall, Var(x) = E(x^2) - [E(x)]^2$

$E(x^2) = \int_0^\infty x^2 f(x)dx$

$f(x) = \theta\lambda e^{\lambda x\gamma} e^{(\frac{\theta}{\gamma})[1-e^{\lambda x\gamma}]}$

$E(x^2) = \int_0^\infty x^2 \theta\lambda e^{\lambda x\gamma} e^{(\frac{\theta}{\gamma})[1-e^{\lambda x\gamma}]} dx$

Let $t = \lambda\gamma, p = \theta\lambda\ and\ z = \frac{\theta}{\gamma}$

$E(x^2) = \int_0^\infty x^2 pe^{tx} e^{z[1-e^{tx}]} dx$

$E(x^2) = \int_0^\infty x^2 pe^{tx} e^{z} e^{-ze^{tx}}$

$E(x^2) = \int_0^\infty x^2 pe^{z}\ e^{tx} e^{-ze^{tx}}\ dx$

Let $s = pe^z$

$E(x^2) = \int_0^\infty x^2 s\ e^{tx} e^{-ze^{tx}}\ dx$ (8)

Let u $= ze^{tx}$, therefore, $e^{tx} = \frac{u}{z}$

$du = zte^{tx}dx, \quad dx = \frac{du}{zte^{tx}} = \frac{du}{tu}$

When $x = 0, u = ze^{tx} = ze^{t(0)} = ze^0 = z$

When $x = \infty, u = ze^{tx} = ze^{t(\infty)} = ze^\infty = \infty$

From (8), $E(x^2) = \int_0^\infty x^2 s\ e^{tx} e^{-ze^{tx}}\ dx$

$E(x^2) = \int_z^\infty x^2 s \frac{u}{z} e^{-u} \frac{du}{tu}$

$$E(x^2) = \int_z^{\infty} \frac{s}{zt} x^2 e^{-u} du = \frac{s}{zt} \int_z^{\infty} x^2 e^{-u}\, du$$

But $= ze^{tx}$, $e^{tx} = \frac{u}{z}$, $tx = ln\frac{u}{z}$, $x = \frac{1}{t} ln\frac{u}{z}$, $x^2 = (\frac{1}{t} ln\frac{u}{z})^2 = \frac{1}{t^2}\ (ln\frac{u}{z})^2$

$$E(x^2) = \frac{s}{zt^3}\int_z^{\infty}(ln\frac{u}{z})^2 e^{-u} du = \frac{pe^z}{\frac{\theta}{\gamma}\lambda^3\gamma^3}\int_z^{\infty}(ln\frac{u}{z})^2 e^{-u} du$$

$$= \frac{\theta\lambda e^{\frac{\theta}{\gamma}}}{\frac{\theta}{\gamma}\lambda^3\gamma^3}\int_z^{\infty}(ln\frac{u}{z})^2 e^{-u} du$$

$$E(x^2) = \frac{e^{\frac{\theta}{\gamma}}}{\lambda^2\gamma^2}\int_z^{\infty}(ln\frac{u}{z})^2 e^{-u} du$$

The variance of GOMPERTZ exponential distribution is hereby derived in a integral form as

$$Var(x) = \frac{e^{\frac{\theta}{\gamma}}}{\lambda^2\gamma^2}\int_z^{\infty}(ln\frac{u}{z})^2 e^{-u} du - \left(\left(\frac{e^{\frac{\theta}{\gamma}}}{\lambda\gamma}\int_z^{\infty} ln\frac{u}{z} e^{-u} du\right)^2\right)$$

$where\ \ z = \frac{\theta}{\gamma}$, $t = \lambda\gamma, u = ze^{tx} = \frac{\theta}{\gamma} e^{\lambda\gamma x}$

The parameters of the GoEp distribution can be estimated using the method of Maximum Likelihood Estimation (MLE) as follows: let

$x_1, x_2, \ldots, x_n$ denote random samples each having the pdf of the GOMPERTZ-exponential distribution, then the likelihood function is given by

$$f(x_1, x_2, \ldots, x_n; \theta, \gamma, \lambda) = \prod_{i=1}^{n}\{\theta\lambda e^{\lambda x_i\gamma} e^{(\frac{\theta}{\gamma})[1-e^{\lambda x_i\gamma}]}\} \qquad (9)$$

Let l denote the log-likelihood function, that is, let

$l = logf(x_1, x_2, \ldots, x_n; \theta, \gamma, \lambda)$, then

$$l = nlog\theta + nlog\lambda + \lambda\gamma\sum_{i=1}^{n} x_i + \frac{\theta}{\gamma}\sum_{i=1}^{n}[\,1 - e^{\lambda x_i\gamma}]$$

$$\frac{\partial l}{\partial\theta} = \frac{n}{\theta} + \frac{1}{\gamma}\sum_{i=1}^{n}\left[1 - e^{\lambda x_i\gamma}\right]$$

$$\frac{\partial l}{\partial\lambda} = \frac{n}{\lambda} + \gamma\sum_{i=1}^{n} x_i - \theta\sum_{i=1}^{n} x_i e^{\lambda x_i\gamma}$$

$$\frac{\partial l}{\partial\gamma} = \lambda\sum_{i=1}^{n} x_i - \frac{\theta}{\gamma^2} - \lambda\sum_{i=1}^{n} x_i e^{\lambda x_i\gamma}$$

Solving $\frac{dl}{d\theta} = 0$, $\frac{dl}{d\lambda} = 0\ and\ \frac{dl}{d\gamma} = 0$ simultaneously gives the maximum likely estimates of parameters θ, λ *and* γ. Meanwhile, the solution cannot be gotten analytically except numerically when data sets are available. Software like R, MATLAB, MAPLE and so on could be used to get the estimates.

The expressions for the reliability function, hazard function (or failure rate), reversed hazard function and odd functions are all derived and established below.

The expressions for the reliability function, hazard function (or failure rate), reversed hazard function and odd functions are all derived and established below.

Reliability or survival function can be obtained from

$$S(x) = 1 - F(x) \tag{10}$$

Therefore, the reliability function of the GoEp distribution is given by

$$S(x) = 1 - \{ 1 - e^{\left(\frac{\theta}{\gamma}\right)[1-e^{\lambda x \gamma}]} \}$$

$$S(x) = e^{\left(\frac{\theta}{\gamma}\right)[1-e^{\lambda x \gamma}]} \quad ,x > 0,\ \theta > 0\ ,\gamma > 0\ ,\lambda > 0 \tag{11}$$

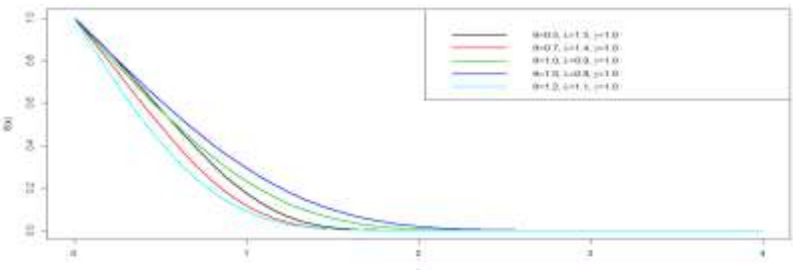

Figure 3: Graph of survival function of GoEp distribution at various parameters.

Hazard function can be obtained from

$$h(x) = \frac{f(x)}{S(x)} \tag{12}$$

Therefore the hazard function of GoEp distribution is given by

$$h(x) = \frac{\theta \lambda e^{\lambda x \gamma} e^{\left(\frac{\theta}{\gamma}\right)[1-e^{\lambda x \gamma}]}}{\left\{e^{\left(\frac{\theta}{\gamma}\right)[1-e^{\lambda x \gamma}]}\right\}}$$

$$h(x) = \theta \lambda e^{\lambda x \gamma} \qquad x > 0\ ,\theta > 0\ ,\gamma > 0\ ,\lambda > 0 \tag{13}$$

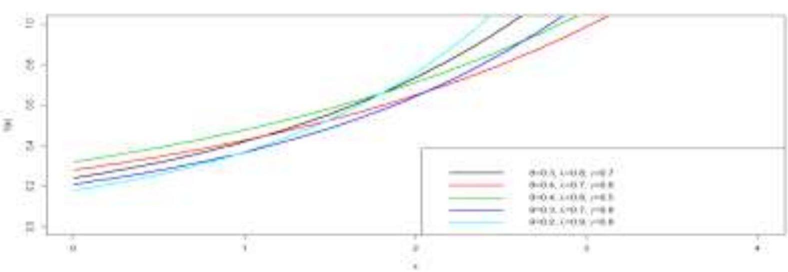

Figure 4: Graph of Hazard function of GoEp distribution at various parameters.

The reversed hazard function can be derived from

$$r(x) = \frac{f(x)}{F(x)} \qquad (14)$$

Therefore, the reversed hazard function of GoEp distribution is given by

$$r(x) = \frac{\left\{\theta\lambda e^{\lambda x\gamma} e^{\left(\frac{\theta}{\gamma}\right)\left[1-e^{\lambda x\gamma}\right]}\right\}}{\left\{1 - e^{\left(\frac{\theta}{\gamma}\right)\left[1-e^{\lambda x\gamma}\right]}\right\}} \ ,\theta > 0 \ ,\gamma > 0 \ ,\lambda > 0 \qquad (15)$$

Odds function can be derived from $O(x) = \frac{F(x)}{S(x)}$ (16)

Therefore, the odds function for the GoEp distribution is given by

$$O(x) = \frac{1 - e^{\left(\frac{\theta}{\gamma}\right)\{1-[1-G(x)]^{-\gamma}\}}}{e^{\left(\frac{\theta}{\gamma}\right)\left[1-e^{\lambda x\gamma}\right]}} \ ,\theta > 0 \ ,\gamma > 0 \ ,\lambda > 0 \qquad (17)$$

Quantile function can be derived from $Q(u) = F^{-1}(u)$ (18)

Therefore, the quantile function of the GoEp distribution is derived as follows:

$$F(x) = 1 - e^{\left(\frac{\theta}{\gamma}\right)\left[1-e^{\lambda x\gamma}\right]} \ , \qquad \theta > 0 \ ,\gamma > 0 \ ,\lambda > 0$$

Let $F(x) = u$

Therefore, $u = 1 - e^{\left(\frac{\theta}{\gamma}\right)\left[1-e^{\lambda x\gamma}\right]}$

$$e^{\left(\frac{\theta}{\gamma}\right)\left[1-e^{\lambda x\gamma}\right]} = 1 - u$$

$$\left(\frac{\theta}{\gamma}\right)\left[1 - e^{\lambda x\gamma}\right] = \log(1-u)$$

$$\left[1 - e^{\lambda x\gamma}\right] = \left(\frac{\gamma}{\theta}\right)\log(1-u)$$

$$e^{\lambda x\gamma} = 1 - \left(\frac{\gamma}{\theta}\right)\log(1-u)$$

$$\lambda x\gamma = log[1 - \left(\frac{\gamma}{\theta}\right)\log(1-u)]$$

$$x = \frac{1}{\lambda\gamma} log[1 - \left(\frac{\gamma}{\theta}\right)\log(1-u)]$$

Therefore, $Q(u) = \frac{1}{\lambda\gamma} log\left[1 - \left(\frac{\gamma}{\theta}\right)\log(1-u)\right]$ (19)

Where $u \sim Uniform\ (0,1)$.

Random numbers can be generated from the GoEp distribution using

$$x = \frac{1}{\lambda\gamma} log\left[1 - \left(\frac{\gamma}{\theta}\right)\log(1-u)\right] \qquad (20)$$

The median of the GoEp distribution can be derived by substituting $u = 0.5$ in (19) as follows:

$$Median = \frac{1}{\lambda\gamma} log\left[1 - \left(\frac{\gamma}{\theta}\right)\log(1-0.5)\right]$$

$$Median = \frac{1}{\lambda\gamma} log\left[1 - \left(\frac{\gamma}{\theta}\right)\log 0.5\right] \qquad (21)$$

Other quantiles can also be derived from (19) by substituting the appropriate values of *u*.

2.0 Materials and Methods

We conducted simulation study for the purpose of investigating the behaviours of the parameters of the new model. Data sets were generated from the GoEp distribution using R software for simulation with a replication m=1000 and random sample of sizes 50, 100 and 150. The simulation was conducted for three different cases by varying the parameter values. The selected parameter values are $\theta = 0.5$, $\lambda = 0.5$, and $\gamma = 0.5$; and $\theta = 1$, $\lambda = 1$, and $\gamma = 1$; and $\theta = 2$, $\lambda = 2$, and $\gamma = 2$ respectively. Results of the simulation study are shown in Tables 1, 2 and 3

A first real life data was on the strengths of 1.5cm glass fibres of workers at the UK national Physical Laboratory. The data has previously been used by [7], [8], [9] and [4] while the second data was on the lifetimes of 50 devices. The data was drawn from [10] and was used by [3].

3.0 Results

Tables 1, 2 and 3, are the Root Mean Square Error (RMSE) which reduces for the selected parameter values as the sample size increases. This indicates that the parameters of Gompertz Exponential distribution are stable. Table 4 revealed that both data I and data II are negatively skewed with coefficients of skewness -0.8999 and –0. 1378 respectively. The performance ratings of the Gompertz-exponential are shown in Tables 5 and 6 below

Table 5 and 6 are the distribution that has the lowest –LL and AIC. The smaller the values of the –LL and AIC the better the fit of the data and this is judged to be the best out of the competing distributions. With this regard to this information, the competing distributions are ranked in the order of best to the least. This implies that Gompertz exponential distribution has the smallest –LL and AIC compare to other distributions like Kumaraswamy Exponential distribution, Generalized Gompertz distribution and Three-Parameter Lindley distribution

4.0 Discussion of Findings

It can be deduced from Tables 1, 2 and 3 that the Root Mean Square Error (RMSE) reduces for all the selected parameter values as the sample size increases. This gives credence to the stability of the parameters of Gompertz Exponential distribution. The Table 4 is about result of the skewness of the real life data I and II which were negatively skewed.

Tables 5 and 6 give information about the fit of the distributions that were compared. The distribution with the lowest –LL and AIC is judged to be the best out of the competing distributions. The competing distributions can be ranked in the following order of best to the least such as from Gompertz-Exponential distribution, Kumaraswamy-Exponential distribution, Generalized Gompertz distribution and three–parameter Lindley distribution for the data on the strengths of glass fibres. The result shows that the data on the lifetimes of 50 devices, the competing distributions can be ranked in the following order (best to the least): GOMPERTZ-exponential distribution, Generalized Gompertz distribution, Kumaraswamy-Exponential distribution and three–parameter Lindley distribution.

5.0 Conclusion

The simulation study conducted showed that the parameters of the Gompertz Exponential distribution are stable. Also the values for biasedness that were generated were small, indicating that the maximum likelihood estimates of the GOMPERTZ exponential distribution are not too far from the true parameter values. The absolute bias and the root mean square values decreases as the sample size increases. An application to real life data shows that the GOMPERTZ exponential distribution performs better than its competitors.

6.0 References

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Table 1: Simulation study at $\theta = 0.5$, $\lambda = 0.5$ and $\gamma = 0.5$

n	Parameters	Means	Bias	Std Error	RMSE
50	$\theta = 0.5$	0.4076	0.0924	3.5553	0.2667
	$\lambda = 0.5$	0.7414	-0.2414	6.4635	0.3595
	$\gamma = 0.5$	0.2177	0.2823	1.8996	0.1949
100	$\theta = 0.5$	0.6787	- 0. 1787	2.9989	0.1732
	$\lambda = 0.5$	3.4324	-2.9324	7.4332	0.2726
	$\gamma = 0.5$	0.7455	-0.2455	3.2873	0.1813
150	$\theta = 0.5$	0.6169	-0.1169	3.7880	0.1589
	$\lambda = 0.5$	0.5608	-0.0608	3.4433	0.1515
	$\gamma = 0.5$	0.3438	0.1562	2.1128	0.1187

Table 2: Simulation study at $\theta = 1$, $\lambda = 1$ and $\gamma = 1$

n	Parameters	Means	Bias	Std Error	RMSE
50	$\theta = 1$	1.2657	-0.2657	5.1286	0.3203
	$\lambda = 1$	0.6676	0.3324	2.6972	0.2323
	$\gamma = 1$	1.5581	-0.5581	6.2999	0.3550
100	$\theta = 1$	1.4071	-0.4071	3.9013	0.1975
	$\lambda = 1$	0.6378	0.3622	1.7612	0.1327
	$\gamma = 1$	1.9934	-0.9934	5.5040	0.2346
150	$\theta = 1$	1.7204	-0.7204	2.3016	0.1239
	$\lambda = 1$	0.4463	0.5537	0.5930	0.0629
	$\gamma = 1$	3.0393	-2.0393	4.0560	0.1644

Table 3: Simulation study at $\theta = 2, \lambda = 2$ and $\gamma = 2$

n	Parameters	Means	Bias	Std Error	RMSE
50	$\theta = 2$	0.7456	1.2544	2.0670	0.2033
	$\lambda = 2$	5.3744	-3.3744	14.7060	0.5423
	$\gamma = 2$	1.3379	0.6621	3.6434	0.2699
100	$\theta = 2$	1.1800	0.8200	0.9210	0.1709
	$\lambda = 2$	2.6480	-0.6480	6.4870	0.2547
	$\gamma = 2$	2.0600	-0.0600	5.0120	0.2239
150	$\theta = 2$	1.9950	0.0050	2.6570	0.1331
	$\lambda = 2$	2.0090	-0.0090	2.6540	0.1330
	$\gamma = 2$	2.1890	-0.1890	2.9070	0.1392

Table 4: The descriptive statistics for the two datasets above are provided in the table below.

Parameters	N	Min.	Q_1	Median	Q_3	Mean	Max.	Skewness	Kurtosis	Variance
Dataset 1	63	0.550	1.375	1.590	1.685	1.507	2.240	- 0.8999	3.9238	0.1051
Dataset II	50	0.10	13.50	48.50	81.25	45.69	86.00	- 0.1378	1.4139	1078.15

Table 5 Performance of Compared Distributions using data on 1.5cm glass fibres

Distributions	Estimates	-LL	AIC
Gompertz-Exponential	$\theta = 0.605800$ $\lambda = 0.145560$ $\gamma = 25.05831$	14.8081	35.61621
Kumaraswamy-Exponential	θ =1756 λ =7.001 γ = 0.2599	15.91371	37.82742
Generalized Gompertz	θ =0.49258 λ=0.48005 γ =0.54581	83.20132	172.4026
Three-Parameter Lindley	θ=0.499886 λ=0.002048 $\gamma = 0.01903$	102.9163	211.8325

Table 6: Performance of Compared Distributions using data on Lifetimes of 50 devices

Distributions	Estimates	-LL	AIC
Gompertz-Exponential	θ =0.01050 λ =0.92555 γ =0.02193	235.3308	476.6617
Generalized Gompertz	θ =0.00143 λ =0.044 γ = 0.2599	235.3920	476.7840
Kumaraswamy Exponential	θ =0.12631 λ=0.46598 γ =0.15839	238.4378	482.8756
Three-Parameter Lindley	θ=0.0049523 λ=0.0103508 γ=0.0001513	322.0525	650.105

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Proximate Composition and Amino Acids Contents in Selected Legumes and Hura crepitans seed in Wukari Taraba State

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***Abstract*:** The study evaluated the proximate composition and amino acid contents of selected legumes and Hura crepitans seed in Wukari,Taraba State, Nigeria. The Sand box seeds were collected from its tree in Wukari town, while black eyed pea and red kidney beans were purchased from Wukari market. The samples were processed into powder for proximate composition and amino profile. In all the samples, 18 amino acids were determined with higher values for aspartic acid, glutamic acid, leucine and phenylalanine while cysteine (0.43-0.79g/ 100g) had the lowest value in the samples analysed. Levels of amino acid ranged as: Sandbox seed had 0.79 ± 0.02 to 10.44 ± 0.02 g/100g, Black eyed pea seed had 0.51 ± 0.12 to 8.53 ± 0.03 g/100g, red kidney bean had 0.43 ± 0.02 to 7.93 ± 0.02 g/100g. The sand box seed had the highest protein content (33.71± 0.02 %), followed by red kidney bean (29.21 ± 0.02%). Nitrogen free extract had the highest value in black eyed pea (63.29±0.01%). The sand box seed had the highest crude fat (7.27 ± 0.02%). All the three crop samples had low safe moisture levels for storage. The study revealed the variation in the nutrients composition of the crop samples. However, sand box seeds had the highest protein content, coupled with high levels of amino acids detected, but the seed is yet to be consumed by humans. Hence, the need for further research on Hura crepitans with the view of reducing the deleterious effects of its antinutrients.

Keyword: Legumes, Proximate composition, Amino acids, High Performance Liquid Chromatography, Energy value

Introduction

Legumes refer to the seeds of *Leguminosae* including peas, beans and pulses. Legumes are considered as "poor man's meat" due to their high protein content and low cost compared to meat and meat products [1]. In most developing countries of the world, including Nigeria where diets are composed mainly of one plant staple food, the occurrence of protein-energy malnutrition especially among children is common[3]. As the cost of producing meat, milk, egg and fish which are foods of high biological values increase, plant proteins offer ready and affordable solution to the problem of a growing protein gap. Low cost, protein-rich and high energy food formulation based on cereal legume mixtures have been suggested [2, 3, 4]. The enrichment or fortification of traditional cereal based diets with other protein sources such as oilseeds and legumes has received considerable attention. This is because oilseeds and legumes proteins are rich in lysine, but deficient in sulphur containing amino acids [5]. Legumes generally contain relatively high amount of protein than other plant food stuffs. Cereals have low protein content and are in general deficient in lysine but are adequate in sulphur containing amino acids. Legume proteins are mainly used in food formulations to complement the protein in cereal grains because of their chemical and nutritional characteristics [6].The problem associated with meat consumption as source of protein has led to renewed interest in vegetation diet [7]. This phenomenon is reinforced by the fact that physicians have pointed out that consumers who eat too many animal products (rich saturated fat) and low amount of plant foods could lead to increase in the risk of cardiovascular diseases and some types of cancer [8]. To this end, intensive efforts were made to find alternative sources of protein from the underutilised leguminous plant in nutrition and in the formulation of new food products [8]. Kidney bean (*Phaseolus vulgaris*) , a grain legume, is one of the neglected tropical legumes that can be used to fortify cereal-based diets especially in developing countries, because of its high protein content [9]. It is also a rich source of vitamins, minerals and relatively high in crude fibre [10]. Kidney bean is one such protein source, which when used in the fortification or enrichment of cereal-based diets could go a long way in improving their nutritional status. This crop is among lesser–known beans grown in Nigeria especially by the people of Bokkos in Plateau State. Sandbox (*Hura crepitans*) seed is an evergreen tree of *Euphorbiaceae* family, that despite its abundance in Nigeria it is still underutilized. It is recognized by many dark pointed spines and smooth brown bark. These spines have caused it to be called "monkey no climb'' [11]. The bark of sandbox tree is used in herbal medicine for human and veterinary. Black eyed cowpea (*Vigna unguiculata*) is popularly known as

Southern pea, China pea, black-eye bean or pea, cowgram in the United States or Nìébé in French speaking Africa [12]. Cowpea is well known for its good source of dietary protein for human consumption and of animal feed in the tropics, especially in Africa, Brazil and India. It thrives well in hotter more arid climates and more infertile soils than other food legume crops due to its symbiotic nitrogen fixing abilities which helps in maintaining soil fertility in peasant cropping systems. Over 65% of the cowpea crop is produced in Africa where Nigeria and Niger produce 50% of the world supply [3].

The cultivation and consumption of different varieties of leguminous seeds in Wukari, Taraba State and Nigeria as a whole have increased over time. Different fertililizers, soil types, texture and other environmental factors can affect yields as well as bioavailability of nutrients in legumes and other crops. There is dearth of information on the nutritional profile of these three crops produced in Wukari, Taraba state. Hence this research was embarked on to furnish this information.

Materials and Methods

Location of study

The study was conducted at Federal University Wukari, Taraba State, which is located in the North eastern region of Nigeria.

Collection of samples

Black eyed pea and red kidney beans were purchased from Wukari market, in Wukari Local Government Area of Taraba State, Nigeria. The sandbox seed were picked from the sandbox tree at Anguwan Marmara in Wukari, Taraba state.

Preparation of samples

All foreign particles from the black eyed pea and kidney beans were removed by hand picking. The sandbox seeds enclosed in hard shells were then soaked in water for about 24h for easy decortication. The seeds were then sun-dried and ground into fine powder prior to analysis.

Determination of proximate composition of samples

The proximate composition of the three crop samples (black eyed pea, kidney beans and sand box) was determined using the standard methods [13]. Nitrogen free extract (soluble carbohydrates) was determined by difference.

100- sum of the content of crude protein, crude fibre, ether extract and ash

Determination of gross energy content of samples

The energy content of the sample was calculated by multiplying the protein content by four, carbohydrate content by four and fat by nine [14] as:

Energy Value = (% crude protein X 4) + (% crude fat X 9) + (%carbohydrate X 4). Values used in this formula are based on dry matter basis which was determined by subtracting moisture content from 100.

Determination of amino acid profile

Sample preparation

Two (2g) of the powdered sample was weighed and transferred into a beaker. The beaker was heated in a water bath at 40^{o}C to melt the sample. To the sample was added 6M HCl and heated at 110 ^{o}C for hydrolysis of protein. Then, the digested sample was transferred into 50ml standard volumetric flask and the volume was made up by adding distilled water to the 50ml mark. The extract was centrifuged, filtered and 30ml of water was added to the residue, which was then sonicated for 30minutes. The solution was then passed through a 0.22µm Millipore membrane and the filtrate was transferred to a 100mL volumetric flask and diluted with water to make up to volume. This solution was passed through a 0.22µm Millipore membrane and the filtrate was used as follows:

Derivatization of Samples

The mixed amino acid solution or filtered sample (10µL) was transferred to a full recovery sampler to which 70µL sodium hexane sulphonic acid buffers was added. The solution was vortexed briefly and then 20µL of reconstituted buffer, and the solution was mixed by vortexing for several seconds. It was then heated on a heating block at 55^{o}C for 10 minutes. Derivatives were stable at room temperature for up to one week.

Preparation of standard amino acid solution

Standard solutions of the amino acids (all essential and the entire non-essential) were prepared. The solution were prepared by adding 0.1M HCl. The concentrations of the standard solutions were serially diluted to give 25, 20, 15, and 10nM each. They were stored in a thermocool freezer at 4^{o}C till used. The mixed standard solution contained 25pmol of each amino acid derivative.

Chromatographic conditions and Procedure

Chromatographic separation of prepared samples was carried out on a Buck scientific BLC10/11-model of HPLC equipped with UV 338nm detector, AC18, 2.5 X 200nm, 5um column and a mobile phase of 1:2:2 (100mM sodium phosphate, pH 7.2: Acetonitrile: Methanol v/v/v) at a flow rate of 0.45 mL / minute and an operating temperature of 40^{o}C. Standard solutions were analysed in a similar manner. In terms of retention time, the composition of each peak was confirmed and using peak area of each amino acid, the concentrations were determined in accordance with both the external standard (by extrapolating from the calibration curve, prepared by plotting a graph of peak area versus concentration of each amino acid and standard solution.

Results

Table 1: Proximate Composition of black eyed pea, red kidney beans and sand box

Parameters (%)	Crude protein	Ether extract	Crude fibre	Ash	Moisture	Nitrogen free extract
Sandbox *(Hura crepitans)* seed	33.71±0.02[a]	7.27±0.02[a]	0.95±0.01[a]	8.22±0.00[a]	12.40±0.00[a]	49.85±0.02[c]
Black eyed pea *(Vigna unguiculata)*	27.21±0.02[c]	3.27±0.02[b]	2.04±0.01[b]	4.19±0.01[b]	9.25±0.00[b]	63.29±0.01[a]
Red kidney bean *(Phaseolus lunatus)*	29.21±0.03[b]	2.68±0.02[c]	2.13±0.01[a]	3.98±0.06[c]	9.10±0.00[c]	62.00±0.03[b]

Data are presented as mean ± standard deviation of three replicates. Means within a column with the same superscript were not significantly different (p>0.05).

Table 2: Amino Acids Profile of sandbox seed, black eyed pea and red kidney bean

Amino acid(g/100g protein)	**Sandbox *(Hura crepitans*) seed**	**Black eyed pea*(Vigna unguiculata)***	**Red kidney bean*(Phaseolus lunatus)***
Lysine	3.63±0.03^{a}	3.41±0.01^{b}	3.25±0.03^{c}
Methionine	0.87±0.01^{b}	0.91±0.02^{a}	0.81±0.01^{c}
Threonine	2.10±0.02^{a}	1.55±0.15^{b}	1.95±0.02^{a}
Isoleucine	2.75±0.02^{c}	3.11±0.01^{a}	2.86±0.02^{b}
Leucine	8.35±0.03^{a}	7.62±0.01^{b}	6.77±0.02^{c}
Phenylalanine	9.33±0.03^{a}	4.02±0.02^{b}	3.83±0.02^{c}
Valine	5.34±0.02^{a}	4.11±0.12^{b}	3.97±0.02^{b}
Tryptophan	4.01±0.02^{a}	3.00±0.02^{b}	2.96±0.02^{c}
Histidine	2.22±0.02^{a}	1.92±0.02^{b}	1.84±0.02^{c}
Arginine	5.31±0.02^{a}	4.00±0.01^{b}	3.82±0.02^{c}
Serine	3.62±0.02^{a}	2.93±0.04^{b}	2.73±0.02^{c}
Cysteine	0.79±0.02^{a}	0.51±0.12^{b}	0.43±0.02^{c}
Tyrosine	3.56±0.01^{a}	3.21±0.12^{b}	3.31±0.02^{b}
Alanine	3.83±0.02^{a}	3.54±0.01^{b}	3.34±0.02^{c}
Aspartic acid	10.44±0.02^{a}	8.06±0.03^{b}	7.53±0.02^{c}
Glutamic acid	9.04±0.01^{a}	8.53±0.03^{b}	7.93±0.02^{c}
Glycine	4.00±0.00^{a}	3.87±0.02^{b}	3.44±0.03^{c}
Proline	3.04±0.02^{a}	2.11±0.03^{b}	2.03±0.02^{c}

Data are presented as mean ± standard deviation of three replicates. Means within the same row carrying different superscripts are significantly different at (p<0.05).

Table 3: The energy content of black eyed pea, red kidney beans and sand box.

	Gross energy	
Samples	**Kcal/100g**	**KJ/100g**
Sandbox *(Hura crepitans*) seed	399.73±0.02^{a}	1672.47±0.02^{a}
Black eyed pea *(Vigna unguiculata)*	392.21±0.02^{b}	1641.01±0.02^{b}
Red Kidney bean*(Phaseolus lunatus)*	389.96±0.03^{c}	1631.59±0.03^{c}

Data are presented as the mean ± standard deviation of three replicates. Means within the same column carrying different superscripts are significantly different (p<0.05).

Table 1 shows the mean proximate composition of the crops analysed. The crude protein values of the crop samples were significantly different (p<0.05) among samples with the highest value observed in sandbox seed with 33.71 ± 0.02%, while the least was gotten for red kidney bean as 29.21 ± 0.03%. Also, it was revealed that there were significant differences ($p<0.05$) in the values of ether extract determined. Other proximate parameters such as crude fibre, ash content, moisture content and nitrogen free extract (NFE) estimated show significant differences among samples with sand box seeds having the highest values of ash and moisture content. However, the highest content of crude fibre was observed in red kidney bean (2.13 ± 0.01%), while the highest value of NFE of 63.29 ± 0.01was revealed in black eyed pea.

Table 2 shows the amino acid profile of three crop samples analysed in this study. The following essential amino acids were detected in these samples: lysine, methionine, threonine, isoleucine, leucine, phenylalanine, valine, tryptophan, histidine and arginine. The remaining eight amino acids in Table 2 not mentioned here were the non-essential amino acids. Variation was observed in the amino acid profile of these samples with sand box seeds having the highest values in the following amino acids: lysine, threonine, leucine, phenylalanine, valine, tryptophan, histidine, arginine, serine, cysteine, tyrosine, alanine, aspartic acid, glutamic acid, glycine and proline.

Table 3 shows the energy content of the crop samples analysed. The variation observed showed significant differences ($p< 0.05$) among samples studied with the highest values of energy content observed in sand box seeds with 399.73 ± 0.02 kcal/ 100g followed by black eyed pea which had value 392.21 ± 0.02 kcal/100g, while the least energy content was found in red kidney bean as 389.96 ± 0.03 kcal/ 100g.

Discussion

Proximate Composition

The proximate composition of the three crops are shown in Table1. The sandbox seed contained the highest protein value (33.71%) while the black eyed pea had the least protein content. The value obtained in this study is higher than 25.16±0.22% for sandbox seed reported by NRC [15]. The amount of protein in the samples make them nutritionally rich and can contribute to the daily protein need of 33.6g for human adults [16]. The high crude protein content of *Hura crepitans (sand box)* seed suggests that it is a good source of protein which can be useful in building up and repair of worn out tissues.

The crude fibre contents of the three legumes were 0.95%, 2.04% and 2.13% for the sandbox seed, black eyed pea and red kidney bean respectively. These fibre contents were lower than 5.30% reported by [17] for donkey-eye bean or ox-eye beans (*Mucuna Sloanei).* The low crude fibre contents of the seeds, in addition to their high protein contents would make them suitable for inclusion in the diets of non-ruminants such fish and poultry where low fibre content is desirable.

The crude fat (ether extract) contents of the samples were within the range of 2.68 -7.27%. The crude fat value of *Hura crepitans* was lower than the value reported by [18,19] and also lower than the values reported for oil seeds which generally have crude fat content that ranged from 18% in soya bean to 43% in groundnut oil.

The low moisture contents of the samples show that the legumes were properly dried to safe level for storage. For the black eyed pea (9.25%), and red kidney bean (9.10%), their low moisture contents would confer longer shelf-life compared to sandbox seeds that contained 12.40% moisture. The low moisture content of the sand box sample in this study is similar to what was reported for sandbox seed [20].

The ash contents of the crop samples ranged between 3.98 and 8.22%. The ash contents of the seeds were higher than that of water melon (*Citrullus lanatus)* (Elegbede, 1998), The ash contents of the black eyed pea and kidney bean were within the range of 3.0-4.8% in the present study, which is higher than the ash contents of grain cereals which ranged from 0.56 % for rice to 1.67 % for millet [21].

The NFE content of the crop samples ranged from 49.85 to 63.29%. The NFE contents of the black eyed pea and red kidney bean were higher than those of three varieties of beans reported by [22]. However, the sandbox seed had the least NFE content of 49.85 ± 0.02 among the crops analysed in this study.

Energy Value

Among the three crop samples evaluated in the present study, the sandbox seed (399.73KCal/100g) had the highest energy value, followed by the black eyed pea (392.21Kcal/100g) and then the red kidney bean (389.96Kcal/100g). The high energy content may be attributed to carbohydrate and ether extract content in the crops. However, the values were lower than the values reported for some leguminous oilseeds [23].

Amino Acid Profile

The amino acid profiles of the three crops are presented in Table 2. In all the amino acids analyzed, higher values were recorded for phenylalanine, glutamic acid and leucine while aspartic acid had the highest value as observed for sand box seeds, cysteine had the lowest value in all the three crops analysed. The following ranges were obtained for the levels of amino acids of the samples: sandbox seed had 0.79 ± 0.02 to 10.44 ± 0.02 g/100g, black eyed pea seed had 0.51 ± 0.12 to 8.53 ± 0.03 g/100g, red kidney bean had 0.43 ± 0.02 to 7.93 ± 0.02 g/100g. The amounts of cysteine and methionine were low in all the seeds ranging from 0.81-0.91 g/100g for methionine and 0.43-0.79 g/100g for cysteine g/100g. [24] showed that the proteins of alfalfa seed contained more arginine, cysteine, glutamic acid, and histidine, and less alanine, aspartic acid, and tryptophan whereas higher values were obtained in the present study for aspartic acid, phenylalanine and leucine. This was similar to earlier research work carried out by [25] who showed that leucaena seed contained high amount of crude protein (30.8%) and was rich in aspartic acid and glutamic acid but low in methionine.

Conclusion

This research revealed that black eyed pea (Vigna unguiculata), red kidney beans (Phaseolus lunatus) and sand box (Hura crepitans) seed contained high protein contents with appreciable amount of energy and other nutrients. All the crop samples contained varying amounts of all essential amino acids. Based on the results of this study, the legumes (black eyed pea and red kidney beans) could be used in the formulation of infant diets for reducing Protein Energy Malnutrition (PEM) in Taraba State and Nigeria. However, more work still needs to be carried out on sandbox seeds in the areas of toxicological study and antinutritional factors, before it can justify its consumption by humans.

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Mean Annual Weather Cycles of some Weather Variables over Warri, Delta State, Nigeria during 2009 to 2018

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Abstract: The importance of analysing the weather cycles of any region cannot be over emphasized considering the dynamic nature of weather and its undesirable impacts on the environment. This study examines the mean annual cyclic behaviour of some weather variables over Warri, Delta State, Nigeria using recent weather data from NiMet for a period of ten years (2009 to 2018). It was observed from the cyclic behaviours from the various weather variables for the ten years period under consideration, that the annual maximum and minimum temperature, vapour pressure and cloud amount cycles follow similar trends, likewise the undulation of the annual soil heat flux cycles. The annual rainfall, wind speed, maximum and minimum relative humidity cycles were found to fluctuate in different patterns. In periods of limited rainfall, relative humidity is at the threshold of ~ 50.0%. A roughly curvilinear fit was noticed between the annual rainfall and relative humidity. While, rainfall appears insensitive to relative humidity changes during the months with lower relative humidity, which tends to be linear during the months with higher relative humidity. Hence, as the rainfall amount increases, there is an increasing tendency towards a curvilinear relationship. The occurrence of the maximum in temperature preceding that of wind speed indicates that the prevalent winds over Warri could be thermally obsessed. The results obtained would assist in providing appropriate panacea to mitigating weather induced environmental hazards, thereby improving agriculture, efficient economic productivity and advance scientific research.

Keywords: cyclic behaviours; weather variables; linear function; curvilinear relationship; polynomial functions

Introduction

Meteorological study which is mostly centred on the study of weather or climate as the case may be is as old as the creation of mankind and has always had a significant influence on the lives of people and shaped their cultures, beliefs, habits, attitudes, behaviour and their environments in general right from the beginning of creation [1-9].

Weather has always been a universal concern that plays a major role in our everyday lives [10-14]. Weather measurements, monitoring and analysis potentially help in keeping track of different meteorological variables such as temperature, relative humidity, atmospheric pressure, light intensity, wind speed, wind direction, precipitation, altitude, solar radiation, light intensity, dew point temperature, specific humidity, absolute humidity, virtual temperature, evaporation, etc. These variables have great importance and have several applications in agricultural, transportation, construction, military operations, radio signal transmission, power generation, solar devices and many other personal and industrial aspects of human lives [1-9]. Weather or meteorological measurements, monitoring and analysis have developed over the years and a lot of knowledge and information have been gathered that have helped in understanding the meteorological conditions of the universe [2-5, 12]. There are many factors that influence weather, some of which are visible and others invisible. These factors include but not limited to the following; latitudinal location, proximity to water bodies, solar distance, air masses, air pressure and elevation [5, 15].

Man has always tried in finding out the causes of different meteorological conditions within his environs and possibly monitors what the weather would be at any given time because there cannot be the study of weather nor its prognostication without the knowledge of the prevailing conditions of the atmosphere. The weather or meteorological variables measured are used for monitoring of the atmospheric conditions. Hence, appropriate studying of the meteorological conditions would make a difference for the survival and prosperity of the human race [2-5]. For this reason, man has always devised means of measuring different variables of the weather and with advancement of technology, new methods and equipment have been developed to measure, collect, monitor and analyse meteorological information and today a whole field of study known as meteorology is dedicated to its study. Meteorology is the science that deals with the study of the atmosphere and its phenomena; especially those aspects that have to do with weather monitoring and prognostications. Its domain is mainly the lower atmosphere (troposphere) of the universe and its practice involves the daily cooperation of every action on the universe. Meteorology is a branch or sub-discipline in Atmospheric Science. Other sub-disciplines of Atmospheric Science include: Climatology, Atmospheric Physics and Atmospheric Chemistry [12]. Meteorological processes are observable climatic events that are illustrated using meteorological terms. These meteorological processes are described and their values/quantities are known by the weather/climate variables or parameters of the earth's atmosphere together with their variations and interactions over time. Hence, the meteorological variables measured and collected are used in monitoring of the various atmospheric conditions and are useful in one way or the other in the course of our daily activities [2-5, 16, 17].

The weather cycles concept as to do with the periodic re-occurrence of the various weather phenomena. It is the average weather events tend to repeat themselves with some order. In this context, cycles entail patterns and order in the average state. Since the departures from the average are not taken into account [18, 19].

Geophysical analogues of weather cycles include: solar, rock and hydrological cycles.

- Solar cycle as to do with the earth revolves round the sun approximately every 365 days.
- Hydrological cycle as to do with rain falls to the earth surface and goes back to the atmosphere through evaporation and transpiration.
- Rock cycle as to do with the transformation of rock from one rock type to another.

Weather cycles may be categorized into two namely: simple cycles and complex cycles. As a result of these cycles, there is an increasing consensus about the anthropogenic impact on the recent change of the earth's climate. Records have it that the global mean near surface air temperature has risen tremendously over the last with a warming rate over the last decades that have no precedent in the instrumental records and this trend is projected to continue in the future [20]. Nevertheless, climate projections are still affected by some important uncertainties, especially related to the role of aerosols and clouds in the climate system. Due to the fact that there is no evidence of natural processes with weekly cycles, the study of such cycles in meteorological variables has become an interesting way to establish links between human activities and their influence on the climate. Apparently, human induced activities such as commercial transportation, industrial activity, etc. are commonly reduced during weekends compared to weekdays, especially in the industrialised regions in the western advanced countries. Consequently, if the mean values of meteorological variables show a weekly cycle, these variations might be linked to human influence and are considered as anthropogenic signals [20].

An increasing number of studies have been devoted to the cycles of meteorological variables over large areas [18-24]. Most of these studies focus on the examination of average values of meteorological variables in order to show weekly cycles or weekly effects. The analyses were designed to find differences between the weekend and the working week, using the Saturday through Monday and Wednesday through Friday periods to define both periods respectively [20].

Over the Atlantic coast of the United States and neighbouring oceanic areas, weekly cycles has been observed in the rainfall and tropical cyclones activity and linked to the downwind pollution transport from the urbanized eastern seaboard [25].

In eastern China, winter diurnal temperature ranges anomalies tend to be larger for weekends compared to weekdays and are associated with increased maximum temperature and total irradiance but decreased relative humidity [26]. On the other hand, the summertime diurnal temperature range anomalies display a much stronger negative weekend effect that is; smaller diurnal temperature range in weekends, linked to decreased maximum temperature and decreased total solar irradiance but increased relative humidity and a greater number of rainy days. The weekly difference is suggested to be physically related to the direct and indirect effects of anthropogenic aerosols [26].

The underlying notion in the search for an orderly behaviour in the weather is that much of the activity's humans engage in, like what to eat or wear clothes are affected by the rhythms of the weather daily. The cyclic behaviour of the weather affects us in all its variety; most of the time these effects are familiar. However, weather never repeats in exactly the same fashion. This underscores the need to search weather records for the occurrence of cycles. Within the meteorological community the debate continues as to whether patterns exist and if they do, whether they are sufficiently well established to provide the physical basis for weather prognostications [18, 19].

There is no doubt that the utilization of inadequate meteorological information for environmental planning and inaccurate analysis of the state of the atmosphere have resulted in widespread weather-induced environmental hazards that have affected agriculture and other aspects of human endeavours and most of these effects are cause by the dynamic nature of weather. The importance of analysing the weather cycles of any region cannot be over emphasized, considering the dynamicity and influence of weather in our everyday lives [2-5, 11, 12]. This study become desirable because records within are disposal show that are limited research studies on weather cycles within the study area (Warri, Delta State, Nigeria). Although, Onyenucheya and Nnamchi [18], analysed the mean diurnal and annual cycles of some weather variables over Nsukka, Enugu

State using the weather data for only two years (2010 and 2011). This study examines the annual cyclic behaviour of some weather variables (minimum temperature, maximum temperature, relative humidity, rainfall, wind speed, vapours pressure and cloud amount) over Warri, Delta State, Nigeria for a period of ten years (2009 to 2018). The rapidly increasing urban population in this city necessitates an improved understanding of the basic meteorological features. Hence, examinations of the annual (during the course of the year) weather cycles and the establishment of the relationship between the annual weather cycles of these weather variables over Warri, Delta State.

Materials and Methods

The Study Area

Warri in Delta State, Nigeria is located on latitude 5.520N and longitude 5.750E with an elevation of about 6.0 m above sea level having a population of over five hundred thousand. The city shares boundaries with Ughelli/ Agbarho, Sapele, Okpe, Udu and Uvwie although most of these places, notably Udu, Okpe and Uvwie, have been integrated to the larger cosmopolitan Warri [27]. The city is one of cosmopolitan cities in southern Nigeria comprising predominantly of Urhobo, Itsekiri and Ijaw people. Warri is predominantly Christian with mixture of African traditional religions like most of the Southern Nigeria. The city is known nationwide for its unique Pidgin English language [27].

The city of Warri is an oil hub in Delta State which is located in the Niger Delta/South-South region of Nigeria. The bulk of the petroleum from Nigeria is from Delta State and this makes Nigeria one of the largest petroleum producers in Africa and around ten largest producers and six largest exporters among the Organization of Petroleum Exporting Countries (OPEC) members of crude oil in the world. The region is so rich in petroleum resources and this has continually made the region a centre of attraction and concern by the local, national and international community economically, politically and otherwise. Despite the huge amount of wealth coming from its exploration and exportation of petroleum, this region is not without numerous disturbances and interruptions. The issue of environmental contaminations as a result of these petroleum activities is now as serious threat not only to this region but the entire country at large [28-31].

Figure 1 shows the map of Nigeria indicating Warri, Delta State.

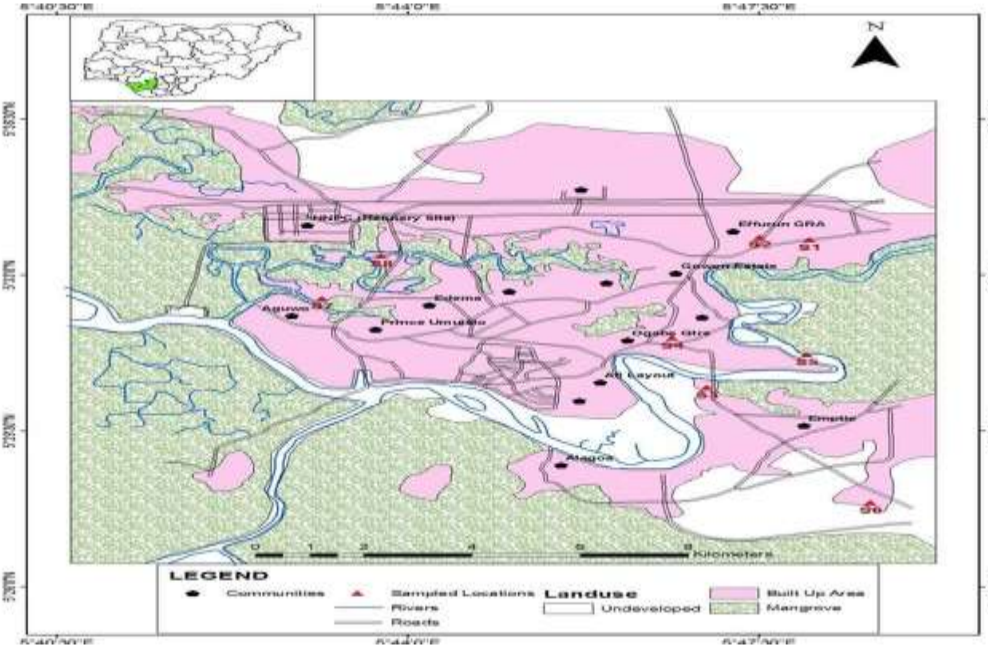

Figure 1: **Map of** Warri, Delta State, Nigeria

Collection of Data

Data for this project work were weather variables which were collected from the archive of the Nigerian Meteorological Agency (NiMet). In this study monthly minimum and maximum temperature (^{0}C), rainfall (mm), vapour pressure (kpa), minimum and maximum relative humidity (%), wind speed (knots), soil heat flux (^{0}C) and cloud amount (oktas) for ten years (2009 to 2018) for Warri, Delta State, Nigeria were used for the analyses.

Analysis of Data

Data on continuous weather variables (minimum and maximum temperature, soil heat flux, minimum and maximum relative humidity, rainfall, wind speed, vapours pressure and cloud amount) were analysed on monthly basis.

On the other hand, rainfall occurrence is considered discrete in time and so the monthly accumulated amounts were analysed. The mean state, the ten year mean of each weather variable were also calculated.

The relationship between the annual rainfall cycles and relative humidity cycles was investigated using a three-stage curve fitting procedure. First, we employed a linear fit (first order model). Then realizing the curve linear nature of the variables when paired, they were modelled using second and third order polynomial functions.

Given a weather variable (P) which is taken to be a response variable that evolves with another (Q) taken to be the predictor variable, the first order model of their linear relationship is given by the function:

$$P = x_1 + x_2 Q + \varepsilon \quad (1)$$

where x_1, x_2 and ε are the intercept, slope of the curve and error term respectively.

Eqn. (1) is a simple linear function, representing the relationship between two weather variables P and Q. However, if the time evolution of P and Q is not linear, it becomes necessary to describe their relationship using other curve fitting methods. Here, we find that the appropriate model will require polynomial terms and may be generalized as follows:

$$P = x_1 + x_2 Q + x_3 Q^2 + \ldots + x_n Q^n + \varepsilon \quad (2)$$

where n represents the order of the polynomial terms.

Results and Discussion

Annual Weather Cycles

The annual weather cycles for the various weather variables used are analysed below:

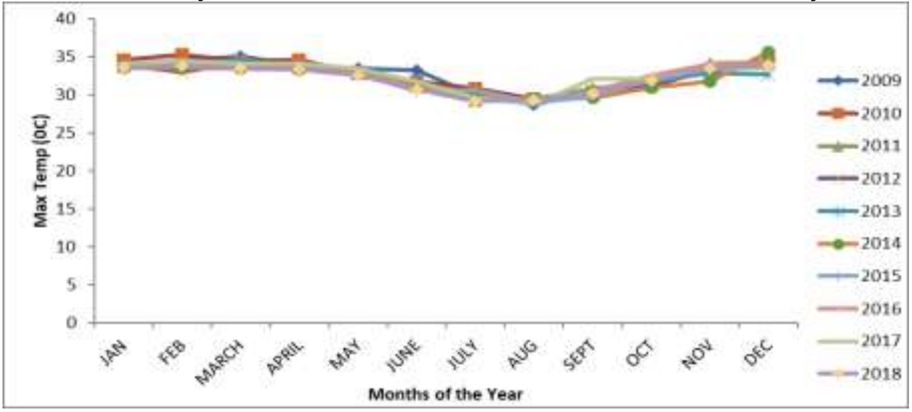

Figure 2: Annual Maximum Temperature Cycles for 2009-2018

From Figure 2, it was observed that the annual maximum temperature cycles for the period under consideration (2009 to 2018) follow similar trends, having the highest value of 35.60 ^{0}C in December, 2014 and lowest value of 28.70 ^{0}C in August, 2009 with an overall average of 32.39 ^{0}C for the ten years period under consideration.

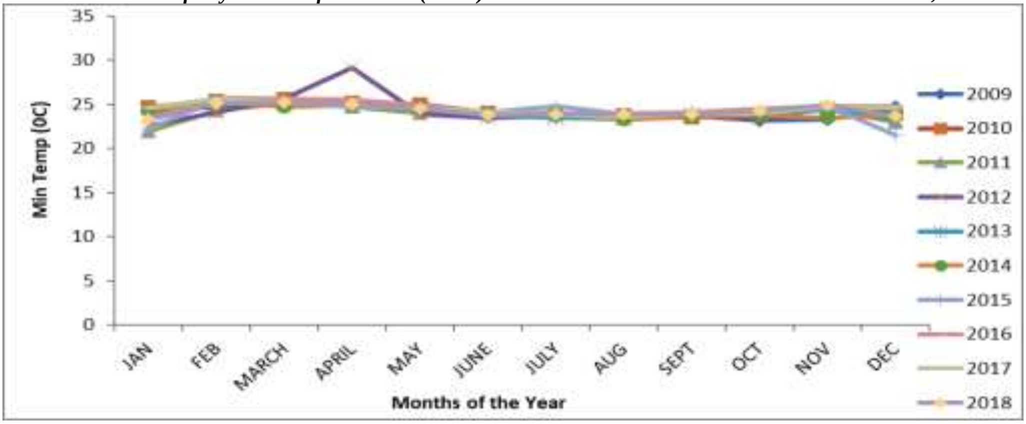

Figure 3: Annual Minimum Temperature Cycles for 2009-2018

From Figure 3, it was observed that the minimum temperature cycles for period under consideration (2009 to 2018) also follow similar trends, except for in the month of April, 2012 where there was a slight increase; having the highest value of 29.10 ^{0}C in April, 2012 and lowest value of 21.50 ^{0}C in December, 2015 with an overall average of 24.25 ^{0}C for the ten years period under consideration.

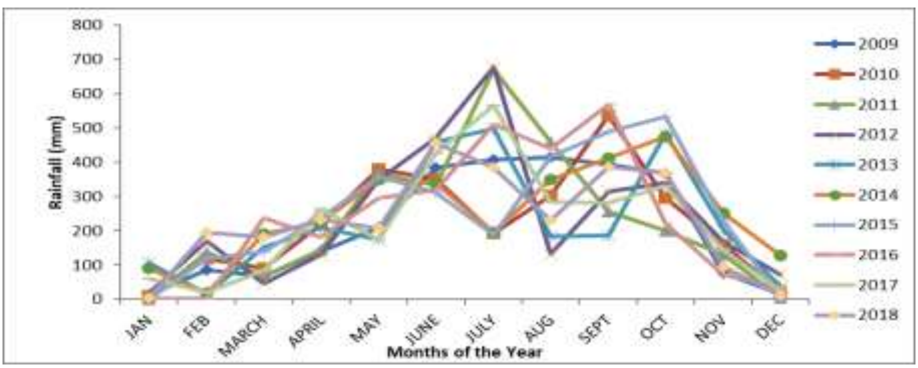

Figure 4: Annual Rainfall Cycles for 2009-2018

From Figure 4, it was observed that the annual rainfall cycles for the under consideration (2009 to 2018) were found to fluctuate in different patterns, having the highest value of 678.10 mm in July, 2011 and lowest value of zero in January, 2011 and 2015, with an overall average of 232.81 mm for the ten years period under consideration.

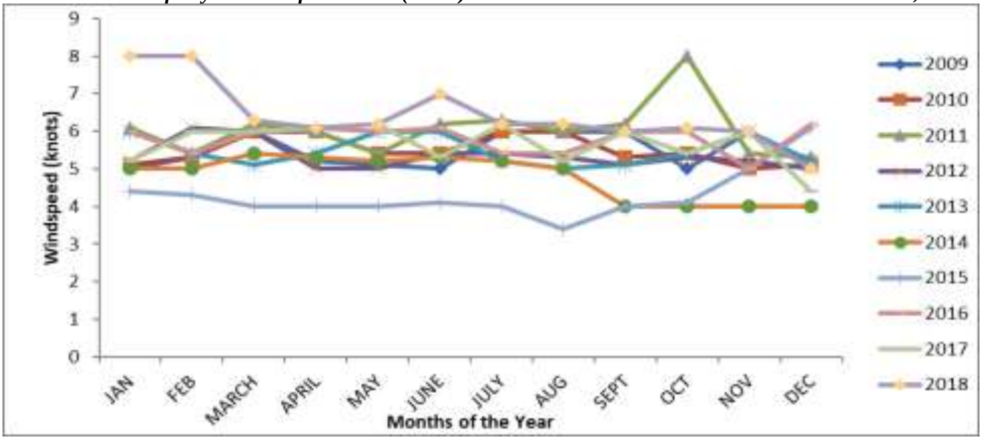

Figure 5: Annual Wind Speed Cycles for 2009-2018

From Figure 5, it was observed that the annual wind speed cycles for the period under consideration (2009 to 2018) were found to fluctuate in different patterns, having the highest value of 8.00 knots in January and February, 2018 and lowest value of 3.40 knots in August, 2015, with an overall average of 5.48 knots for the ten years period under consideration.

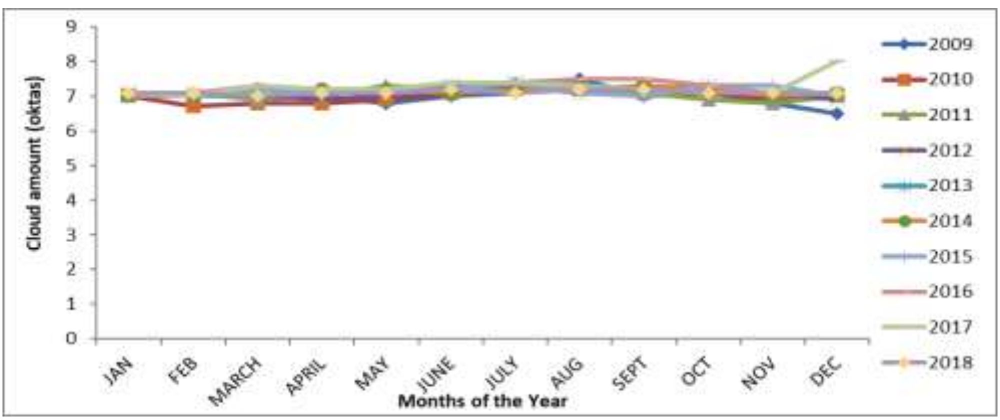

Figure 6: Annual Cloud Amount Cycles for 2009-2018

From Figure 6, it was observed that the annual cloud amount cycles for the ten years period under consideration (2009 to 2018) follow similar trends, having the highest value of 8.0 oktas in December, 2017 and lowest value of 6.5 oktas in December, 2009, with an overall average of 7.12 oktas for the ten years period under consideration.

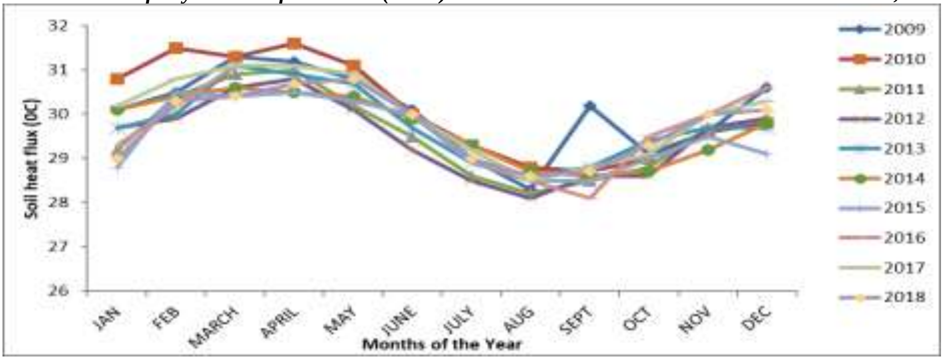

Figure 7: Annual Soil Heat Flux Cycles for 2009-2018

From Figure 7, it was observed that the annual soil heat flux cycles for the ten years period under consideration (2009 to 2018) undulate with similar trends, having the highest value of 30.60 ^{0}C in April, 2010 and lowest value of 28.10 ^{0}C in August and September, 2016, with an overall average of 29.21 ^{0}C for the ten years period under consideration.

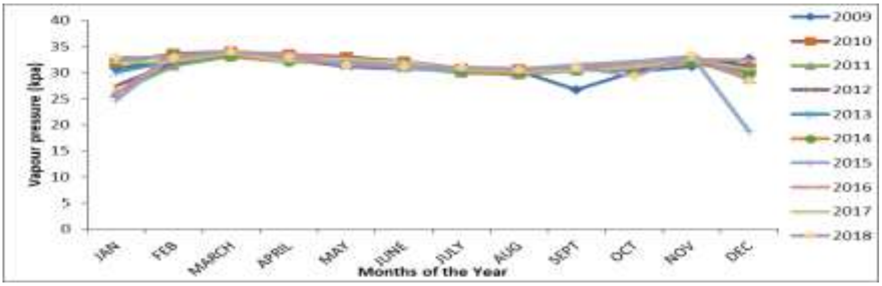

Figure 8: Annual Vapour Pressure Cycles for 2009-2018

From Figure 8, it was observed that the annual vapour pressure cycles for the ten years period under consideration (2009 to 2018) follow similar trends, except for December, 2015; having the highest value of 34.0 kpa in March, 2018 and lowest value of 18.70 kpa in December, 2015, with an overall average of 31.30 kpa for the ten years period under consideration.

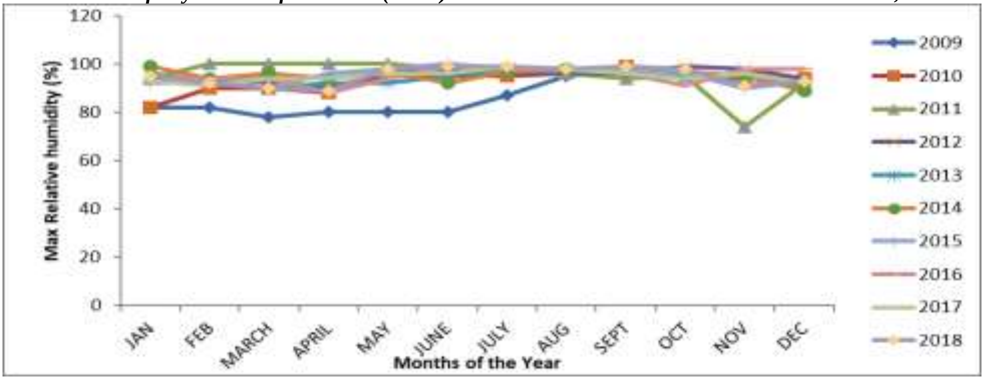

Figure 9: Annual Maximum Relative Humidity Cycles for 2009-2018

From Figure 9, it was observed that the annual maximum relative humidity cycles for the ten years period under consideration (2009 to 2018) fluctuate in different patterns, having the highest value of 100.0% in February to May, 2011 and June, 2015 and lowest value of 74.0% in November, 2011, with an overall average of 94.03% for the ten years period under consideration.

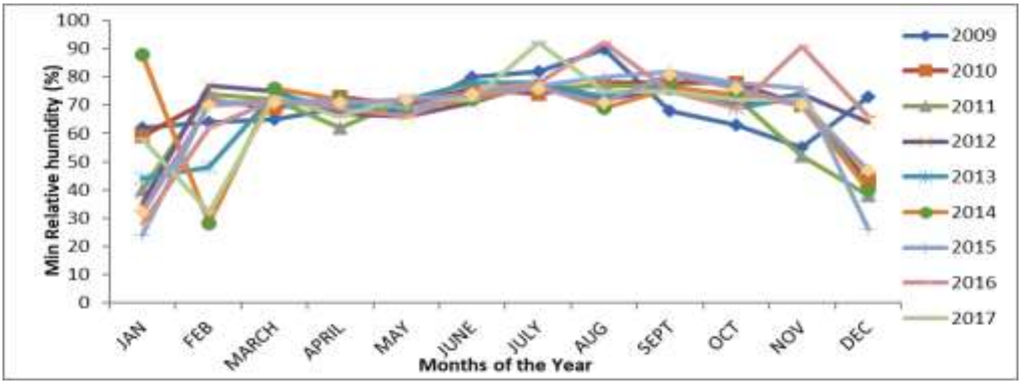

Figure 10: Annual Minimum Relative Humidity Cycles for 2009-2018

From Figure 10, it was observed that the annual minimum relative humidity cycles for the ten years period under consideration (2009 to 2018) also fluctuate in different patterns, having the highest value of 92.0 % in July, 2017 and August, 2015 and lowest value of 24.0% in January, 2015, with an overall average of 67.96% for the ten years period under consideration.

Nevertheless, the cyclic behaviours from the weather data used to some extent are in conformity with the work of Onyenucheya and Nnamchi [18], where they carried out the diurnal and annual weather cycles over Nssuka area in Nigeria. We would not be far from the truth to assert that the occurrence of the maximum in temperature preceding that of wind speed is an indication that the prevalent winds over Warri could be thermally obsessed.

Relationship in Annual Cycles of the Weather Variables

The relationship between the annual rainfall cycles and relative humidity cycles using the ten years monthly mean data are shown in Figure 11. The relationship between the annual rainfall cycles and relative humidity cycles over Warri appears to be best described by polynomials in the range of $1 \geq n \leq 3$; where $n = 1$ corresponds to a linear function of the form shown as Eqn. (1).

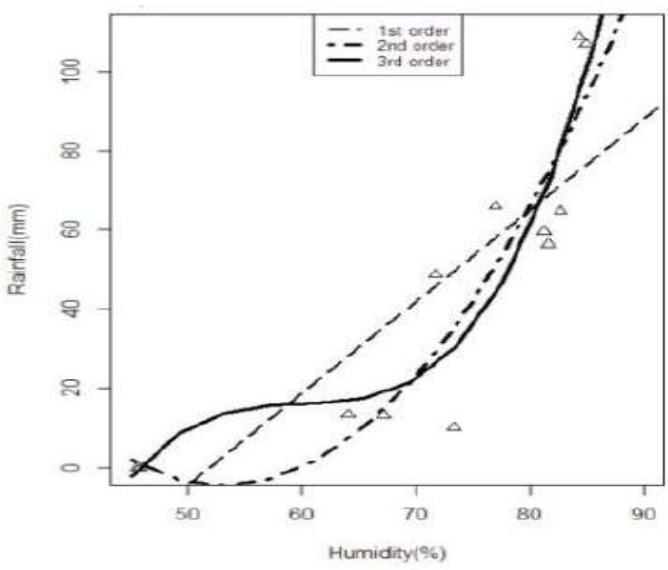

Figure 11: Relationship between the Annual Rainfall Cycles and Relative Humidity Cycles

From Figure 11, it can be seen that at periods of little or no rainfall, relative humidity is at the threshold of ~ 50.0%. From the annual cycle plots, we could suggest that this occurrence is mainly during the dry season. Even though, the atmospheric water vapour content may fluctuate, it hardly reaches saturation. It is observed that as the rainfall amount increases (during the months with high rainfall), there is an increasing tendency towards a curvilinear relationship.

Conclusion

This research study examined the annual cycles of some weather variables (minimum temperature, maximum temperature, relative humidity, rainfall, wind speed, vapour pressure and cloud amount) over Warri, Delta State, Nigeria. The study further described a curvilinear relationship between relative humidity and rainfall using monthly weather data.

It is important to note that the analysis carried out in this study is based on ten years (2009 to 2018) for which uninterrupted record are available. In essence, long term changes in the weather cycles due to inter-annual, decadal or multi-decadal modulations in the climate system are not accounted for in this study. Despite this caveat, the results provide key features of the annual weather cycles of weather over Warri, Delta State, Nigeria. We would therefore suggest that further studies utilizing longer time series should be carried out to characterize inter-annual, decadal or multi-decadal modulations in the climate system.

Albeit, the results obtained from this research study hitherto will assist in providing the appropriate panacea to mitigating meteorological induced environmental hazards, thereby improving agriculture and economic efficiency and productivity, as well as advance scientific research.

Competing Interests

The authors declare that they have no conflict of interest.

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Magnetic Spin Susceptibility of quasi-particles in metals using the Landau Fermi Liquid Theory

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In this work, the magnetic spin susceptibility of quasi-particles in metals were computed for some metals based on the modified Landau Fermi Liquids Theory using the electron density parameter. The results showed that for each metal, the Landau magnetic spin susceptibility of quasi-particles is higher than the computed magnetic spin susceptibility of quasi-particles and experimental values. This may be due to the fact that the Landau parameter must have been over estimated in its application. The computed magnetic spin susceptibility of quasi-particles is in good agreement with the experimental values of metals available with a remarkable agreement at $F_0^a \geq -9$. The better estimation of the magnetic spin susceptibility of quasi-particles using the modified Landau Fermi Liquid theory were compared with available experimental values. This show that the introduction of the electron density parameter in the Landau Fermi Liquid theory is promising in predicting the contribution of quasi-particles to the bulk properties of metals. The magnetic spin susceptibility of quasi-particles for transition metals is higher than most of the magnetic spin susceptibility of quasi-particles for alkali metals. This suggests that the magnetic spin susceptibility is considerably higher for most transition metals due to the incomplete inner electronic shells as more quasi-particles can be excited which enhances their susceptibility than the alkali metals.

Keywords: Quasi-particles, Electron density parameter, Magnetic spin susceptibility, Fermi

Liquids, Landau parameter F_0^a .

1.0 Introduction

The Landau's theory of Fermi liquids is a basic fundamental paradigm in many-body physics that has recorded a remarkable success in solving the properties of a wide range of interacting fermion systems, such as liquid helium-3, nuclear matter, and electrons in metals. The Landau theory of Fermi liquids gives a good understanding of weakly correlated, gapless Fermi systems at low temperatures, such as ^{3}He atoms in the normal liquid state and travelling electrons in metals [1, 2, 3]. It provides the understanding of metals in terms of weakly interacting quasi-particles which is the basis effects of interaction between electrons on the metallic state. It also gives account of puzzling observation that despite strong interactions between the constituent fermions, many Fermi systems behave essentially as free Fermi gases, except for the renormalization of their physical properties which is captured by dimensionless quantities known as Landau parameters. These Landau parameters describe how the elementary excitations of the Fermi Liquid that is the quasi-particles and quasiholes interact with one another [4, 5].

The instabilities in spin and charge channels for Landau parameters in the non-degenerate extended using Hubbard model with intersite coloumb and exchange interaction was investigated by Lhoutellier *et al*., [6]. The inverse propagator was determined using spin rotational invariant slave boson approach. It derived the spin Landau parameter F_0^a of the non-degenerate Hubbard model towards ferromagnetism by $F_0^a = -1$ for the divergence of the magnetic susceptibility for half-filled band uncovers intrinsic. It results showed instability in the strongly correlated metallic regime for any lattice in two or three dimensions.

As discussed by Lundgren and Maciejko, [7], the d-dimensional boundaries of (d + 1)-dimensional topological phases of matter give new types of many-fermion systems that are topologically distinct from conventional systems. It constructed phenomenological Landau theory for the two-dimensional helical Fermi liquid on the surface of a 3-dimensional time reversal invariant topological insulator. In the presence of rotation symmetry, interactions between quasi-particles are described by ten independent Landau parameters per angular momentum channel. As a result of this nontrivial Berry phase, projection can increase or lower the angular momentum of the quasiparticle interactions to the Fermi surface. It also accounted for the equilibrium properties, criteria instabilities, and collective mode dispersions.

Chubukov, *et al.* [8], considered the non-analytic temperature dependences of the specific heat coefficient, CT=T, and spin susceptibility, sT, of 2D interacting fermions beyond the weak-coupling limit. It demonstrated within the Luttinger-Ward formalism that the leading temperature dependences of CT=T and sT are linear in T, and are described by the Fermi liquid theory. It concluded that the temperature dependences and are universally determined by the states near the Fermi level.

Rodriguez-Ponte *et al*. [9] studied Fermi liquids with a Fermi surface that lacks continuous rotational invariance and, in the presence of an arbitrary quartic interaction. The results gives generalized static susceptibilities which measured linear response of a generic order parameter to a perturbation of the Hamiltonian. These results were applied to spin and charge susceptibilities. Based on this, a proposal for the definition of the Landau parameters in non-isotropic Fermi liquid was made.

2.0 Theory and calculations.

2.1 Magnetic Spin susceptibility of quasi-particles.

Susceptibility is generally defined as the ratio of the induced magnetization to the inducing magnetic force. Determination of magnetic spin susceptibility is defined by [10],

$$M = \chi H = \mu_B\left(\delta n_\uparrow - \delta n_\downarrow\right), \qquad (1)$$

the change of the quasi-particle distribution function due to an external magnetic field applied in z-direction was computed. The quasi-particle energies changes because of the field and the change in the distribution function,

$$\delta\varepsilon_{p\sigma} = -\mu_B\sigma_z H + \sum_{p'\sigma'} f_{p\sigma,p'\sigma'}\delta n_{p'\sigma'}, \qquad (2)$$

with $\sigma_z = \pm 1$. The change in the distribution function is given by,

$$\delta n_{p\sigma} = \frac{\partial n^0_{p\sigma}}{\partial\varepsilon_{p\sigma}}\left(\delta\varepsilon_{p\sigma} - \delta\mu\right), \qquad (3)$$

the change of the chemical potential $\delta\mu$ is proportional to H^2 and can be neglected in the calculation of the linear susceptibility. For $T = 0$ and **p** on the Fermi surface, equation (3) reduces to,

$$\delta n_{p\sigma} = -\delta\varepsilon_{p\sigma}, \qquad (4)$$

from equation (2), it is seen that $\delta\varepsilon_{p\sigma}$ and $\delta n_{p\sigma}$ are independent of the direction of **p** and of opposite sign for spin up and spin down particles, Therefore, equation (2) becomes,

$$\delta\varepsilon_{p\sigma} = -\mu_B\sigma_z H + 2 f^a_0\delta n_\sigma \qquad (5)$$

where, $\delta n_\sigma = \sum_p \delta n_{p\sigma}$ (6)

δn_σ is the change in the total number of particles per unit volume of spin σ. Summing equation (5) over **p** and using equation (4), we get,

$$\delta n_\sigma = \frac{1}{2}N(0)\left(\mu_B\sigma_z H - 2 f^a_0\delta n_\sigma\right) \qquad (7)$$

The net spin polarization is given by,

$$\delta n_\uparrow - \delta n_\downarrow = 2\delta n_\sigma\sigma_z = \mu_B\frac{N(0)H}{1+F^a_0} \qquad (8)$$

and the total magnetization is given by,

$$\mu_B\left(\delta n_\uparrow - \delta n_\downarrow\right) = \mu_B^2\frac{N(0)H}{1+F^a_0} \qquad (9)$$

The magnetic spin susceptibility of quasi-particles becomes,

$$\chi = \mu_0 \mu_B^2 \frac{N(0)}{1+F_0^a} \quad (10)$$

which is again the same result as for a free Fermi gas divided by a factor due to the interaction.

where, $$F^a(\theta) = -\frac{1}{2}U\left(2p_F \sin\frac{\theta}{2}\right) \quad (11)$$

The Landau parameter $F_0^a(\theta)$ is the dimensionless spin-antisymmetric Landau parameter, which characterize the effect of the interaction on the quasi-particle energy spectrum. The coefficient F_0^a has anti-symmetric in the spin index and spherical symmetric (L = 0). It is the Landau amplitude related to the exchange interaction, and for strongly correlated systems $F_0^a \geq -0.9$. The denominator is the change with respect to the non-interacting result. Usually, F_o^a is negative, and the magnetic susceptibility is enhanced. If F_o^a becomes positive, it means that it diverges [2, 11, 12, 13]. This corresponds to a ferromagnetic instability and the ground state without field changes qualitatively by creating a spontaneous magnetization. This is how the Fermi liquid description creates its own stability criteria.

Recall that the quasi-particle density is given as,

$$N(0) = \frac{m^* P_F}{\pi^2 \hbar^3} \quad (12)$$

Also, the Fermi momentum of the quasi-particle at the Fermi level is given as,

$$P_F = \hbar k_F = \hbar \left(\frac{9\pi}{4}\right)^{\frac{1}{3}} \frac{1}{r_s} \quad (13)$$

By inserting equation (13) into equation (12) we obtained,

$$N(0) = \frac{m^*}{\pi^2 \hbar^2} \left(\frac{9\pi}{4}\right)^{1/3} \frac{1}{r_s} \quad (14)$$

Then, inserting equation (14) into (10), the modified Landau Fermi liquid theory's expression for the magnetic spin susceptibility of quasi-particles in terms of the electron density parameter (r_s) was obtained as,

$$\chi = \frac{\mu_0 \mu_B^2}{1+F_0^a} \frac{m^*}{\pi^2 \hbar^2} \left(\frac{9\pi}{4}\right)^{\frac{1}{3}} \frac{1}{r_s} \quad (15)$$

3.0 Results and Discussion

3.1 Magnetic Spin susceptibility of quasi-particles.

Figure 1(a and b) show the variation between computed magnetic spin susceptibility of quasi-particles in metals and Landau Parameter F_0^a for some metals. Figure 2 (a and b) show the variation between Landau magnetic spin susceptibility of quasi-particles in metals and Landau Parameter F_0^a for some metals. The computed magnetic spin susceptibility and the Landau magnetic spin susceptibility of quasi-particles decreased as the Landau Parameter F_0^a increased for all the metals investigated. It is again observed from the figure for each metal, the Landau magnetic spin susceptibility of quasi-particles is higher than the calculated magnetic spin susceptibility of quasi-particles. The difference may be due to the value of electron density parameter which was used in the computation of the calculated magnetic spin susceptibility of quasi-particles but was not accounted for in the Landau magnetic spin susceptibility of quasi-particles. This may also suggest that magnetic spin susceptibility depends on other properties of metals, such as band structure energy, crystal binding and the nature of bonds between the quasi-particles in the metals [14, 15, 16]. Also, it was observed that the Landau magnetic spin susceptibility of quasi-particles in metals are not in good agreement with experimental values. The Landau Fermi liquid theory overestimated the magnetic spin susceptibility of quasi-particles. This seems to suggest that the Landau parameter must have been over estimated in its application. The computed magnetic spin susceptibility of quasi-particles is in good agreement with experimental values in all the ranges of the electron density parameter. This suggests that the modified version can effectively account and predict the magnetic spin susceptibility and magnetic properties of quasi-particles in metals.

From Tables 1 and 2, it was noticed that the magnetic spin susceptibility of quasi-particles for noble metals is higher than most of the magnetic spin susceptibility of quasi-particles for alkali metals. This is due to the d-block electrons that have filled electron shell which lies high up in the conduction band of noble metals. The magnetic spin susceptibility is considerably higher for most transition metals due to the incomplete d-orbital shells as more quasi-particles can be excited which enhances their susceptibility than the alkali metals [11, 17]. Also, transition metals have high value of conduction electron concentration. This shows that more quasi-particles could be formed when excited. The high values of the magnetic spin susceptibility of quasi-particles for transition metals could also be attributed to their electron density parameter that lies within the high density region $r_s \leq 3$.

4.0 Conclusion

The expression for the modified Landau Fermi Liquid Theory in terms of the electron density parameter was used to compute the magnetic spin susceptibility of quasi-particles in metals and the computed values are compared with Landau values and experimental values available. The computed magnetic spin susceptibility and the Landau magnetic spin susceptibility of quasi-particles show same trend with Landau Parameter F_0^a that is, as the Landau Parameter F_0^a increased for all the metals investigated, magnetic susceptibility of Quasi-particles decreased. Thus, the Landau magnetic spin susceptibility of quasi-particles in metals are not in good agreement with experimental values. The Landau Fermi liquid theory overestimated the magnetic spin susceptibility of quasi-particles while the computed magnetic spin susceptibility of Quasi-particles shows good agreement with available experimental values. This suggests that the modified Landau Fermi Liquid Theory can effectively account and predict the magnetic spin susceptibility and magnetic properties of quasi-particles in metals.

Table 1: Calculated Magnetic Spin Susceptibility of Quasi-particles in terms of the electron density parameter (r_s)

Metals	m^*	r_s (a.u)	Calculated values of Magnetic Spin Susceptibility quasi-particles at different Landau parameter(F_0^a) $10^6\chi$									Exp. Susceptibility $10^6\chi$
			-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9	
Li	2.3	3.28	0.19	0.21	0.24	0.29	0.34	0.43	0.57	0.86	1.71	2.0
Na	1.3	3.99	0.09	0.10	0.11	0.13	0.16	0.20	0.27	0.40	0.80	1.1
K	1.2	4.96	0.06	0.07	0.08	0.10	0.12	0.15	0.20	0.30	0.59	0.85
Rb	1.3	5.23	0.06	0.07	0.08	0.10	0.12	0.15	0.20	0.30	0.61	0.8
Cs	1.5	5.63	0.07	0.08	0.09	0.11	0.13	0.16	0.22	0.33	0.65	0.8
Cu	1.3	2.67	0.13	0.15	0.17	0.20	0.24	0.30	0.44	0.60	1.19	1.24
Ag	1.1	3.02	0.09	0.11	0.13	0.15	0.18	0.22	0.30	0.45	0.89	0.9
Au	1.1	3.01	0.09	0.11	0.13	0.15	0.18	0.22	0.30	0.45	0.89	1.4
Mg	1.3	2.66	0.13	0.15	0.17	0.20	0.24	0.30	0.40	0.60	1.19	1.2
Ca	1.8	3.27	0.15	0.17	0.19	0.22	0.27	0.34	0.45	0.67	1.35	2.1
Zn	0.85	2.30	0.10	0.11	0.13	0.15	0.18	0.23	0.30	0.45	0.90	0.38
Cd	0.74	2.59	0.07	0.08	0.10	0.12	0.14	0.17	0.23	0.35	0.70	0.39

Table 2: Landau Magnetic Spin Susceptibility of Quasi-particles

Metals	m^*	K_f ($10^{10}m^{-1}$)	Landau values of Magnetic Spin Susceptibility quasi-particles at different Landau parameter(F_0^a)									Exp. Susceptibility $10^6\chi$
			-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9	
Li	2.3	1.12	5197	5846	6681	7795	9354	11692	15590	23384	46769	2.0
Na	1.3	0.92	1692	1903	2175	2538	3045	3807	5075	7613	15226	1.1
K	1.2	0.75	1273	1432	1637	1910	2292	2864	3819	5729	11458	0.85
Rb	1.3	0.70	1287	1448	1655	1931	2317	2896	3862	5793	11585	0.80
Cs	1.5	0.65	1379	1552	1773	2069	2483	3103	4138	6206	12413	0.80
Cu	1.3	1.36	2501	2814	3215	3751	4502	5527	7503	11254	22508	1.24
Ag	1.1	1.20	1867	2101	2401	2801	3361	4201	5602	8402	16805	0.90
Au	1.1	1.21	1883	2118	2421	2824	3389	4236	5648	8472	16945	1.40
Mg	1.3	1.36	2501	2814	3215	3751	4502	5627	7503	11254	22508	1.2
Ca	1.8	1.11	2826	3180	3634	4239	5087	6359	8479	12718	25437	2.1
Zn	0.85	1.58	1900	2137	2443	2850	3420	4274	5699	8549	17098	0.38
Cd	0.74	1.40	1465	1649	1884	2198	2638	3297	4396	6595	13189	0.39

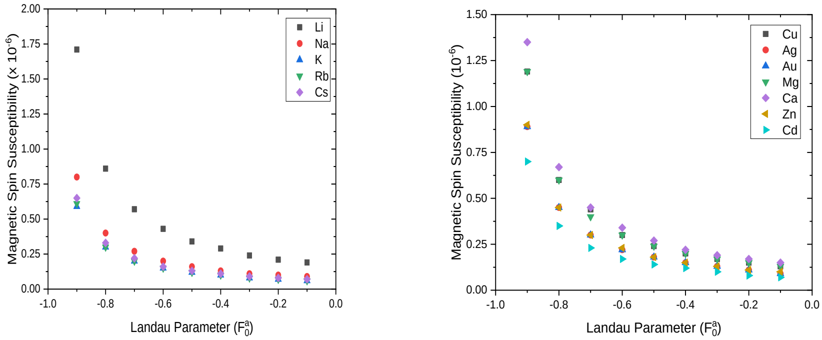

Figure 1: Variation of Calculated Magnetic Spin Susceptibility of quasi-particle of (a) Alkali Metals with Landau parameter (F_0^a) (b) Transition Metals with Landau parameter (F_0^a)

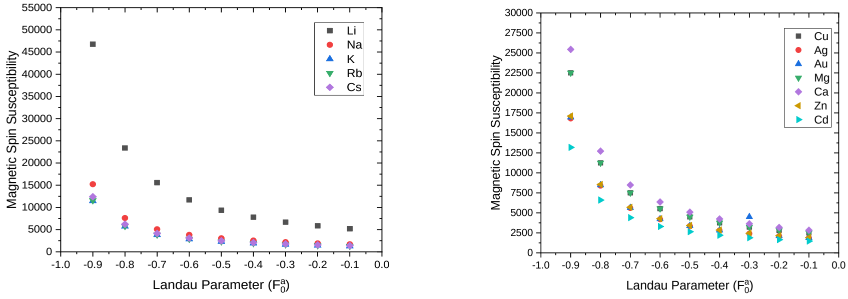

Figure 2: Variation of Landau Magnetic Spin Susceptibility of quasi-particle of (a) Alkali Metals with Landau parameter (F_0^a) (b) Transition Metals with Landau parameter (F_0^a)

5.0 Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this work.

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Estimating the Parameters of GARCH Models and Its Extension: Comparison between Gaussian and non-Gaussian Innovation Distributions

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Abstract: Innovation distributions play significant role in determining the fitness as well as forecasting performance of volatility models. Several studies aimed at comparing the performance of volatility have been carried out but most of the studies focused on the use of Gaussian innovation distribution. Hence, this study compares the performance of GARCH models and its extensions using five innovation distributions, one Gaussian distribution (normal distribution) and four non- Gaussian innovation distributions(Student –t distribution, generalized error distribution, skewed Student- t and skewed generalized error distribution). Data on the daily closing prices of Zenith bank (04/01/2007 to 31/12/2019) and ETI (04/01/2007 to 31/12/2019) were obtained from cashcraft website and then converted to daily returns. Hence, using these five innovation distributions, the parameters of GARCH(1,1), TGARCH(1,1), EGARCH(1,1), IGARCH(1,1) and GJR- GARCH(1,1) were estimated. The performances of these models were compared in terms of fitness using AIC and forecasting performance based on Root Mean Square Error. Result of analysis revealed that GARCH models and its extensions estimated using non- Gaussian innovation distributions outperformed other innovation distributions both in terms of fitness and forecasting accuracy. Result also shows that among the non-Gaussian innovation distributions considered, the skewed generalized error distribution performed better than other non-Gaussian innovation distributions. The TGARCH (1,1)-sged and E-GARCH (1,1)-sged were recommended as the best model for predicting the volatility in ETI and Zenith bank stocks respectively.

Keywords: Gaussian distribution, non-Gaussian distribution, innovation distributions, volatility.

1.0 Introduction

Over the years, volatility modelling has gained the attention of researchers especially those in financial time series [10; 12; 14; 15; 17]. This is because volatility is the major indices used to evaluate investment. Several volatility models have evolved overtime, one of which is Autoregressive Conditional Heteroscedasticity model (ARCH) proposed by [1]. The ARCH though was observed to capture true volatility, it was observed that a higher order of ARCH is needed and to overcome the problem of model parsimony, the generalized form of ARCH model called Generalized Autoregressive Conditional Heteroscedasticity model (GARCH) was proposed by [2]. The introduction of GARCH model helped to reduce the number of estimated parameters from infinity to just two. Due to the limitations of ARCH and GARCH models which is their inability to capture volatility modelling which is one of the major properties of asset returns, other forms of volatility models were proposed some of which include Exponential GARCH (E-GARCH) by [3], the Integrated Generalized Autoregressive Conditional Heteroscedastic model (IGARCH) by [4]), Glosten, Jagannathan and Runkle – Generalized Autoregressive Conditional Heteroscedastic model (GJR-GARCH) by [5], Absolute Value Generalized Autoregressive Conditional Heteroscedastic (AVGARCH) of [6], Asymmetric Power Autoregressive Conditional Heteroscedastic (APARCH), Fractional Integrated Exponential Generalized Autoregressive Conditional Heteroscedastic model (FIEGARCH (p,d,q)) by [7], the Hyperbolic Autoregressive Conditional Heteroscedastic (HYGARCH (p,d,q)) by [8], Asymmetric Power Autoregressive Conditional Heteroscedastic (APARCH) model by [9] among other models were proposed.

Furthermore, in order to estimate the parameters of these heteroscedastic models, various distribution of error innovation have been proposed. This is because as suggested by [10] the distribution of error distribution plays significant role in estimating the parameters of the heteroscedastic model. Notable among these innovation distributions are the normal distribution, Student- t distribution, generalized error distribution among others. Also, efforts have also been made by researchers ([11] and [12]) at estimating the parameters of volatility models using any of these distributions of error innovation. But the major gap in these studies was that their conclusion were derived by most of these studies based on normal distribution and given the recent developments in Nigeria most importantly government policies it very important to carry out a more recent study on this subject using other non-Gaussian innovation distribution (Student-t and generalized error distribution, skewed Student- t and skewed generalized error distributions). Hence, this study therefore compares the performance of GARCH models and its extensions using normal, Student- t distribution and generalized error distribution.

Several studies have been conducted on volatility modelling. [13] modeled and forecast the volatility of the Malaysian stock markets. The study made of high – frequency data so as to enhance the comparison of volatility forecast. The study focused on three volatility model which are GARCH(1.1), EGARCH(1.1) and NAGARCH(1.1) which were estimated using six distributions of error innovation. These include the normal, skew normal, student t, GED and NIE (GED – Generalized error distribution, NIG-normal inverse Gaussian distributions). The result suggested that heavy tailed error distribution gave a better variance forecasts comparing to using normal distribution. The study therefore concluded that the successful forecast of volatility depends largely on the choice of the error distribution rather than the choice of the GARCH model. Similarly, [14] estimated stock market volatility using asymmetric GARCH models. The asymmetric GARCH models used in the study include the GJR-GARCH, APARCH, and EGARCH. The study was carried out in Tel Avis Stock Exchange (TASE) in Israel and three distributional form of error innovation were used namely normal, student – t, and skewed-student-t. The study also quantified the day of the week effect and the leverage effect on volatility of Tel. Avis Stock Exchange in Israel. The result revealed that asymmetric GARCH model with fat tailed densities improved overall estimation of measuring conditional varies. The study also found that the skewed student-t distribution is the most successfully distribution for forecasting the volatility of TASE indices.

Also, [15] modeled the market volatility with APARCH model. The study discussed the APARCH model and its ability to forecast the conditional volatility of standard and poor 500 stock market daily closing price index and MSCI Europe Index under the various density functions normal distribution, student-t distribution and skewed student-t distribution. The study found that skewed student-t distribution is the most efficient distribution under APARCH model. The APARCH model under skew student-t distribution has a larger likelihood and smaller error compared to other distribution.

Similarly, [16] modeled the volatility in the Nigerian Stock using the new class of volatility models precisely Generalized Autoregressive Score (GAS), Exponential GAS (EGAS) and Asymmetric Exponential GAS (AEGAS). These models were applied to data on the Nigeria All Share Index (ASI) from January 3, 2006 to July 22, 2014. Parameters of these models were estimated using the Quasi Maximum Likelihood (QML) approach, and in-sample conditional volatility forecasts from each of the models were evaluated using the minimum loss function approach. The findings showed that the EGARCH-Beta-t innovation outperformed IGARCH- Student-t innovation. In Pakistan, [17] evaluated and forecasted the volatility of stocks in Karachi stock exchange, Pakistan. Data were collected between the between 1998 and 2011. The study fitted various forms of volatility models to the data. The study considered three distribution of error innovations namely Gaussian distribution, generalized error distribution, Student- t distribution and. The findings revealed the superiority of Student-t distribution over other innovation distributions considered. The findings also showed that asymmetric volatility models were better than symmetric volatility models. [18] carried a study which compared the performance of GARCH, EGARCH and GJR in estimating financial volatility. Data used in the study was a 1278 daily closing value of USD – INR exchange rate from 11th June, 2007 to 20th August, 2013. Models considered were GARCH model, EGARCH and GJR models with afferent order of autoregressive and moving average. The normal (Gaussian) distribution form was used. Result revealed that among the twenty GARCH types of model, GARCH specifications, particularly GARCH (1, 1) specification was measured to be better than advanced EGARCH and GJR – GARCH Specifications.

In Nigeria, [19] modeled the volatility in Nigerian stock market using Nigeria All Share Index (ASI) between 02/10/2001 and 29/03/2018. The study considered five volatility models; GARCH(1,1), APARCH (1,1), GJR-GARCH(1,1), IGARCH(1,1) and EGARCH(1,1) which were estimated using skewed normal, skewed Student- t distritbution and skewed generalized error distributions. Result revealed evidence of volatility clustering and high persistence of volatility. Result also showed that among the competing models, APARCH(1,1)- skewed normal distrbution outperformed other volatility models.

Also, [22] examined the persistence of shock, symmetric and asymmetric responses in Nigerian stock market using one symmetric volatility model [GARC(1,1)] and two asymmetric volatility models [EGARCH(1,1) and TARCH(1,1)] which were estimated using normal, Student-t, skewed Student- t, generalized error distribution and skewed generalized error distribution. The study obtained All Share Index data between 3rd July, 1999 and 12th June 2017 and January 1985 to March 2017 respectively. Result showed evidence of volatility clustering and high persistence of volatility shocks with explosive tendency. Only few of these studies carried out in Nigeria considered modeling volatility using non Gaussian innovation distribution. The few that considered skewed innovation distribution do not consider the price of individual stock listed on the Nigeria Stock Exchange (NSE) but rather make use of All Share Index as a proxy for stock price. These identified gaps served as a motivation for this study.

2.0 Methods

2.1 Study Data

Data used in conducting this study were the daily closing price of Zenith bank (04/01/2007 to 31/12/2019) and ETI (04/01/2007 to 31/12/2019). These data were accessed through the official website of Cashcraft which is one of the leading stock broking firms in Nigeria (www.cashcraft.com). The R statistical package was used in data analysis.

2.2 Generation of daily return series from price

The daily returns series for each stock were generated from price using the daily price using the formula below:

$$r_t = \log\left(\frac{P_t}{P_{t-1}}\right), \text{ t = 2, n} \qquad (1)$$

where, P_t is the closing price at day t (present day) while P_{t-1} is the daily closing price at the day t-1(previous day).

2.3 Normality of the result series

To assess the normality of the daily return series of the selected stock, the Jacque Bera test was used. The Jacque Bera test is given by:

$$JB = \frac{n}{6}\left[\rho^2 + \frac{(\eta-3)^2}{4}\right] \qquad (2)$$

where, ρ is the skewness and η is the kurtosis. The test statistics is approximately χ_2^2 and the null hypothesis is rejected if the probability value is less than .05.

2.4 Stationarity test for the daily return series

The stationarity of the daily return series were tested using Augmented Dickey Fuller Test (ADF) with the null and alternative hypotheses stated below:

The null hypothesis is: $H_0 : \theta = 1$

The alternative hypothesis is $H_0 : \theta \prec 1$

The test statistic,

$$\text{t-ratio} = \frac{\hat{\theta}-1}{Std(\theta)} = \frac{\sum_{r=2}^{n} p_{t-1}e_t}{\hat{\sigma}^2\sqrt{\sum_{r=2}^{n} p_{t-1}^2}} \qquad (3)$$

where, $$\hat{\theta} = \frac{\sum_{r=2}^{n} p_{t-1}p_t}{\sum_{r=2}^{n} p_{t-1}^2} \qquad (4)$$

and, $$\hat{\rho}^2 = \frac{\sum_{r=2}^{n}(p_t - \hat{\theta}p_{t-1})^2}{n-1} \quad (5)$$

where, n is the sample size which in the observations for returns. The null hypothesis is rejected if the probability value is less than 0.05($p<0.05$).

2.5 Innovation Distributions considered in the study

Normal distribution/ Gaussian distribution

$$f(z_t) = \frac{1}{\sqrt{2\pi}} e^{-z_t/2} \qquad -\infty < z_t < \infty \quad (6)$$

Student t-distribution (Non- Gaussian distribution)

$$f(z_t) = \frac{\Gamma\left(\frac{\rho+1}{2}\right)}{\sqrt{\rho\pi\Gamma\left(\rho/2\right)}}\left(1+\frac{z_t^2}{\rho}\right)^{-\left(\frac{\rho+1}{2}\right)}, \quad -\infty < z_t < \infty \quad (7)$$

where, ρ denote the number of degrees of freedom and Γ is the Gamma function.

Generalized Error Distribution (GED) (Non- Gaussian distribution)

$$f(z_t, \mu, \sigma, \rho) = \frac{\sigma^{-1}\rho e^{\left[-0.5\left|\left(\frac{z_t-\mu}{\sigma}\right)\lambda\right|^{\rho}\right]}}{\lambda 2^{\left[1+\left(\frac{1}{\rho}\right)\right]\Gamma\left(\frac{1}{\rho}\right)}} \quad -\infty < \eta_t < \infty \quad (8)$$

$\rho > 0$ is the degree of freedom or tail thickness parameters and

$$\lambda = \sqrt{2^{\left(-\frac{2}{\rho}\right)\Gamma\left(\frac{1}{\rho}\right)} \Big/ \Gamma\left(\frac{3}{\rho}\right)} \quad (9)$$

If $\rho = 2$, the GED will give the normal distribution.

Skewed Student t-distribution

$$f(z_t, \mu, \sigma, \phi, \lambda) = \begin{cases} bc\left[1+\frac{1}{\phi-2}\left(\frac{b\left(\frac{\eta_t-\mu}{\sigma}\right)+a}{1-\lambda}\right)^2\right]^{-\frac{\rho+1}{2}}, z_t < -\frac{a}{b} \\ bc\left[1+\frac{1}{\phi-2}\left(\frac{b\left(\frac{\eta_t-\mu}{\sigma}\right)+a}{1+\lambda}\right)^2\right]^{-\frac{\rho+1}{2}}, z_t \geq -\frac{a}{b} \end{cases} \quad (10)$$

where, ϕ and λ represent the shape and skewness parameters respectively.

$$a = 4\lambda c\left(\frac{\phi - 2}{\phi - 1}\right),\ b = 1 + 3\lambda^2 - a^2,\ c = \frac{\Gamma\left(\frac{\phi+1}{2}\right)}{\sqrt{\pi(\phi - 2)\Gamma\left(\frac{V}{2}\right)}} \qquad (11)$$

Skewed Generalized Error Distribution

$$f(z_t / \rho, \varepsilon, \theta, \delta) = \frac{\rho}{2\theta\Gamma\left(\frac{1}{\rho}\right)} \exp\left[-\frac{|z_t - \delta|^\rho}{[1 + sign(z_t - \delta)\varepsilon]^\rho \theta^\rho}\right]$$

$$\theta > 0,\ -\infty < z_t < \infty,\ \rho > 0,\ -1 < \varepsilon < 1 \qquad -\infty < z_t < \infty \qquad (12)$$

where,

$$\theta = \Gamma\left(\frac{1}{\rho}\right)^{0.5} \Gamma\left(\frac{3}{V}\right)^{-0.5} S(\varepsilon)^{-1},$$

$$\delta = 2\varepsilon S(\varepsilon)^{-1},$$

$$S(\varepsilon) = \sqrt{1 + 3\varepsilon^2 - 4A^2\varepsilon^2},$$

$$A = \Gamma\left(\frac{2}{\rho}\right)\Gamma\left(\frac{1}{\rho}\right)^{-0.5} \Gamma\left(\frac{3}{\rho}\right)^{-0.5}$$

where, $\rho > 0$ is the shape parameter, ε is a skewness parameter with $-1 < \varepsilon < 1$.

2.6 GARCH model and its extensions considered in the study

(i.) The Generalized Autoregressive Conditional Heteroscedasticity model (GARCH).

$$R_t = \mu + \varepsilon_t, \quad \eta_t^{\ 2} = \omega + \sum_{j=1}^{p} \beta_j \eta_{t-j}^2 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2. \quad \varepsilon_t = \eta_t z_t \qquad (13)$$

$\omega, \beta_j,\ \alpha_i \geq 0$ and for stationarity, $\alpha_i + \beta_j < 1$, ω is constant term, β_j is GARCH term while α_i is the ARCH term, η_t is the volatility, R_t is the returns and is ε_t the residuals.

(ii.) Threshold Generalized Autoregressive Conditional Heteroscedasticity model (TGARCH).

$$\eta_t^{\ 2} = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j \eta_{t-j}^2 + \sum_{k=1}^{w} \gamma_k I_{t-i} \varepsilon_{t-1}^2,\ \varepsilon_t = \eta_t z_t \qquad (14)$$

where, ω is constant term, α_i is ARCH term while β_j is the GARCH term, $\omega \geq 0$, α_i and $\beta_j \geq 0$, η_t is the volatility and I_{t-i} is an indicator variable.

$$I_{t-i} = \begin{cases} 1, \varepsilon_{t-i} \prec 0 \\ 0, \varepsilon_{t-i} \geq 0 \end{cases}$$

(iii.) Glosten, Jagannathan and Runkle Generalized Autoregressive Conditional Heteroscedasticity model (GJR-GARCH).

$$\eta_t^{\,2} = \omega + \sum_{i=1}^{p} \left(\alpha_i \varepsilon_{t-1}^2 + \gamma_1 I_{t-i} \varepsilon_{t-1}^2 \right) + \sum_{j=1}^{q} \beta_j \eta_{t-i}^2 . \;\; \varepsilon_t = \eta_t z_t \qquad (15)$$

$$I_{t-i} = \begin{cases} 1, \varepsilon_{t-i} \prec 0 \\ 0, \varepsilon_{t-i} \geq 0 \end{cases}$$

ω is constant term, α_i is ARCH term while β_j is the GARCH term, γ_1 is the leverage term, $\omega \geq 0$, α_i and $\beta_j \geq 0$ and η_t is the volatility.

(iv.) Exponential Generalized Autoregressive Conditional Heteroscedasticity model (EGARCH)

$$R_t = \mu + \varepsilon_t , \;\; \ln(\eta_t^2) = \omega + \sum_{i=1}^{p} \alpha_i \left[\lambda \varepsilon_{t-i} + \gamma \left\{ \left| \varepsilon_{t-i} \right| - \sqrt{\frac{2}{\pi}} \right\} \right] + \sum_{j}^{q} \beta_j \ln(\eta_{t-j}^2) , \;\; \varepsilon_t = \eta_t z_t$$

(16)

where, ω is constant term, α_i is ARCH term while β_j is the GARCH term and, γ is the leverage term and η_t is the volatility.

(v.) Integrated Generalized Autoregressive Conditional Heteroscedasticity model (IGARCH)

$$R_t = \mu + \varepsilon_t , \; \eta_t^{\,2} = \omega + \sum_{j=1}^{q} \beta_j \eta_{t-j}^2 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 . \qquad \varepsilon_t = \eta_t z_t \qquad (17)$$

where, ω is constant term, α_i is ARCH term while β_j is the GARCH term and

$$\sum_{j=1}^{p} \alpha_j + \sum_{i=1}^{q} \beta_j = 1 \; .$$

3.0 Results

Table 1: Descriptive statistics for daily prices and returns series of Zenith banks and ETI stocks

Statistic	**Zenith bank**		**ETI**	
	Daily price	Daily returns	Daily price	Daily returns
n	3131	3130	3131	3130

Mean	22.0806	-0.00009	36.3125	-0.00052
Maximum	68.9700	0.051335	300.9800	0.65321
Minimum	9.00000	-0.176257	6.00000	-0.69897
Standard deviation	10.9943	0.011426	58.51499	0.024400
Skewness	1.8189	-1.652441	2.65007	-8.63473
Kurtosis	5.9658	26.48196	8.65986	573.2944
Jacque Bera	2873.9560	73336.51	7843.879	4245505
p-values	0.0000	0.000	0.0000	0.0000

Table 2: Augmented Dickey Fuller (ADF) test result summary and test of heteroscedasticity

Stocks	ADF Test Statistic	Probability values	Comment	ARCH test F-stat.	p-value
Zenith	-45.045	0.0001	Stationary at level	5.18183	0.0229
ETI	-46.410	0.0001	Stationary at level	324.1762	0.0000

Table 1 presents the descriptive summary for both the daily prices and the returns of the two selected stocks. Result showed that the mean returns of the two selected stocks were negative meaning that the stock recorded loss within the periods under study. The skewness obtained for ETI (-8.63473) and Zenith bank stock (-1.652441) were both negative indicating that the returns of these stocks decreased more than it increased hereby corroborating the results of the mean returns. The Jacque Bera test showed p-value less than 0.05 both for the daily prices as well as the daily returns of the two selected stock meaning that the daily prices and the daily returns of these stocks do not follow normal distribution. The ADF test result revealed that these returns are stationary ($p<0.05$) (Table 2). The ARCH effect was found to be significantly present in the returns series ($p<0.05$). This therefore necessitated the need to subject the daily returns series of ETI and Zenith bank stocks to volatility models. The result also revealed evidence of volatility clustering in both stocks which is an indication that large changes in volatility were followed by large changes in volatility while small changes in volatility were also followed by small changes in volatility. The leverage effect which measures whether there is a negative relationship between asset returns and volatility was found to be significant in both stocks ($p<0.05$)(Tables 3 and 4). The result also revealed that in terms of fitness and forecasting performance based on LL, AIC and RMSE, volatility model estimated using the non Gaussian innovation distributions(Student-t, generalized error distribution, skewed Student- t and skewed generalized error distributions) were found to outperform that of the Gaussian innovation distribution both in terms of fitness performance and forecasting performance(Table 5). Result also reveals that among the non- Gaussian innovation distributions considered, the skewed generalized error distribution outperformed other non- Gaussian innovation distributions both in terms of fitness and forecasting performance.

Table 3a: Parameter estimates and fitness for GARCH (1,1), TGARCH(1,1) and EGARCH(1,1) using normal, Student-t, generalized error distribution, skewed Student-t and skewed generalized error distribution for Zenith bank returns.

Model		μ	ω **(p-value)**	α_1 **(p-value)**	β_1 **(p-value)**	γ_1 **(p-value)**	**LL**	**AIC**	**ARCH test for diagnostic checking**
GARCH (1,1)	norm	-0.000095 (0.18597)	0.000005 (0.0000)	0.198940 (0.0000)	0.784670 (0.0000)	-	9940.362	-6.3491	0.9841
	std	0.00000 (0.9999)	0.00000 (0.0000)	0.18883 (0.0000)	0.80821 (0.0000)	-	10243.24	-6.5420	0.9858
	ged	0.00000 (0.9999)	0.00000 (0.54556)	0.13288 (0.0000)	0.86358 (0.0000)	-	10279.67	-6.5653	0.8810
	sstd	0.00000 (0.93636)	0.00000 (0.9999)	0.18629 (0.0000)	0.81072 (0.0000)	-	10243.09	-6.5413	0.9857
	sged	0.000000 (0.98449)	0.000005 (0.0000)	0.164108 (0.0000)	0.786454 (0.0000)	-	**10292.07**	**-6.5726**	0.9248
TGARCH (1,1)	norm	-0.000087 (0.00156)	0.001377 (0.029192)	0.164227 (0.0000)	0.819651 (0.0000)	-0.048584 (0.299116)	9974.613	-6.3697	0.4167
	Std	0.000000 (0.99955)	0.000001 (0.56158)	0.183007 (0.0000)	0.857547 (0.0000)	0.035299 (0.29330)	10527.41	-6.7223	0.9858
	ged	0.000000 (0.99992)	0.007107 (0.00000)	0.165637 (0.0000)	0.880555 (0.0000)	-0.429430 (0.00000)	**10745.77**	**-6.8618**	0.9857
	sstd	0.000000 (0.99940)	0.000001 (0.61839)	0.163696 (0.0000)	0.868822 (0.00000)	0.015927 (0.61683)	10442.81	-6.6676	0.9859
	sged	0.000000 (0.99993)	0.004978 (0.0000)	0.195998 (0.0000)	0.854360 (0.000000)	-0.161770 (0.002415)	10514.04	-6.7131	0.9857
EGARCH (1,1)	norm	-0.000213 (0.0000)	-0.748281 (0.0000)	0.004178 (0.7581)	0.914749 (0.00000)	0.336637 (0.0000)	9963.755	-6.3634	0.4248
	Std	0.000004 (0.44142)	-0.404546 (0.0000)	-0.03685 (0.0400)	0.954585 (0.0000)	0.384687 (0.0000)	10251.26	-6.5465	0.8387
	ged	0.00000 (0.99982)	-0.44615 (0.0000)	-0.04405 (0.0956)	0.94813 (0.0000)	0.49146 (0.0000)	10360.31	-6.6155	0.8563
	sstd	-0.000067 (0.0000)	-0.362049 (0.0000)	-0.03866 (0.0291)	0.959294 (0.0000)	0.382385 (0.0000)	10252.73	-6.5468	0.8392
	sged	0.000000 (0.99582)	-0.447791 (0.0000)	-0.06924 (0.0213)	0.947852 (0.0000)	0.505887 (0.0000)	**10360.31**	**-6.6162**	**0.8737**

Bolded values are the highest value of likelihood function and the least value of AIC, norm- normal distribution std- Student-t distribution, ged- generalized error distribution, sstd- skewed Student- t distribution and sged- skewed generalized error distribution.

Table 3b: Parameter estimates and fitness for IGARCH (1,1) and GJR-GARCH(1,1) using normal, Student-t, generalized error distribution, skewed Student-t and skewed generalized error distribution for Zenith bank returns.

Models		μ	ω (p-value)	α_1 (p-value)	β_1 (p-value)	γ_1 (p-value)	LL	AIC	ARCH test for diagnostic checking
IGARCH (1,1)	norm	-0.00010 (0.0803)	0.000005 (0.0000)	0.210754 (0.0000)	0.789246 (0.0000)	-	9939.165	-6.3490	0.9626
	std	-0.000001 (0.99969)	0.000001 (0.9999)	0.192966 (0.9866)	0.807034 (0.0000)	-	10237.22	-6.5388	0.9841
	ged	0.00000 (0.9999)	0.00000 (0.88321)	0.14003 (0.0000)	0.85996 (0.0000)	-	**10285.82**	**-6.5699**	**0.7637**
	sstd	0.000001 (0.96596)	0.000000 (0.99896)	0.191053 (0.0000)	0.808947 (0.0000)	-	10237.59	-6.5384	0.9841
	sged	0.00000 (0.99979)	0.00000 (0.90048)	0.13647 (0.0000)	0.86353 (0.0000)	-	10285.73	-6.5692	0.8732
GJR-GARCH (1,1)	norm	-0.000097 (0.18393)	0.000005 (0.0000)	0.198140 (0.0000)	0.784314 (0.0000)	0.002646 (0.9219)	9940.367	-6.3485	0.9817
	std	0.00001 (0.98774)	0.000000 (0.99999)	0.196905 (0.0000)	0.790381 (0.0000)	0.019792 (0.3634)	10250.17	-6.5458	0.9857
	ged	0.000000 (0.9999)	0.000000 (0.8502)	0.130632 (0.0000)	0.858021 (0.0000)	0.020688 (0.2846)	10284.78	-6.5673	0.8886
	sstd	0.000001 (0.91335)	0.000000 (0.9999)	0.166659 (0.0000)	0.811290 (0.0000)	0.037696 (0.0691)	10244.29	-6.5414	0.9288
	sged	0.000000 (0.99998)	0.000000 (0.86014)	0.129816 (0.0000)	0.858727 (0.0000)	0.020853 (0.2792)	**10284.84**	**-6.5679**	0.8843

Bolded values are the highest value of likelihood function and the least value of AIC, norm-normal distribution std- Student-t distribution, ged- generalized error distribution, sstd- skewed Student- t distribution and sged- skewed generalized error distribution.

Table 4a: Parameter estimates and fitness for GARCH (1,1), TGARCH(1,1) and EGARCH(1,1) using normal, Student-t, generalized error distribution, skewed Student-t and skewed generalized error distribution for ETI stock.

Models		μ	ω (p-value)	α_1 (p-value)	β_1 (p-value)	γ_1 (p-value)	LL	AIC	ARCH test for diagnostic checking
GARCH (1,1)	norm	-0.000387 (0.0000)	0.000004 (0.0000)	0.165005 (0.0000)	0.833994 (0.0000)	-	9435.445	-6.0265	0.9780
	Std	0.00000 (0.98889)	0.00000 (0.9999)	0.33017 (0.0000)	0.6530 (0.0000)	-	12002.60	-7.6630	0.9998
	ged	-0.000517 (0.0000)	0.000001 (0.33939)	0.050000 (0.0000)	0.900000 (0.0000)	-	6302.196	-4.0238	0.7701
	sstd	0.00000 (0.98548)	0.00000 (0.9999)	0.33066 (0.0000)	0.65224 (0.0000)	-	**12002.83**	**-7.6657**	**0.9998**
	sged	-0.000517 (0.0000)	0.000001 (0.29726)	0.050000 (0.0000)	0.900000 (0.0000)	-	6302.196	-4.0231	0.9547

TGARCH (1,1)	norm	-0.000028 (0.80816)	0.000110 (0.00000)	0.167073 (0.00000)	0.859810(0.0000)	-0.225313 (0.00000)	9504.962	-6.0696	0.9530
	Std	0.00000 (0.999234)	0.00000 (0.336918)	0.34381 (0.0000)	0.68964 (0.0000)	0.11260 (0.0000)	**12070.22**	**-7.7081**	**0.9721**
	ged	-0.000517 (0.0000)	0.000001 (0.0000)	0.050000 (0.0000)	0.900000 (0.0000)	0.050000 (0.0000)	6301.908	-4.0223	0.8166
	sstd	0.000000 (0.994474)	0.000000 (0.454084)	0.331444 (0.0000)	0.702610 (0.0000)	-0.045771 (0.0000)	12029.33	-7.6814	0.9998
	sged	-0.000517 (0.0000)	0.000001 (0.00000)	0.050000 (0.0000)	0.900000 (0.0000)	0.050000 (0.0000)	6301.908	-4.0217	0.9547
EGARCH (1,1)	norm	0.000021 (0.68489)	-0.408695 (0.0000)	0.108233 (0.0000)	0.948265 (0.0000)	0.251125 (0.0000)	9521.375	-6.0808	0.9518
	std	0.00000 (0.9997)	-0.61282 (0.0000)	0.65907 (0.0000)	0.93291 (0.0000)	1.05076 (0.0000)	12028.55	-7.6815	0.9546
	ged	0.00000 (0.9997)	-0.61282 (0.0000)	0.65907 (0.0000)	0.93291 (0.0000)	1.05076 (0.0000)	14821.73	-9.4663	0.9546
	sstd	0.000007 (0.46381)	-0.170598 (0.0000)	0.682461 (0.0000)	0.969759 (0.0000)	1.969245 (0.0000)	10592.17	-6.7637	0.9684
	sged	-0.000016 (0.0000)	-0.709868 (0.0000)	0.346432 (0.0000)	0.908134 (0.0000)	0.494257 (0.0000)	**14821.75**	**-9.4669**	0.9546

Bolded values are the highest value of likelihood function and the least value of AIC, norm-normal distribution std- Student-t distribution, ged- generalized error distribution, sstd- skewed Student- t distribution and sged- skewed generalized error distribution.

Table 3b: Parameter estimates and fitness for IGARCH (1,1) and GJR-GARCH(1,1) using normal, Student-t, generalized error distribution, skewed Student-t and skewed generalized error distribution for ETI stock.

Models		μ **(p-value)**	ω **(p-value)**	α_1 **(p-value)**	β_1 **(p-value)**	γ_1 **(p-value)**	**LL**	**AIC**	**ARCH test for diagnostic checking**
IGARCH (1,1)	norm	-0.000134 (0.50405)	0.000000 (0.14590)	0.025732 (0.00000)	0.974268 (0.0000)	-	9000.746	-5.7494	0.9797
	Std	0.00000 (0.94640)	0.00000 (0.93444)	0.25578 (0.0000)	0.74422 (0.0000)	-	10783.19	-6.8877	**0.9546**
	ged	-0.000517 (0.00000)	0.000001 (0.00000)	0.050000 (0.0000)	0.950000 (0.0000)	-	6763.717	-4.3193	0.9645
	sstd	0.00000 (0.73544)	0.00000 (0.94191)	0.30018 (0.0000)	0.69983 (0.0000)	-	**10800.25**	**-6.8979**	0.9479
	sged	-0.000517 (0.0000)	0.000001 (0.0000)	0.050000 (0.0000)	0.950000 (0.0000)		6763.717	-4.3187	0.9645
GJR-GARCH (1,1)	Norm	-0.000235 (0.0000)	0.000004 (0.0000)	0.232767 (0.0000)	0.830418 (0.0000)	-0.12837 (0.0000)	9466.374	-6.0456	0.9922
	std	-0.000232 (0.0000)	0.000007 (0.0000)	0.232763 (0.0000)	0.830416 (0.0000)	-0.12822 (0.0000)	9486.362	-6.0556	0.9977
	ged	-0.000517 (0.0000)	0.000001 (0.002169)	0.050000 (0.0000)	0.900000 (0.0000)	0.05000 (0.0000)	5959.125	-3.8039	0.9858
	sstd	0.00000	0.00000	0.30562	0.66246	0.04273	**11985.01**	**-7.6537**	**0.9721**

	(0.98141)	(0.9999)	(0.0000)	(0.0000)	(0.18062)			
sged	-0.000517	0.000001	0.050000	0.900000	0.050000	5959.125	-3.8033	0.9536
	(0.00000)	(0.004027)	(0.0000)	(0.0000)	(0.0000)			

Bolded values are the highest value of likelihood function and the least value of AIC, norm- normal distribution std- Student-t distribution, ged- generalized error distribution, sstd- skewed Student- t distribution and sged- skewed generalized error distribution.

Table 5: Fitness and forecasting performance for GARCH models estimated using normal, Student- t, generalized error distribution, skewed Student-t and skewed generalized error distribution

Stocks	**Volatility models**		**Normal**	**STD**	**GED**	**SSTD**	**SGED**
ETI	GARCH(1,1)	RMSE	0.024399	0.024395	0.024392	0.024320	**0.024318**
	TGARCH(1,1)	RMSE	0.024499	0.024499	0.024482	0.024418	**0.024314**
	EGARCH(1,1)	RMSE	0.024418	0.024399	0.024392	**0.024380**	0.024385
	IGARCH(1,1)	RMSE	0.024419	0.024410	0.024412	0.024319	**0.024412**
	GJR-GARCH(1,1)	RMSE	0.024400	0.024300	0.0244310	**0.0244210**	0.0244220
Zenith bank	GARCH(1,1)	RMSE	0.011424	0.011422	0.011420	**0.011414**	0.011418
	TGARCH(1,1)	RMSE	0.011455	0.011453	0.011440	**0.011430**	0.011433
	EGARCH(1,1)	RMSE	0.011441	0.011439	0.011433	0.011432	**0.011410**
	IGARCH(1,1)	RMSE	0.011460	0.011455	0.011453	**0.0114300**	0.011420
	GJR-GARCH(1,1)	RMSE	0.011477	0.011472	0.011453	0.0114500	**0.011428**

MSE- Mean Square Error, RMSE- Root Mean Square Error. Bolded values are the least Root Mean Square Error (RMSE)

4.0 Discussions

This study found that GARCH model and its extensions estimated using non-Gaussian innovation distribution gave better results in terms of fitness and forecasting performance than those estimated under the assumption of normally distributed innovation distribution. The advantage of the non-normally distributed error innovation over normally distributed error innovation could be as a result of the fact that the normal distribution does not have the ability to capture the leptokurtosis (excess kurtosis) that is usually exhibited by asset returns. This finding could also be due to the fact that the non- Gaussian innovation distributions have fatter tail than the normal distribution. This finding agrees with that of the finding by [11] on estimation of GARCH models for Nigerian rates under non- Gaussian innovations were the non- Gaussian distribution precisely student- t distributions and generalized error distribution were found to be superior than the Gaussian distribution when estimating parameters of GARCH models.

Also, this finding is in line with that of the finding by Atoi(2014) on the volatility of Nigerian stock market using GARCH models which found that the non- Gaussian distributions (Student- t distribution and generalized error distribution) gave better fitness and forecasting ability than the normal distribution. This finding agrees with that of [21] on characteristic responses of symmetric and asymmetric volatility shocks in the Nigerian Stock Market where the heavy tailed distributions were found to better capture the volatility than Gaussian distribution. But this finding is not in line with that of the finding by [16] in Sweden OMXS 30 where TGARCH model with normal distribution for error innovation was found to be superior to both the student-t distribution and generalized error distribution. This disparity in finding could be due to the period where the former study was conducted and that of the present study as the volatility behaviour in 2011 may not be the same as that of 2019 due to the present realities.

5.0 Conclusion and Recommendation

This study has examined the performance of GARCH model and its extensions estimated using Gaussian and non- Gaussian distributions. The empirical analysis using daily closing prices of ETI and Zenith bank between 04/01/2007 to 31/12/2019 showed that the non- Gaussian distributions outperformed Gaussian innovation distributions. This study therefore recommends the use of non- Gaussian distributions when estimating parameters of GARCH models and its extensions. Also, among the competing volatility models, TGARCH (1,1)-sged and E-GARCH (1,1)-sged were recommended as the best model for predicting the volatility in ETI and Zenith bank stocks respectively.

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Haematological and Hepatological effects of Pito, Burukutu-Guinea corn and Burukutu-Millet in Albino Rats

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***Abstract*:** This study investigated the haematological and hepatological effects of selected locally brewed beers in albino rats. Three locally brewed beers were purchased from locally brewed beer joint in Wukari, Nigeria. Twenty male albino rats were used and were randomly distributed into four groups of five rats each. Group 1 served as normal control, while groups 2, 3 and 4 were administered pito, burukutu-Guinea corn and burukutu-millet (10mL/kg bwt) respectively for 21 days before being sacrificed. Result showed that ALT and AST activities increased in all the groups administered the different beer compared to the control. Cholesterol increased in group 2, but decreased in group 4. Potassium and glucose reduced in all test groups compared to the normal control. The differences in cholesterol, potassium and glucose levels are statistically less-significant ($p>0.05$) compared to the control. The liver histoarchitectural state of the test animals administered the beers compared to the control animals showed the beers had toxic effect on the animals. There is evidence of infiltration and distortion of some regions of the liver tissue in the test animals. This agrees with the results of serum biochemical parameters evaluated. The WBC, LYM and GRA increased in group 3 and reduced in groups 2 and 4 compared to the control. The MID reduced in all the test groups compared to the control. RBC, Hb and HCT increased in all the test groups compared to the control. The MCV increased only in group 4 and decreased in groups 2 and 3. The MCH, MCHC and RDWc reduced in all the test groups, while PLT, PCT, MPV and PDWc increased in all the test groups compared to the control. This study has shown that constant administration of pito, burukutu-guinea corn and burukutu-millet in the test animals for a long duration caused alterations and negative effect on the liver function, but may not interfere negatively with the Hb and RBC count.

***Keywords*:** Burukutu-guinea corn, burukutu-millet, haematological, liver tissue, pito.

Introduction

Burukutu is a popular alcoholic beverage of vinegar-like flavour, consumed mainly in the northern region of Nigeria, in the republic of Benin, and in Ghana. It is produced mainly from the grains of guinea corn of the species *Sorghum vulgare* and *Sorghum* bicolor [1] and millet. Preparation of burukutu involves steeping, germination, fermentation and maturation [2]. The resulting product is a cloudy alcoholic beverage called burukutu. Burukutu contains almost all essential amino acids in required proportion except cysteine and tryptophan which are being completely destroyed by heat during boiling [3].

Traditionally, burukutu is brewed with red or white sorghum variety and/or maize malts [4]. It has a sour taste resulting from the action of the lactic acid bacteria (*Lactobacillus spp.*) and opaque colour because of suspended solid and yeast materials [5, 6] with thin consistency. The production process of burukutu is time consuming, complex and sometimes carried out under unhygienic conditions. Back slopping (the addition of an old fermented batch of a previous brew to serve as an inoculum) is usually done to hasten the fermentation process. Burukutu has a very short shelf-life and is expected to be consumed within five days after back slopping. It can however stay much longer (about a week or two) if not back slopped, and tightly covered. Souring of the left-over beverage after five days is usually over combed by mixing it with a freshly prepared one to make it fresh again for consumption.

Pito is a traditionally brewed alcoholic beverage. It is produced mainly from the grains of guinea corn (*Sorghum vulgare* or *Sorghum bicolor*) and millet [1]. Pito brewing is serving as a lucrative business particularly for the rural folks. It is produced traditionally by malting, mashing, fermentation and maturation of the grains which are steeped in water over night, after which excess water is drained. Pito is golden yellow to dark brown in colour, with taste varying from slightly sweet to sour. It has been observed that, pure cultures of microorganism can be used to reduced fermentation time and improve production process of the pito [7]. Such pure cultures include *Lactobacillus plantarum* in combination with *Saccharomyces cerevisiae* and

Pediococcus halophilus in combination with *Candida tropicalis* [7]. The pH, colour, titrable acidity, alcohol content, specific gravity, taste and flavour of Pito produced by use of pure culture can be compared favourably with that produced using the traditional method [7]. Compared with European beers, pito is heavier and darker, but less bitter [2]. It is mostly neither bottled nor canned, but purchased directly from the household in which it is brewed. It is typically served in a calabash or bottle outside the producer's home where benches are provided for the consumers to sit on and enjoy the beverage. Meanwhile, it has been observed that this beverage can be processed, bottled and stored for 2 months with little or no effect on its characteristics and qualities [8]. Nevertheless, fresh samples of pito have been accepted as better than the stored ones in terms of both microbiological and nutritional quality [9, 10]. All the health risks commonly associated with overconsumption of alcoholic beverages [11] also apply to the misuse of pito.

Documented information on the effects of these locally brewed beers is few and thus, very little research has been done to understand how these locally brewed beers affects some body organs such as the liver. The present study is therefore designed to investigate the effect of these liquors in albino rats. The results of this study will help provide information on the probable effects of these selected locally brewed beers on haematological and liver function indices of consumers and the general public.

Materials and Methods

Duration and year of study

This study was carried out from the month of March to July, 2018 in Wukari, Nigeria.

Procurement of the Beers

The burukutu-millet, burukutu-guinea corn and pito used in this study were purchased from locally brewed beer joint in Wukari, Taraba State, Nigeria. The beers were properly identified and labeled accordingly. The procurement of the beers was done on a two-days interval and administered fresh, while the remnants was kept in the refrigerator for not more than 48 hours. The beers are believed to be rich in carbohydrates, proteins, fat, crude fibre, iron and calcium.

Experimental Animals

Twenty healthy male albino rats of 8 weeks of age, weighing between 94g-125g used for this study were procured from the animal house Department of Animal production, National Veterinary Research Institute (NVIRI) Vom, Plateau State, Nigeria and transferred to the animal house Department of Biochemistry, Federal University Wukari, Taraba State, Nigeria. The animals were allowed to acclimatize for fourteen days prior to the experiment.

Experimental Design

The animals were randomly placed into four groups of 5 animals each. Group 1 served as normal control, while groups 2, 3 and 4 served as test animals. The animals were allowed access to feed and water *ad libitum.* The animals were kept in a well-ventilated wired cage after which their body weights were measured accordingly before the start of the feeding regiment. Standard laboratory protocols for animal studies were maintained as approved by the Department of Biochemistry, Faculty of Pure and Applied Sciences, Federal University Wukari, Nigeria. Group 1 animals served as normal control and did not receive any beer; group 2 animals were administered pito (10mL/kg bwt); group 3 animals were administered burukutu-guinea corn (10mL/kg bwt), while group 4 animals were administered burukutu-millet (10mL/kg bwt). The beers were administered for twenty-one days through oral route.

Blood Collection

After administration of the beers, the animals were sacrificed after overnight fasting. The animals were anaesthetized with chloroform; incisions were made into their thoracic cavity and blood samples collected by cardiac puncture using a 10mL hypodermic syringe and dispensed into two different types of tubes. The first part of the blood was dispensed into an anti-coagulant containing sample tube for haematological analysis. The second part of the blood was dispensed into a very cleaned plain tube and allowed to clot for fifteen minutes and centrifuged for 10 minutes at 4000 rpm. Serum was separated from the clot using pasteur pipette for the serum biochemical analysis.

Biochemical and Histological Analysis

Serum biochemical analysis was carried out on each sample. The biochemical parameters selected were Aspartate transaminase (AST), Alanine transaminase (ALT), Cholesterol, glucose and Potassium. These were determined using an auto-analyzer (Reflotron Plus). The haematological parameters were analysed using an auto-analyser (Abacus 380 haematological auto-analyzer). The auto analyzers were switched on and allowed to calibrate. Each of the Samples (tubes) was placed directly into the sample carrier slot of the auto analyzer, the sample was identified by simple ID given by the operator. The tests were set and the analyzer aspirates the samples. Once the sample is processed, the measurements and results are displayed. The liver of all the animals were harvested and examined histologically (Stain: Haematoxylin & Eosin). Photomicrographs of liver sections of the rats were taken and examined.

Statistical Analysis

The biochemical results were subjected to statistical analysis using the One-Way Analysis of Variance (ANOVA) and further with Duncan Multiple Comparisons using Statistical Package for Social Science (SPSS) version 21. The means were compared for significance at $p \leq 0.05$ and the group results were presented as mean ± standard deviation (n=5).

Results

Table 1: Concentration of selected liver function indices in rats administered Pito, Burukutu-Guinea corn and Burukutu-millet

Parameters	Group 1 (Normal control)	Group 2 (Pito 10mL/Kg bw)	Group 3 (Burukutu-Guinea corn 10mL/Kg bw)	Group 4 (Burukutu-millet 10mL/Kg bw)
ALT(IU/L)	55.87 ± 6.31[a]	69.40 ± 17.04[a,b]	74.23 ± 1.19[b]	69.20 ± 1.04[a,b]
AST (IU/L)	249.67 ± 16.50[a]	255.00 ± 22.72[a]	271.67 ± 35.64[a]	328.33 ±35.02[b]
Cholesterol (mmol/L)	2.62 ± 0.04[a]	2.65 ± 0.10[a]	2.62 ± 0.06[a]	2.59 ± 0.00[a]
Potassium (mmol/L)	5.91 ± 0.76[a]	4.91 ± 0.19[a]	5.41 ± 0.65[a]	5.58 ± 0.36[a]
Glucose (mmol/L)	5.61 ± 1.96[a]	5.10 ± 1.26[a]	4.93 ± 0.34[a]	4.93 ± 1.20[a]

Result represent mean ± standard deviation of group serum result obtained (n=5).

Means in the same row, having different letters of the alphabet are statistically significant ($p<0.05$).

Result showed that ALT increased in all the groups administered the different beers compared to the control. AST also increased in all the groups administered the different beer compared to control. Cholesterol increased in group 2, but decreased in group 4. Potassium and glucose decreased in all the test groups compared to the normal control. The differences in cholesterol, potassium and glucose are statistically less-significant (Table 1).

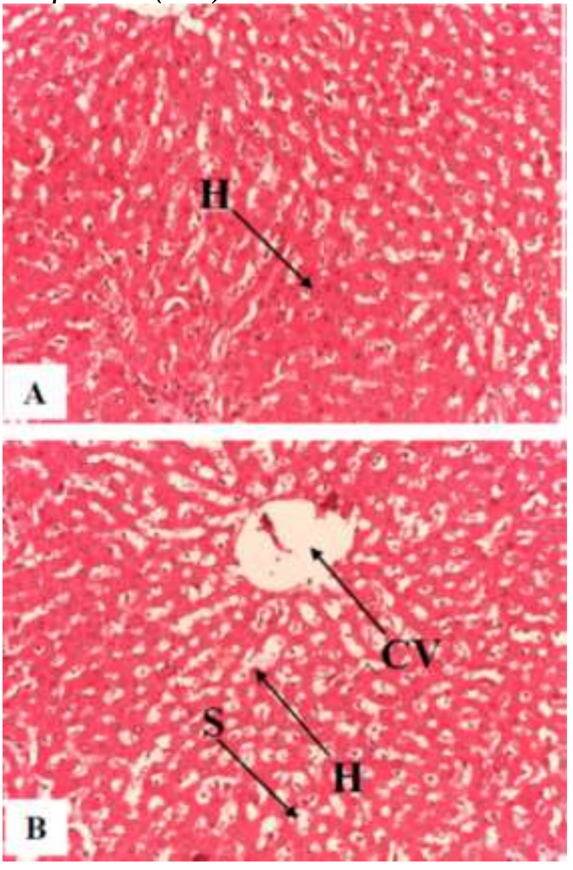

Figure 1: Photomicrographs of liver sections from rat in group 1 (normal control).

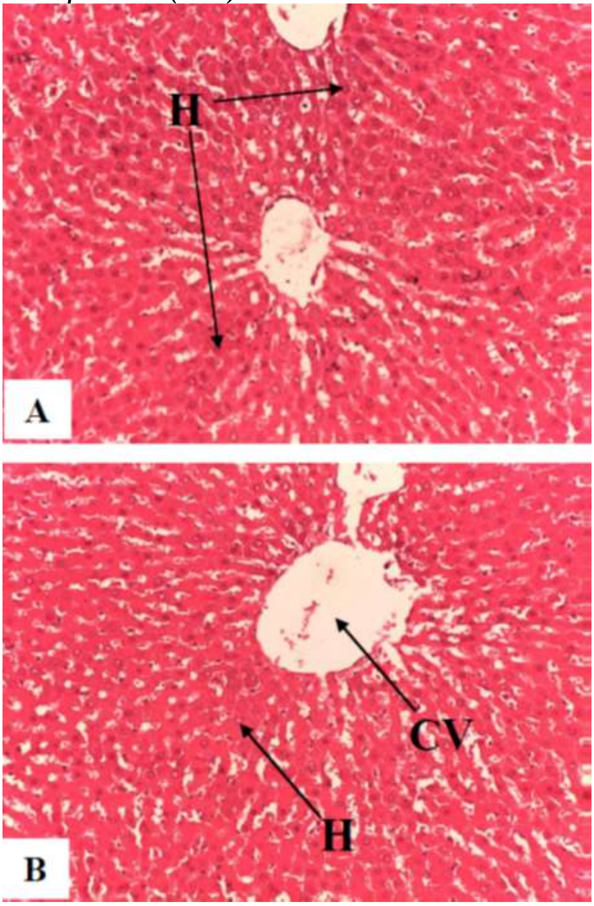

Figure 2: Photomicrographs from liver sections of rat administered Pito (10mL/Kg bw).

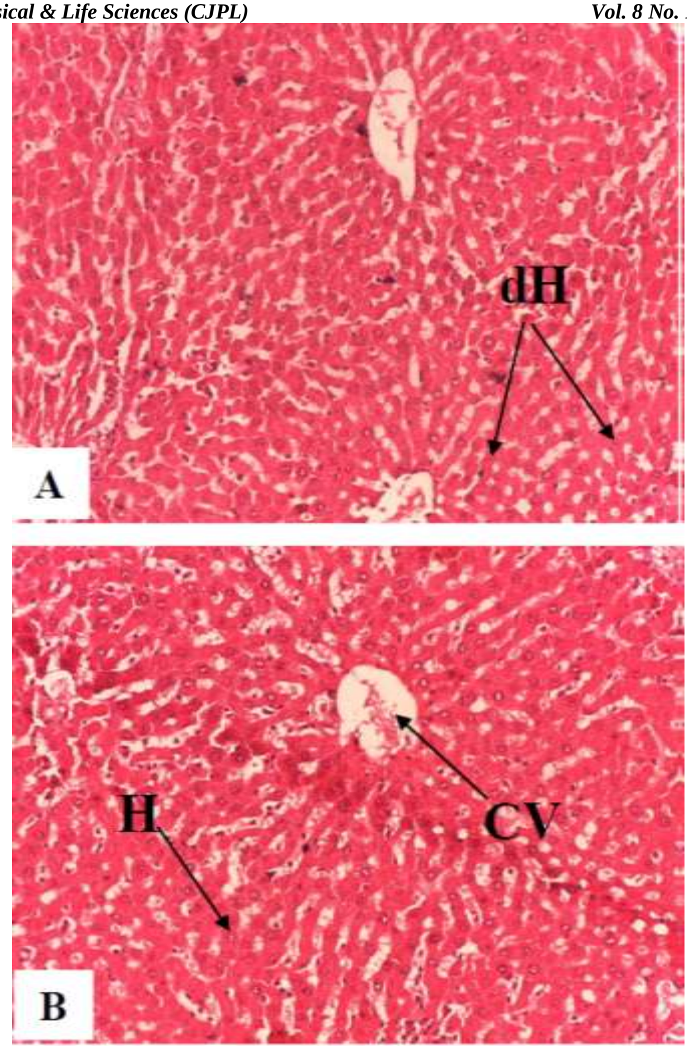

Figure 3: Photomicrographs from liver sections of rat administered Burukutu-Guinea corn (10mL/Kg bw).

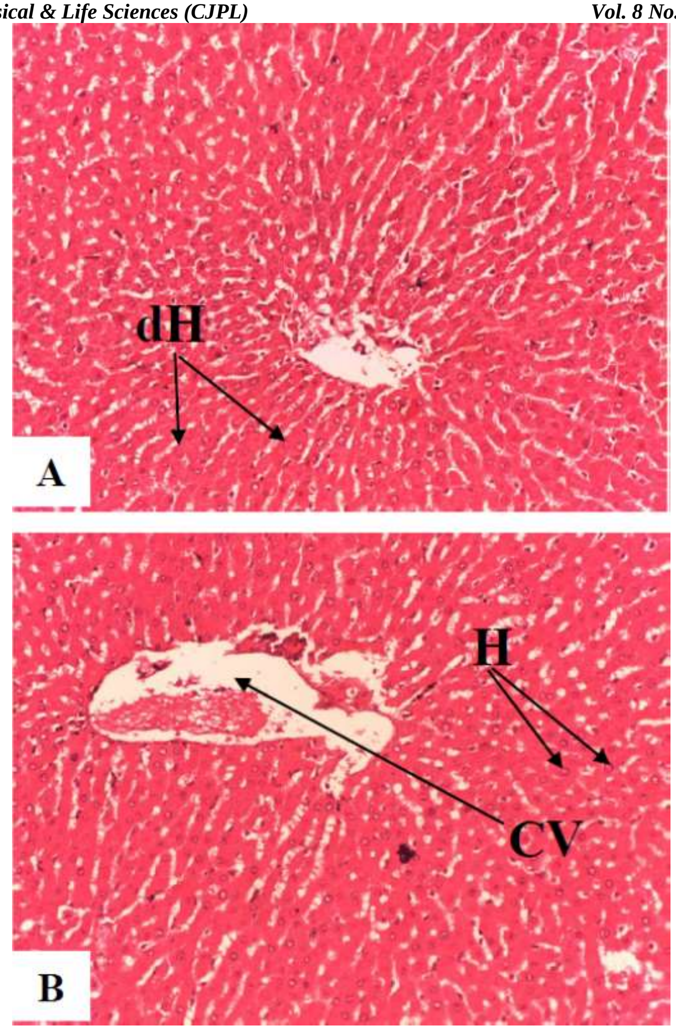

Figure 4: Photomicrographs from liver sections of rat administered Burukutu-millet (10mL/Kg bw).

Table 2: Concentrations of white blood cells (10^9/L) in rats administered Pito, Burukutu-Guinea corn and Burukutu-millet

Parameters	Group 1 (Normal control)	Group 2 (Pito 10mL/Kg bw)	Group 3 (Burukutu-Guinea corn 10mL/Kg bw)	Group 4 (Burukutu-millet 10mL/Kg bw)
WBC	10.07 ± 4.81[a]	6.99 ± 1.52[a]	10.72 ± 2.69[a]	6.61 ± 2.34[a]
LYM	6.97 ± 3.92[a]	4.87 ± 1.23[a]	7.00 ± 1.82[a]	4.06 ± 1.33[a]
MID	1.37 ± 0.48[a]	0.74 ± 0.04[a]	1.34 ± 0.63[a]	0.96 ± 0.76[a]
GRA	1.84 ± 0.52[a,b]	1.39 ± 0.35[a]	2.38 ± 0.30[b]	1.58 ± 0.26[a]

Result represent mean ± standard deviation of group serum result obtained (n=5).
Means in the same row, having different letters of the alphabet are statistically significant ($p<0.05$).
Key: WBC= white blood cell; LYM= lymphocyte; MID= mid-size cells; GRA= granulocyte.

Result showed that WBC, LYM and GRA increased in group 3 and reduced in groups 2 and 4 compared to the control (group 1). The MID reduced in all the groups compared to the control. The alterations that exist in all the groups for all the parameters are not statistically significant ($p>0.05$) compared with the control (Table 2).

Table 3: Concentrations of RBC, Hb and HCT in rats administered Pito, Burukutu-Guinea corn and Burukutu-millet

Parameters	Group 1 (Normal control)	Group 2 (Pito 10mL/Kg bw)	Group 3 (Burukutu-Guinea corn 10mL/Kg bw)	Group 4 (Burukutu-millet 10mL/Kg bw)
RBC (10^{12}/L)	7.05 ± 0.88[a]	8.61 ± 0.19[b,c]	9.02 ± 0.55[c]	7.71 ± 0.51[a,b]
Hb (g/dl)	12.47 ± 1.06[a]	14.17 ± 0.12[b]	14.73 ± 0.83[b]	13.20 ± 0.96[a,b]
HCT (%)	39.84 ± 4.31[a]	45.98 ± 1.28[a,b]	49.08 ± 4.04[b]	43.79 ± 4.11[a,b]
MCV (fl)	56.33 ± 1.15[a,b]	53.33 ± 0.58[c]	54.33 ± 1.15[a,c]	56.67 ± 1.53[b]
MCH (pg)	17.73 ± 0.60[a]	16.50 ± 0.36[b,c]	16.33 ± 0.12[c]	17.13 ± 0.32[a,b]
MCHC (g/dl)	31.37 ± 0.81[a]	30.87 ± 0.76[a]	30.10 ± 0.90[a]	30.23 ± 0.71[a]
RDWc (%)	22.27 ± 0.49[a]	21.70 ± 1.05[a]	22.03 ± 0.75[a]	20.77 ± 0.67[a]

Result represent mean ± standard deviation of group serum result obtained (n=5).
Means in the same row, having different letters of the alphabet are statistically significant ($p<0.05$).
Key: RBC= red blood cell; Hb= haemoglobin; HCT= hematocrit; MCV= mean corpuscular volume; MCH= mean corpuscular haemoglobin; MCHC= mean corpuscular haemoglobin concentration; RDWc= red blood cell distribution width count.

Result showed that RBC, Hb and HCT increased in all the test groups compared to the control. The MCV increased only in group 4 and decreased in groups 2 and 3. The MCH, MCHC and RDWc reduced in all the test groups compared to the control (Table 3).

Table 4: Concentration of platelets in rats administered Pito, Burukutu-Guinea corn and Burukutu-millet

Parameters	Group 1 (Normal control)	Group 2 (Pito 10mL/Kg bw)	Group 3 (Burukutu-Guinea corn 10mL/Kg bw)	Group 4 (Burukutu-millet 10mL/Kg bw)
PLT (10^9/L)	443.33 ± 48.26^a	625.00 ± 86.69^b	521.67 ± 27.59^{a,b}	456.33 ± 65.13^a
PCT (%)	0.32 ± 0.06^a	0.51 ± 0.09^b	0.42 ± 0.04^{a,b}	0.37 ± 0.08^a
MPV (fl)	8.00 ± 0.85^a	8.13 ± 0.32^a	8.07 ± 0.35^a	8.10 ± 0.44^a
PDWc (%)	34.60 ± 1.91^a	35.67 ± 0.95^a	36.13 ± 1.33^a	34.93 ± 1.27^a

Result represent mean ± standard deviation of group serum result obtained (n=5).
Means in the same row, having different letters of the alphabet are statistically significant ($p<0.05$).
Key: PLT= platelet; PCT= plateletcrit; MPV= mean platelet volume; PDWc= platelet distribution width count.

Result showed that PLT, PCT, MPV and PDWc increased in all the test groups compared to the control. The increase in PLT and PCT in group 2 is statistically significant ($p<0.05$) compared to the control. The alterations that exist in all the test groups for MPV and PDWc are not statistically significant ($p>0.05$) compared with the control (Table 4).

Discussion

The administration of pito, burukutu-guinea corn and burukutu-millet to the test animals caused changes in the serum activities of AST and ALT. The increase in ALT activity of the test groups showed that consumption of the three different beers for the duration used in this study could cause hepatic toxicity. This is because increase in the activities of liver-maker enzymes such as ALT and AST is used in accessing liver health. A comparative analysis of the serum activity of ALT in the three test groups showed that administration of burukutu-guinea corn caused a significant increase compared to the control, while administration of pito and burukutu-millet caused a less-significant increase ($p>0.05$). The highest elevation of ALT activity in the group administered the burukutu-guinea corn showed it may have the ability to cause liver alteration or damage in its consumers more than pito and burukutu made from millet. The regular administration of the beers may be causing the enzymes to leak out of the liver into the blood. This negative effect is one of the health risks commonly associated with overconsumption of alcoholic beverages [11]. Kukoyi *et al*. [12] in their similar research reported that regular consumption of red wine for a long period of time may have the ability of interfering with some liver functions. The administration of red wine in their research caused an elevation of serum ALT and AST activities in albino rats. This agrees with the result of this present study.

The result of AST activity showed that administration of burukutu-millet caused a significant increase ($p<0.05$) when compared to the control, while administration of pito and burukutu-guinea corn caused a less-significant increase ($p>0.05$). This increase in all the test groups support the result of ALT, thereby confirming evidence of hepatic toxicity in all the test animals. This showed that individuals who consume these beers regularly for a long period of time are liable to have elevated serum AST and ALT which is an indication of liver toxicity. Cellular leakage of AST and ALT into the blood have been reported to occur due to malfunctioning of cell membrane of some organs [13, 14], such as the liver. However, the highest elevation of AST in group 4 animals administered burukutu-millet showed that it is possible that beside the liver, it may be affecting another organ that may predominantly contain AST, such as the kidney, heart and brain.

Cholesterol level was not significantly altered in all the test animals. Cholesterol level increased less-significantly ($p>0.05$) in the animals administered pito, but reduced less-significantly in the animals administered burukutu-guinea corn and burukutu-millet (Table 1). Cholesterol is a precursor of other steroids and an important constituent of the cell membrane and bile acids [15, 16]. This showed that consumption of the three different beers may not cause any apparent alteration of cholesterol level. It therefore means that though the beers altered AST and ALT levels, they may not be able to cause the incidence that may lead to hyperlipidaemia or atherosclerosis. Elevated serum cholesterol and LDL- cholesterol have been reported to constitute risk factors in the development of diseases such as cardiovascular problem. During the transport of cholesteryl esters deposition in the blood vessels, hardening and narrowing of the vessels may result which could result to cardiovascular diseases, especially atherosclerosis [17-19].

Serum glucose level reduced less-significantly ($p>0.05$) in all the groups administered the beers when compared to the control. However, the result showed the beers have a mild potency of reducing the serum glucose level. Potassium level reduced less-significantly ($p>0.05$) in all the groups administered the beers when compared to the control. Potassium is known to be in the intracellular fluid and has been reported by Nurminen *et al*. [20] to be among the protective electrolytes against hypertension. The less-significant decrease in potassium level of the animals administered the beers when compared with the control animals is an indication that some membrane channels may possibly be mildly protected or stabilized. The mild reduction of potassium levels agrees with the reduction of AST and ALT levels in the test animals.

The liver histoarchitectural state of the test animals administered the beers compared to the control animals showed that the beers had toxic effect on the liver (Figure 1-4). Photomicrographs of liver sections from rat in group 1 (normal control) showed normal features of the hepatic tissue. The hepatocytes (H), central vein (CV) and sinusoids (S) are normal (Figure 1). Photomicrographs from liver sections of rat administered Pito (10mL/Kg bw) showed infiltration of the central vein (CV) and distortion of regions around the central vein. The hepatocytes (H) appeared normal (Figure 2). Photomicrographs from liver sections of rat administered Burukutu-guinea corn (10mL/Kg bw) showed distortion of some periportal regions. The central vein (CV) appear mildly intact. There were evidence of some degenerative hepatocytes (dH) (Figure 3). Photomicrographs from liver sections of rat administered Burukutu-millet (10mL/Kg bw) showed infiltration and dilation of the central vein (Figure 4). There were evidence of some degenerative hepatocytes (dH). This histoarchitectural state of the liver sections of the animals agrees with the results of serum biochemical parameters evaluated in this study.

White blood cell count reduced in the animals administered pito and burukutu-millet, but increased less significantly ($p>0.05$) in the animals administered burukutu-guinea corn when compared with the control animals (Table 2). The implication of the white blood cells result is that consumption of the local beers, especially pito and burukutu made from millet are able to alter the WBC counts and could interfere with the immune index since WBC is used for measuring immune index. Imo *et al*. [13] reported that WBC is a common immune function index that supports in defense against diseases and pathogens that affects animals, thereby promoting the immune system. White blood cells are also reported by Metcalf [21] to originate from pluripotent haemopoietic stem cells.

Administration of the beers caused an increased RBC, Hb and HCT levels in all the test groups compared to the control (Table 3). The increase in RBC and Hb levels in groups 2 and 3 were statistically significant ($p<0.05$), while the increase in HCT level showed statistically significant difference only between the normal control and group 3. This implies that consumption of pito, burukutu made from guinea corn and burukutu made from millet have blood boosting property or the ability of improving some composition of blood and may prevent certain conditions such as anaemia. The red blood cells are reported to be the animals' principal means of transporting oxygen to the body tissues through blood circulation [22]. Guinea corn and millet contain appreciable levels of carbohydrates, proteins, fat, crude fibre, iron and calcium. The nutritive constituent of guinea corn and millet may be responsible for improving the Hb and RBC levels in the test animals. The results of this study agree with the report of Morebise *et al*. [23] that consumption of plant as foods usually promotes the synthesis of haemoglobin due to their high minerals and vitamins contents as observed in this study. The increased Hb and RBC levels in the test animals indicate that there will be adequate supply of oxygen to the body cells and could promote the immune system of the animals. The increased Hb level may have contributed to the increased RBC counts in the test animals. This is because haemoglobin level usually drops when the numbers of healthy red blood cells drop [22]. Despite the selective negative effects exhibited by the beers, they also possess the ability to improve the animals' blood system. Platelets are very important for clotting of blood. The increase in platelet counts of the test animals when compared with the control animals (Table 4) implies that the test animals may not suffer condition such as thrombocytopenia. However, if the number of platelets increase excessively, the animals may suffer thrombocytosis.

Conclusion

This study has shown that administration of pito, burukutu-guinea corn and burukutu-millet in the test animals caused alterations and negative effect on the liver function of the male albino rats. This is evident with the increased liver-maker enzymes, reduced levels of potassium and glucose and distortions of some histoarchitectural state of the liver sections of the test animals. However, administration of the beers may not interfere negatively with Hb level and RBC count. Regular consumption of these three beers for a long duration, such as used in this study is therefore discouraged, as this may pose danger to the liver of the consumers.

List of abbreviations

AST: aspartate transaminase; ALT: alanine transaminase; WBC: white blood cell; RBC: red blood cell; Hb: haemoglobin; HCT: hematocrit; PLT: platelets; H: hepatocytes; CV: central vein; S: sinusoids; dH: degenerative hepatocytes.

Competing interests

The authors declare that they have no competing interests.

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