FOREWORD

In recent times, it has become imperative to engage more in collaborative research in the area of pure and applied science to provide long-term solutions to numerous problems in the 21st century. Hence, I am excited to introduce to you the Federal Polytechnic Ilaro—Journal of Pure and Applied Sciences (FEPI-JOPAS) as a platform for the dissemination and unveiling of thought-provoking information and research findings in applied science. I welcome our readers, scientific audience, and researchers' community to volume 6, issue 1, of this peer-reviewed and accredited multi-disciplinary journal of international repute that is indexed in the Database of African Journal Online (AJOL). FEPI-JOPAS publishes short communication, full-length research work, critical reviews, and other review articles. It archives research information to 21st-century researchers, professionals, policymakers, manufacturers, production staff, research and development personnel, and governmental and non-governmental agencies.

In this edition, the effect of co-fermentation of millet grains with spices (garlic or ginger) on flour properties and porridge quality was investigated by Adebowale and Ajibode. Assessment of the free radical scavenging activity of various solvent fractions of *Justicia. carnea*, and evaluation and quantification of the phenolic (TPC) and flavonoid (TFC) content in various solvent fractions of the methanolic extract of *J. carnea* were unveiled by Omotayo and Adeboye. The anticorrosion activity of *Launaea taraxacifolia* leaves on mild steel in an acid medium was the central focus of the research work of Jesusina and Ajayi. In another study, Olufayo and coworkers examined the impact of *Phyllanthus niruri* leaf meal (PNLM) on the caecum microbial population and layers chicken's blood profiles during the growth stage. The quality assessment of flour and amala produced from white yam (*Dioscorea rotundata*), unripe plantain (*Musa paradisiaca*) and sweet potato (*Ipomoea batatas*) was carried out by Babalola and co-workers.

In addition, Alaba and Gabriel examined the anthropometric status and cognitive performance of school-age children in Sagamu, Ogun State, Nigeria. This was followed by the design, construction and performance evaluation of a walk-behind driven mono wheel agro-chemical boom sprayer which was the main aim of the research effort of Enamaku and Ogunlade. A review by Ibidapo-Obe and Yusuff highlighted the current state of aquaculture in Nigeria, the challenges faced, and the potential benefits of diversifying fish species. The work of Okosode and Sokale dealt with food preferences and foraging ecology of the black and white mannikin bird (*Spermestes bicolor*) found in Ilaro, Ogun State, Nigeria. The next study by Gabriel and Alaba assessed the nutritional status and functional capacity of the Elderly in selected communities in Yewa South, Ogun state. The research work of Sangosina and Akinlade described the effect of sex and environmental parameters on the performance and physiology of rabbits. Buoye and Akinbola presented a comprehensive exploration of leveraging blockchain technology to enhance database backup and recovery processes, thereby safeguarding data integrity. Adeyeye and Okedairo explored the acoustic characteristics of non-traditional Agidigbo musical instruments. Another study by Oduwole surveyed the direct effect of moderating variables on behavioural intention to surveying practice. Amao et al. evaluated the effect of clove powder (*Syzygium aromaticum*) on semen characteristics, haematological and serum-biochemical indices of cocks. The research effort of Adedokun and co-workers aimed to reduce malnutrition in the tropics, and a mixture of sorghum and pigeon peas at ratios: of 100:0, 90:10, 80:20, 70:30, and 60:40%) were co-fermented to produce dried 'Ogi' flour.

Furthermore, the efforts of the dedicated Editorial Board members, reviewers, and authors are gratefully acknowledged for the timely delivery of this rich-content edition of volume 6, issue 1 of FEPI-JOPAS. The authors are solely responsible for the information, data, and authenticity of the data provided in their articles submitted for publication in the Federal Polytechnic Ilaro– Journal of Pure and Applied Sciences (FEPI-JOPAS).

We look forward to receiving your manuscripts for subsequent publications. Visit our website (https://fepi-jopas.federalpolyilaro.edu.ng/index.php/journal) for more information, or contact us via email at *fepi.jopas@federalpolyilaro.edu.ng*
Thank you and best regards.

Prof. Olayinka O. AJANI

THE EFFECT OF CO-FERMENTATION OF MILLET GRAINS WITH SPICES (GARLIC OR GINGER) ON FLOUR PROPERTIES AND PORRIDGE QUALITY

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ABSTRACT
The effect of co-fermentation of millet grains with spices (garlic or ginger) on flour properties and porridge quality was investigated. Millet grains were co-fermented with spices (at 2% and 4% of garlic or ginger) singly and when combined for 72 h at 25±2 °C, each in a separate container. The resulting fermented mash of each sample was separated into two equal portions, one dried into flour and the other made into porridge. Samples without garlic or ginger were used as a control. Bulk density, water absorption and swelling capacities of flours were determined. At the same time, the porridges were analysed for their pH, total titratable acidity (TTA), specific gravity (SG), and sensory quality using standard procedures. The results showed a significant increase in values of bulk density and swelling capacity, while the water absorption capacity decreased in samples containing ginger or garlic. The pH, TTA and SG increased significantly with adding garlic or ginger. The aroma, viscosity, mouthfeel, aftertaste and residual particles of porridge samples showed significant differences with spice addition. Thus porridge with a combination of 4% garlic and ginger had the highest overall acceptability score. Panellists' preference for porridge prepared from 4% garlic and 4% ginger is higher compared to the other porridges. Porridge made from flours containing individual spices was perceived to exhibit a reduction in viscosity with mouth feel. This suggests that porridge with ginger or garlic could be an ideal weaning diet for the elderly or sick

Keywords: Gruel, millet, spices, weaning food

1.0 INTRODUCTION
Pearl millet is one of the staple cereal crops for people living in sub-Saharan Africa because it is climate-resilient and has great potential to combat hunger and malnutrition and assure food security (Taylor et al., 2022). No wonder the year 2023 was designated for millets by the FAO (Yashvardhan, & Gupta, 2024). The origin of millets in-totality was traced to West Africa, and the production output from this region from 2016 to 2020 exceeded 3,500,000 tons per year (FAOSTAT, 2022). Generally, copper, iron, magnesium, phosphorus, selenium, and zinc are some of the essential mineral elements found in millet (Banwo et al., 2022). For instance, the pearl millet variety contains nearly 14.5% proteins, which is comparable to that of wheat (14.4%) and is also rich in complete essential amino acids (Bombom et al., 2023). Common beverages that have been developed from millets and are widely consumed in African regions are *Uji, fura*, *Benkida, Ogi, Ajon*, and *Bushera* (Bamidele, Adebowale, & Xi, 2023). In light of the qualities associated with millet in general, could co-fermentation of millet and spices like garlic or ginger produce acceptable porridge for the vulnerable or the generality of the populace in sub-Saharan African regions?

Thin porridge is made from fermented cereal slurry after cooking the slurry on an open fire. The cooking procedure for thin porridges begins by making a dilution of the starch slurry or sediment with cool water to the desired consistency and cooking it in boiling water (Ladunni et al., 2020). Consumers derive pleasure by taking the porridge with varieties of protein-rich food products from legume seeds such as *robo* (fried-melon meal cake), *akara* (fried cowpea paste), *moimoi* (steamed cowpea paste), *Jogi* (steamed melon paste), and spiced vegetable sauce (Adebowale & Adeyanju, 2022). The consumption of porridges is becoming the norm among the Islamic faithful in West African sub-regions, especially during the Holy month of Ramadan. Most parts of the sub-Saharan African region traditionally use porridges prepared from cereal grains as a staple food and weaning diet. (Adisa & Enujiugha, 2020). This could be because porridge or gruel being a fermented product, has enhanced digestibility and appetizing sensory quality (Itaman & Nwanchukwu, 2021).

Generally, spices are associated with pleasant, aromatic, and volatile flavours, making them important cooking ingredients in most cuisines (Ryu & Kang, 2017). Spices such as garlic and ginger have bioactive components that chelate free radicals and could promote the health of consumers when incorporated into diets (Oluwasola et al., 2021). Numerous studies have documented the inclusion or co-fermentation of various cereal grains with spices (Olaniran & Abiose, 2019; Olaniran et al., 2019; Adebowale & Adeyanju, 2022;

Adejobi et al., 2024). Adebowale and Adeyanju (2022), investigated the physicochemical properties and sensory quality of sorghum-Ogi (gruel) complemented with spices (garlic and ginger). The authors found that a sample with garlic and ginger (1:2) caused a decrease in flour bulk density and gruel viscosity. The low viscosity displayed by the cooked gruel could enhance easy swallowing by vulnerable consumers. Recently, Adejobi et al. (2024) investigated the effect of ginger and garlic inclusion (5-25%, singly and in combination) on the performance of *Lactobacillus plantarum* in maize fermented into Ogi (gruel). The authors found that the inclusion of spices (ginger and garlic) in maize-Ogi had a positive effect on the performance of the microbial strain during fermentation. The authors stress further that an improvement in the nutritional value of maize-ogi was established. However, none of the studies investigated the co-fermentation of millet (pearl-type) with garlic or ginger, with an emphasis on the sensory quality of the porridge.

There is a paucity of information on the effects of the co-fermentation of millet with spices such as garlic and ginger. Consequently, this study seeks to evaluate the effects of co-fermenting millet (pearl variety) with garlic or ginger on flour properties (including bulk density, water absorption and swelling capacities) and porridge qualities (including pH, Total titratable acidity, specific gravity and sensory quality) to promote value-added porridge.

2.0 MATERIALS AND METHODS
Sourcing of Materials
Millet grains (pearl variety), garlic, and ginger were sourced from a retail market at Kuto market in Abeokuta, Ogun State. All the materials were processed into flours and porridges under hygienic conditions, ensuring their suitability for human consumption. All the analyses and porridge evaluations were carried out in the Department of Food Technology, Federal Polytechnic Ilaro.
Methods
Samples Formulation for Co-fermentations
Samples were formulated as indicated in Table 1

Table 1: Addition of garlic and ginger into Millets for Co-fermentation

Sample	Spices (%)	
	Garlic	Ginger
Pearl Millets (control)	0	0
Pearl Millets +2% garlic	2	0
Pearl Millets +4% garlic	4	0
Pearl Millets +2% ginger	2	0
Pearl Millets +4% ginger	4	0
Pearl Millets +2% garlic+2% ginger	2	2
Pearl Millets +2% garlic +4% ginger	2	4
Pearl Millets +4% garlic +2% ginger	4	2
Pearl Millets +4% garlic+4% ginger	4	4

Co-fermentation of millets with or without garlic or ginger

Whole millet grains and the spices were completely cleaned manually and co-fermented in clean water for 3 days (72 h) at 25±2 °C. The fermented mass was wet-milled and sieved. The filtrate, primarily starch suspension, was allowed to settle overnight, and the floating liquid was decanted. The solid was then compressed to remove inherent moisture using a hydraulic-screw device to obtain a low-moisture cake. The cake was pulverized manually using a traditional shifter, to reduce the particles for quick and uniformly dried matter, using a cabinet dryer that was set at 60±5°C, 5 h). The dried matter was milled into flour (500 µm size), packaged, and kept in the fridge (4 °C) until needed for analyses and porridge preparation.

Determination of flour properties

Flour properties (bulk density, water absorption and swelling capacities) were determined using the methods outlined previously (Bamidele, Fasogbon, Oladiran, & Akande, 2015). An average of 10 g of sample was carefully weighed into a measuring cylinder (25 ml cap.) and tapped softly on the edge of the laboratory desk until the volume of the cylinder content remained constant. Bulk density (BD) was calculated as shown in Equation i:

$$BD \ (g/ml) = \frac{weight\ of\ the\ sample}{volume\ of\ sample\ after\ tapping} \quad ……Equation\ (i)$$

The water absorption capacity (WAC) was determined by gently introducing a 2 g sample into a centrifuge tube containing hot water (30 ml). The mixture was agitated by vortexing (20 min), at 10 min each on two occasions, followed by centrifugation (4100 x g, 15 min) at 25±2 °C. The floating liquid was decanted, and the sediment was weighed. Water absorption capacity was calculated as shown in Equation ii:

$$WAC \ (g/g) = \frac{W2-W1}{W1} \quad …… Equation\ (ii)$$

W_1= weight of dry sample; W_2 = sample weight after centrifugation

Swelling capacity: The sample (3.0 g) was weighed into a clean graduated cylinder (50 ml), and the volume was recorded. Exactly 30 ml of distilled water was mixed with the samples and swirled. The mixture was left to stand for 60 min and the volume change was recorded at intervals of 15, 30, 45, and 60 min. The swelling capacity was then calculated as a multiple of the original volume.

Porridge preparation

The suspension of 40 g of flour in 100 ml of cold water was mixed into a uniform, thin paste and cooked in a stainless-steel pot containing 300 ml of boiling over an electric hot plate with a uniform burner diameter. To prevent lump formation, the boiling viscous mass was stirred continuously. The porridge was allowed to simmer for 10-20 min at low electric heat while being stirred at intervals (Adebowale, Taylor, & de Kock, 2020).

Determination of Porridge properties

Porridge properties, including pH, total titratable acidity (TTA), and specific gravity (SG), were determined using the procedures described by AOAC (2012). The pH of the porridges was determined using an electrically operated glass electrode pH meter that has been standardized with buffer solutions of pH 4.0 and 7.0. The electrode was inserted into 10 ml sample aliquots. The TTA was determined by taking 10 ml of porridge into 25 ml of distilled water and mixing it in a conical flask. Exactly 200 ml of a 0.1 M aqueous sodium hydroxide (NaOH) solution was titrated against the porridge sample. Three (3) drops of phenolphthalein indicator were used until the formation of a pink colour was sighted, which indicated the endpoint.

$$TTA \ (\%) = \frac{(T2-T1)\ x\ M\ x\ V\ x\ m}{W} \quad …….Equation\ (iii)$$

V= volume of 0.1 M of NaOH; T_1 = Blank value; T_2 = Titre value; m = ml equivalent of lactic acid (meq) = 0.0640; W = sample weight

For the specific gravity (SG), the principle of density was used to estimate the samples. This procedure involved taking the weight of the dry and empty density bottle. Thereafter, the weight of the bottle was measured after filling it with porridge and again after filling it with distilled water. (Jude-Ojei, Ajayi, & Ilemobayo, 2017).

$$SG = \frac{W2-W1}{W3-W1} \quad …… Equation\ (iv)$$

W_1= weight of empty bottle; W_2= weight of bottle when filled with sample; W_3= weight of bottle when filled with water

Sensory evaluation

Regular consumers of porridge (from the polytechnic community) of about 65 (29 males and 36 females) in number, volunteered for the evaluation. These people were screened and selected, with their ages ranging between 18 and 42 years. Porridges (40 g) were served into 3-digit code plastic cups covered with aluminum foil, in a randomised arrangement. Portable and cleaned water was given to each panel member to cleanse the palate in between sample evaluations. Individual sensory attributes were rated on a 9- 9-point hedonic scale, ranging from 1 (dislike extremely) as the lowest to 9 (like extremely) as the highest value as previously reported by Adebowale et al. (2020).

Statistical analysis

Raw data collated from the experiment was subjected to analysis of variance (ANOVA) a one-way option. Tabulated results were expressed and presented as means ± standard deviations of replicate determinations (n=3). The means of the results were separated using the Duncan New Multiple Range Test evaluated at a 5% significance level (*p*<0.05). The XLSTAT software for Windows version 2018 (XLSTAT® Addinsoft™, New York).

RESULTS AND DISCUSSION

Table 2 below presents the functional properties, including bulk density (BD), water absorption capacity (WAC), and swelling capacity (SC), of the flour obtained from millet grains co-fermented with garlic and ginger. The BD, WAC and SC of the fermented flour

samples showed significant differences ($p < 0.001$) with the inclusion of garlic and ginger in pearl millets. The bulk density and swelling capacity values increased, while the water absorption capacity of samples with spices decreased steadily when compared to that of the sample without spices (control). The slight change in BD suggests that fermented millet with the spices created more porous and less compact compared with the control (Adebowale & Adeyanju, 2022). The samples' respective values for bulk density, water absorption capacity, and swelling capacity ranged from 0.67–0.89 g/ml, 166.5–186.7 (g/g), and 3.64–4.78 (g/g). Bulk density which is useful for measuring heaviness in packaging and transportation shows that grain flour. Lower BD is desirable for easy dispersibility when dissolved in water and reduction of paste viscosity, which is an essential factor in infant feeding (Bamidele, Oladiran, Kayitesi, & Ogundele, 2020). Water absorption capacity measures wholly, the amount of hydrated flour per gram of protein as a result of protein molecules reactions of other solutes with water. Swelling capacity measures the tendency of flour to absorb water during heating from 30 °C to 90 °C in an aqueous suspension (Shiqi, Mario, & Benjamin, 2019).

Table 2: Flour Properties of Co-Fermented Millets-Garlic and Ginger

Samples (Flour)	Flour Properties		
	BD (g/ml)	WAC (g/g)	SC (g/g)
Pearl Millet (Control)	0.67±0.02[cd]	184.4±2.8[b]	3.76±0.01[g]
Pearl Millet +2% garlic	0.68±0.01[cd]	180.3±2.1[d]	4.78±0.03[e]
Pearl Millet + 4% garlic	0.71±0.04[bcd]	175.7±2.1[f]	4.17±0.01[c]
Pearl Millet + 2%ginger	0.68±0.02[cd]	181.5±2.1[c]	3.94±0.04[f]
Pearl Millet +4% ginger	0.72±0.03[bc]	171.3±6.4[g]	4.23±0.02[b]
Pearl Millet +2% garlic+2% ginger	0.87±0.02[a]	166.5±3.5[h]	4.24±0.03[b]
Pearl Millet +2% garlic+4% ginger	0.71±0.07[bcd]	186.7±1.4[a]	4.38±0.05[a]
Pearl Millet + 4 garlic+2% ginger	0.74±0.06[b]	177.3±5.6[e]	3.64±0.01[h]
Pearl Millet +4% garlic+4% ginger	0.89±0.03[a]	156±2.8[i]	4.08±0.08[d]
p-value	***	***	***

The results are means (±standard deviation) of three determinations. Means with different superscripts within the column are significantly different at $p< 0.0001$
Key:
BD = bulk density
WAC = water absorption capacity
SC = swelling capacity
*** = $p < 0.001$

Porridge properties
Table 3 presents the physicochemical properties of fermented porridge made from pearl millet, garlic, and ginger, as measured by pH, total titratable acidity (TTA), and specific gravity (SG). The pH, TTA and SG of the porridge samples ranged from 4.22-4.37, 0.35-0.80 and 76.5-76.9, respectively. The low pH values recorded for all the porridge samples suggest that the fermenting microorganisms produced lactic acid or other organic acids during fermentation (Adeyanju, Krugar, Taylor, & Duodu, 2019; Olaniran & Abiose, 2019). The pH and titratable acidity are well known to be inversely related, and so, the slight increase in pH values of some samples could be attributed to the decrease in total titritable acidity (Rehman et al., 2014). The increase in TTA of samples with garlic and/or ginger could be attributed to the potency antimicrobial activities of the spices (Yinusa, Malomo, & Fagbemi, 2022). In other words, high TTA levels of porridge samples can retard or inhibit the population or growth of non-aciduric microorganisms (Oluwasola et al., 2021). The decrease observed in the values recorded for the specific gravity of the porridge samples could be attributed to the reduction of grain matter for certain volumes despite an increase in moisture content.

Table 3: Porridge Properties of Co-Fermented Millets-Garlic and Ginger

Samples	Porridge Properties		
	pH	TTA	SG
Pearl Millet (Control)	4.29±0.06[abc]	0.30±0.14[bc]	76.5±0.1[d]
Pearl Millet +2% garlic	4.20±0.01[d]	0.35±0.07[bc]	76.8±0.3[ab]
Pearl Millet + 4% garlic	4.32±0.05[ab]	0.60±0.05[ab]	76.8±0.1[ab]
Pearl Millet + 2%ginger	4.37±0.02[a]	0.50±0.28[abc]	76.7±0.4[c]
Pearl Millet +4% ginger	4.31±0.06[ab]	0.50±0.14[abc]	76.5±0.2[d]
Pearl Millet +2% garlic+2% ginger	4.32±0.00[ab]	0.20±0.02[c]	76.9±0.3[ab]
Pearl Millet +2% garlic+4% ginger	4.22±0.01[cd]	0.20±0.03[c]	76.8±0.5[ab]
Pearl Millet + 4 garlic+2% ginger	4.25±0.04[bcd]	0.85±0.21[a]	76.9±0.1[a]
Pearl Millet +4% garlic+4% ginger	4.22±0.03[cd]	0.80±0.28[a]	76.7±0.08[c]
p-value	*	*	***

The values are means and standard deviation of three determinations. Means with same letter(s) within the column are not significantly different.

Key
TTA = Total titratable acidity
SG = Specific gravity
* = $p < 0.05$
*** = $p < 0.001$

Sensory Evaluation of Co-Fermented Millet-Garlic and Ginger Porridge
The sensory attributes including appearance, aroma, flavour, taste, mouth feel, aftertaste, residual taste, and overall acceptability of the co-fermented millet-garlic and ginger porridges are presented in Table 4. Samples co-fermented with the spices, whether individually or combined, had significantly ($p < 0.05$) higher scores compared to porridge without spices. However, porridge without spices (7.2) and that with 4% garlic (7.4) exhibited a higher overall acceptability compared to some of the porridges with added spices (ranging between 6.5 and 7.0). Generally, porridge with 4% garlic and 4% ginger received the highest overall acceptability score (7.9) among the samples, indicating it is the most preferred by the panellists, while the least was that with 2% garlic (6.5). This could be because the combined spices, each at 4%, provide a better aroma and flavour to the porridges compared to when they are added separately. This could be that the combined spices at 4% each impart a better aroma or flavour in the porridges making the porridges more acceptable to the panellists than the naturally fermented millet porridge. The improvement in the sensory attributes of the fermented millet could be attributed to the flavour compounds present in both garlic and ginger (Li et al., 2016). Porridge with a higher concentration of pure garlic (4%) recorded lower preference and was highly objectionable to the panellists. and this may account for its lower preference. Therefore, co-fermenting millet with spices such as garlic and ginger can improve the sensory quality of porridge. This statement agrees with some other previously documented reports on maize and sorghum gruels (Olaniran & Abiose, 2019; Adebowale & Adeyanju, 2022).

Table 4: Sensory Properties of Co-fermented Millet-Garlic and Ginger Porridges

Samples (Porridge)	Sensory Properties								Willingness-to-buy
	Colour	Taste	Aroma	Viscosity	Mouth feel	After taste	Residual Particle	Overall acceptability	
Pearl Millet (Control)	7.2±0.6[ab]	7.0±1.13	6.8±0.7[bc]	7.0±1.1[bc]	7.2±1.1[abc]	7.2±1.2[a]	6.9±1.0[b]	7.2±1.0[abc]	6.8±0.9[c]
Pearl Millet +2% garlic	6.6±0.8[b]	6.9±0.96	6.3±0.9[c]	6.6±0.8[c]	6.4±0.9[d]	6.4±0.9[b]	6.1±0.6[c]	6.5±0.7[d]	6.8±1.0[c]
Pearl Millet + 4% garlic	6.8±0.7[b]	7.2±0.94	6.7±0.7[bc]	6.7±0.7[c]	7.0±1.1[bcd]	6.9±0.8[ab]	6.7±0.9[bc]	7.4±0.9[abc]	7.2±0.5[abc]
Pearl Millet + 2%ginger	6.8±1.3[b]	7.1±1.25	6.8±1.1[bc]	6.8±0.8[bc]	6.8±1.1[bcd]	6.8±1.0[ab]	6.8±1.0[bc]	6.8±0.9[cd]	6.8±1.1[c]
Pearl Millet +4% ginger	7.0±1.2[ab]	7.0±1.16	6.8±0.9[bc]	6.8±1.2[bc]	7.0±1.0[bcd]	6.8±1.3[ab]	6.8±0.9[b]	7.0±0.8[bcd]	7.0±0.8[bc]
Pearl Millet +2% garlic+2% ginger	6.7±1.2[b]	7.0±1.13	6.3±0.9[c]	6.8±0.8[bc]	6.6±1.3[bcd]	6.7±1.2[ab]	7.0±1.0[ab]	7.0±1.4[bcd]	6.9±1.2[bc]
Pearl Millet +2% garlic+4% ginger	7.2±0.9[ab]	7.2±1.10	6.7±0.8[bc]	7.0±0.9[bc]	6.5±0.8[cd]	6.9±1.2[ab]	6.8±1.1[b]	6.8±1.0[cd]	7.0±1.0[abc]
Pearl Millet + 4 garlic+2% ginger	7.2±0.8[ab]	6.9±0.88	7.1±1.0[ab]	7.4±0.8[ab]	7.3±1.1[ab]	7.0±1.1[ab]	7.1±1.0[ab]	7.5±1.1[ab]	7.6±0.9[ab]
Pearl Millet +4% garlic+4% ginger	7.7±0.46[a]	7.4±0.91	7.6±0.9[a]	7.8±0.8[a]	7.9±0.4[a]	7.4±0.5[a]	7.6±0.8[a]	7.9±0.7[a]	7.7±0.7[a]
p-value	ns	ns	*	*	**	ns	*	***	*

The values are presented as mean and standard deviations of evaluation in two sessions using the same panellists. Mean values with the different superscripts are significantly different.
Key
ns = not significant
* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

CONCLUSION

Co-fermented millet grains with spices-garlic or ginger, separately or in combination were studied. The sample had an increase in bulk density and swelling capacity, while the water absorption capacity decreased. The resulting porridges from flour samples containing garlic or ginger have a lower pH, a higher total titratable acidity, and a higher specific gravity. Porridge aroma, viscosity, mouthfeel, aftertaste, and residual particles are significantly different. Intense garlic aroma is associated with porridges fermented with a larger amount of garlic alone, which led to porridge's lower preference by the panellists. Thus, porridge with a combined 4% garlic and 4% ginger had the highest overall acceptability score over other samples. A reduction in porridge viscosity, especially in samples co-fermented with garlic or ginger, was detected by the panellists. Low viscous porridge could be recommended as a meal for the elderly and the sick, as this could be swallowed easily and conveniently by the vulnerable group. Increasing food utilization of pearl millet and, garlic or ginger could enhance more value-added products, and promote food security and economic development.

REFERENCE

Adebowale, O.J., & Adeyanju, A.A. (2022). Evaluation of sorghum-Ogi gruel complemented with ginger and garlic powders. *Journal of Culinary Science and Technology*, 21(6), 922-931.

Adebowale, O.J., Taylor, J.R.N., & de Kock, H.L. (2020). Stabilization of wholegrain sorghum flour and consequent potential improvement of food product sensory quality by microwave treatment of the kernels. *LWT-Food Science and Technology*, *132*, 109827.

Adejobi, T.H., Olorunwusi, J.O., Adegbanke, O.R., Oguntoyinbo, O.O., & Enujiugba, V.N. (2024). Effect of ginger and garlic inclusion on the performance of *Lactobacillus plantarum* in maize (*Zea mays*) fermented Ogi. *IPS Journal of Applied Microbiology and Biotechnology*, *3*(1), 46-56.

Adeyanju, A. A., Krugar, J., Taylor, J. R. N., & Duodu, K. G. (2019). Effect of different souring methods on the protein quality and iron and zinc bioaccessibility of non-alcoholic beverages from sorghum and amaranth. *International Journal of Food Science and Technology*, *54*(3), 798–809.

Adisa, A. M., & Enujiugha, V. N. (2020). Microbiology and safety of ogi fermentation: a review. *European Journal of Nutrition and Food Safety*, *12*(5), 90-100.

AOAC. (2012). *Official methods of analysis of the Association of Official Analytical Chemists*. (20th Ed.). Washington D.C.

Bamidele, O.P., Adebowale, O.J., & Feng, X. (2023). Sensory perspective into indigenous fermented foods in the tropics: challenges and opportunities. *In: Indigenous Fermented Foods for the Tropics*. Pp. 483-502. doi: http://doi.org/10.1016/B978-0--323-98341-9.00023-2

Bamidele, O.P., Fasogbon, M.B., Oladiran, D.A., & Akande, E.O. (2015). Nutritional composition of fufu analogue flour produced from cassava root (*Manihot esculenta*) and cocoyam (*Colocasia esculenta*) tuber. *Food Science and Nutrition*, 3, 597–603.

Bamidele, O.P., Oladiran, D. A., Kayitesi, E., & Ogundele, O.M. (2020). Physicochemical, functional, and nutritional evaluation of wheat and cocoyam flour blends. *Journal of Food Processing and Preservation*, 44(2), e14923

Banwo, K., Oyeyipo, A., Mishra, L., Sarkar, D., & Sheltie, K. (2022). Improving phenolic bioactive–linked functional qualities of traditional cereal-based fermented food (Ogi) of Nigeria using compatible food synergies with underutilized edible plants. *Nigeria Food Journal*, 27, 1-12.

Bombom. A., Kawesi, T., Walugembe, F., Bhebhe, S., & Maphosa, M. (2023). Millets: Traditional "Poor Man's" crop or future smart nutria-cereals? In: Millets-rediscover ancient grains. *IntechOpen*. doi:http://dx.doi.org/10.5772/intechopen.110534

FAO (2022). The state of food security and nutrition in the world. Food and Agriculture Organization of the United Nations, Rome. Available from www.fao.org. Accessed on May 27, 2024. 11:52 am (WAT Zone)

Itaman, V. O., & Nwachukwu, E. (2021). Bacteriological and nutritional assessment of fermented maize (ogi) fortified with Ugba (*Pentaclethra macrophylla*). *Nigerian Journal of Microbiology*, *35*(2), 5906 – 5917

Jude-Ojei, B.S., Ajayi, I.O., & Ilemobayo, S. (2017).Functional and pasting properties of maize-Ogi supplemented with fermented moringa seeds. *Journal of Food Processing and Technology, 8*,674. doi:10.4172/2157-7110.1000674

Kaur, G., Ahmadzadeh-Hashemi, S., Amir, S., Khan, Z.S., Gulsunoglu-Konuskan, Z., Karimidastjerd, A. … Aijaz, T. (2024). From Millet to Marvels: An Improved Future Food through Innovative Processing. *Future Foods*, https://doi.org/10.1016/j.fufo.2024.100367

Ladunni, E., Aworh, O. C., Oyeyinka, S. A., & Oyeyinka, A. T. (2013). Effects of drying method on selected properties of Ogi (gruel) prepared from sorghum (*Sorghum vulgare*), millet (*Pennisetum glaucum*) and maize (*Zea mays*). *Journal of Food Processing and Technology,* 4, 248.

Li, J. L., Tu, Z. C., Zhang, L., Sha, X. M., Wang, H., Pang, J. J., & Tang, P.P. (2016). The effect of ginger and garlic addition during cooking on the volatile profile of grass carp soup. *Journal of Food Science and Technology*, *53*(8), 3253–3270.

Olaniran, A.F., Abiose, S.H., Adeniran, H.A., Gbadamosi, S.O., & Iranloye, Y.M. (2020). Production of a cereal based product (Ogi): Influence of co-fermentation with powdered garlic and ginger on the micro-biome. *Agro search*, *20*(1), 81-93.

Olaniran, A. F., Abiose, S. H., & Gbadamosi, S. O. (2019). Nutritional quality and acceptability evaluation of Ogi flour bio fortified with garlic and ginger. *Journal of Health Science*, *7*, 101–109

Olaniran, A.F., & Abiose, S.H. (2019). Nutritional evaluation of enhanced unsieved Ogi paste with garlic and ginger. *Preventive Nutrition and Food Science*, *24*(3), 348-356.

Oluwasola, E.I., Ahamd, A.I., Robinson, J.G., Arinola, S.O., & Balogun, O.S. (2021). Micronutrients profiles and nutraceuticals potential of developed instant zero "Zobo" blends for a diabetics. *Materials Today: Proceedings, 42*, 234-239

Ryu, J. H., & Kang, D. (2017). Physicochemical properties, biological activity, health benefits, and general limitations of aged black garlic: A review. *Molecules*, *22*(6), 919.

Shiqi, H., Mario, M. M., & Benjamin, M. B. (2019). The composition and functional attributes of commercial flours from tropical fruits (Breadfruit and Banana). *Foods,* 8 (11) 586.

Taylor, J.R.N., de Kock, H.L., Makule, E., Adebowale, O.J., Hamaker, B.R., & Milani, P. (2022). Opportunities and challenges for wholegrain staple foods in sub-Saharan Africa. *Journal of Cereal Science, 104*, 103438.

Yashvardhan, V., & Gupta, P. (2024). The forgotten grains – millets: A review. International *Journal of Environmental and Agriculture Research*, 10 (2), 5-26

Yinusa, M.A., Malomo, S.A., & Fagbemi, T.N. (2024). Storage

changes in antioxidants and qualities of single strength beverage produced from blends of Zobo (*Hibiscus sabdarriffa*), carrot, oranges and pineapples. *Journal of Culinary Science and Technology,*

doi: 10.1080/15428052.2022.2029658

INVITRO ANTIOXIDANT ACTIVITY OF THE DIFFERENT SOLVENT FRACTIONS OF CRUDE METHANOLIC EXTRACT OF *JUSTICIA CARNEA*

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ABSTRACT
The necessity to examine medicinal plants for phytochemicals and bioactivities has been brought to light by the recent increase in interest in using native medicinal plants to treat diseases. This study aimed to assess the free radical scavenging activity of various solvent fractions of Justicia. carnea, and to evaluate and quantify the phenolic (TPC) and flavonoid (TFC) content in various solvent fractions of the methanolic extract of J. carnea. The TPC was discovered to be high in methanolic and n-hexane fractions at $(31.28 \pm 0.020$ and 21.40 ± 0.020 mg GAE/g respectively) a similar trend was also observed in TFC with n-hexane and methanolic fractions having a highest concentration at $(18.30 \pm 0.015$ and 19.29 ± 0.023 mg QE/g). The result of the DPPH assay showed a concentration-dependent increase in activity across all fractions with the n-hexane faction displaying the highest activity at $80.21\pm0.025\%$, the aqueous, ethylacetate and methanol fraction had DPPH radical scavenging activity of 60, 68 and 61.67%, respectively. The FRAP assays showed that all fractions had a concentration-dependent increase in invitro antioxidant activity with the n-Hexane, aqueous, methanol and ethylacetate fractions displaying the highest activity to be 63.92%, 74.26, 57.61 and 65.20%, respectively. The activity observed can be attributed to the flavonoid content of the fractions. The findings from this study show that J. carnea is a viable medicinal alternative in preventing and treating diseases associated with oxidative stress.

Keywords: antioxidant, flavonoid, fractions, invitro

1.0 INTRODUCTION

Plants have since earliest times been a source of medicine for mankind especially in developing countries. They are a rich store of molecules with pharmaceutical potential. The search for bioactive compounds from natural sources continues to be a viable research area and has always been of great interest to researchers looking for new sources of drugs useful in various diseases. *J. carnea* is a plant in the family Acanthaceae. (Otuokere, Amaku, Igwe, & Chinedum, 2016) identified several bioactive compounds in the ethanol extract of *J. carnea* leaves, suggesting its pharmacological importance. (Anigboro, Avwioroko, Ohwokevwo, Pessu, & Tonukari, 2021; Oloruntola et al., 2022) established the proximate composition of *J. carnea* as well as outlining its phytochemical profile. The anti-diabetic properties of J.carnea were observed by (Ani, Udedi, Akpata, Onyishi, & Nwakudu, 2020) suggesting its role in reducing blood sugar levels. The anti-inflammatory and antioxidant properties of *J. carnea* leaf powder was reported by (Anigboro et al., 2021) and suggested that the *J. carnea* leaf powder may play a significant role in acting as an antioxidant. Traditionally *J. carnea* has been used to replenish blood levels in anaemic patients. Studies have also revealed it to contain high concentrations of elements necessary for healthy blood, with potential uses in improving food quality and as a treatment for blood conditions like anemia (Anthonia, Ikechukwu, Uzoma, & Sunday, 2019), this is particularly important for developing countries considering this disproportionately affects its populations, pregnant women, and cancer patients. These findings encourage more research into identifying the bioactive compounds that are present in different fractions of this plant. Consequently, the goal of the research was to evaluate the phytochemical content of each solvent fraction of the *J. carnea* extract as well as each fraction's antioxidant capacity in vitro.

2.0 METHODOLOGY

Plant Collection and Identification
The *J. carnea* leaves was obtained from Ilaro, Ogun, Nigeria. It was identified and authenticated at the University of Lagos, Lagos, Nigeria, and a specimen was put in the University Herbarium with a voucher number LUH: 10064

Preparation of crude methanolic extract
The fresh *J. carnea* leaves were carefully washed with water, air-dried and milled with an electric blender. 500 g of the milled plant was soaked in 2.5L Methanol and left to macerate for (72 h) following this a wine-coloured filtrate was filtered by the use of a muslin cloth, the filtrate was concentrated using a rotary evaporator and a water bath at 60 °C was used to obtain the extract termed *J. carnea* methanol extract (JCmE).

Fractionation
Separating funnel method: To commence the fermentation process, JCme is entirely dissolved or moistened with 250 mL of water. Following that, the material is transferred to a funnel for separation, shaken, and allowed to settle. In addition, 250 millilitres of n-hexane, the least polar solvent, were added and stirred. After the material had settled, the aqueous layer was removed by opening the bottom of the separating funnel. To extract the n-hexane fraction, the remaining material in the separating funnel was moved to a sterilized container. After adding the same amount of n-hexane again, shake well and separate. The addition was done until the top layer of n-hexane became transparent. A similar cycle was carried out with ethyl acetate. Since the crude extract was originally dissolved in water, the leftover portion after the fractionation was known as the aqueous fraction.

Qualitative Phytochemicals Analysis
Using standard laboratory procedures described by (Sofowora, 1996) the phytochemical analysis was carried out for qualitative assessment. Phenols, saponins, flavonoids, alkaloids, tannins, cyanogenic glycosides, and sterols are among the phytochemicals examined.

Phenol Analysis: methanol 20 millimetres was used to extract 2 milligrams of the material, which was filtered using filter paper. To One milliliter the filtrate was added one milliliter of 20% $NaCO_3$ and one milliliter of Folin-Clarkeon; the presence of phenol is shown by the dark blue color.

Alkaloids: 2ml of Wagner's reagent was combined with the extract, a reddish-brown precipitate formed, which suggested that alkaloids was present.

Cyanogenic Glycosides: Fehling's Test: 3 ml of the filtrate was combined with 5ml of Fehling's solution I and II in equal amounts, and the mixture was heated for 5 minutes. Glycoside presence was confirmed by a thicker brick red precipitate.

Saponins: To determine whether saponins were present, a foam test was conducted. After adding 6 ml of water to the 2 ml of extract in a test tube and giving it a good shake, the presence of saponins was confirmed by looking for the production of a persistent foam.

Flavonoids: Testing for the presence of flavonoids was done using an alkaline reagent assay. The extracts were combined with 2 millilitres of a 2% NaOH solution. The presence of flavonoids was revealed by the formation of a bright yellow hue that went colourless

and colourless upon the addition of a few drops of diluted acid H_2SO_4.

Tannins: A quantity of 5g was heated to a boil in 40 ml of water, filtered, and utilized for the ferric chloride examination. Ferric Chloride Test: A small amount of ferric chloride solution was added to around 3millilitress of the filtrate. The presence of tannin is indicated by a greenish-black precipitate.

Sterols: Salkowski test: A few drops of strong sulfuric acid were added to the test samples in chloroform, and sterols were detected by the appearance of red colour in the lower layer.

Determination of Flavonoid
Distilled water 1ml was used to dissolve about 0.25 g of the extract. Next, 5% $NaNO_2$ solution, 0.150 ml of freshly made ($AlCl_3$), and 1 M NaOH solutions were added. After letting the mixture remain for five minutes, a spectrophotometer measured the absorbance at 510 nm. The outcome was given as equivalents of quercetin (QE) (Seifu, Mehari, Atlabachew, & Chandravanshi, 2017).

Determination of Total Phenol
The folin-Ciocalteu technique (Singleton, Orthofer, & Lamuela-Raventós, 1999) was used to determine this. To 125 µl of the extract, Folin-Ciocalteu's reagent and distilled water was added. The 7% sodium carbonate solution was added after the mixture had stood for six minutes. The combination was let to stand for ninety minutes. At a wavelength of 760nm the absorbance of the mixture was measured and the result was expressed in gallic acid equivalents (GAE).

DPPH radical scavenging assay
The method outlined was used to determine the hydrogen-donating or the investigated plant extracts' capacity to scavenge radicals, with ascorbic acid serving as a positive control (Baliyan et al., 2022). At 517 nm, the reaction mixture's color shift was seen. In summary, 2.5 ml of different sample concentrations and standard ascorbic acid were combined with a 1 ml aliquot of an ethanolic solution containing 0.3 mM DPPH. For 30 minutes the mixture was left in the dark after incubation, at which point the absorbance at 517 nm was measured. The blank used was ethanol. As a negative control, DPPH solution (1 ml, 0.3 mM) plus ethanol (2.5 ml) are used. The

Result and Discussion

degree to which the tested extract decolourized DPPH from purple to yellow indicated how effective it was in scavenging. Three test runs (n = 3) were conducted, and average values were determined. Using the following formula, It was calculated what proportion of the radical scavenging activity was suppressed.

$$\frac{Abs\ control - Abs\ sample}{Abs\ control} \times 100 = DPPH\ radical\ scavenging\ activity\ (\%)$$

Abs sample = Absorbance of DPPH radical + sample or standard,
Abs control = Absorbance of DPPH radicals + methanol.

Ferric Reducing Antioxidant Power (FRAP) Assay
In this method, the antioxidant ability in the extract is confirmed by measuring its reducing power. Depending on the reducing power of each molecule used in this assay, the test solution's yellow color changes to different colours of green and blue. The plant extract under test was found to have a Fe^{3+} reducing power using the approach described by (Hazra, Biswas, & Mandal, 2008). After mixing 0.5 ml of phosphate buffer (pH 6.6) and 0.5 ml of 0.1% potassium hexacyanoferrate [$K_3Fe\ (CN)_6$] with standard ascorbic acid in various concentrations (100, 200, 300, 400, and 500 µg/ml), the mixture was incubated for 20 minutes at 50°C in a water bath. 0.5 ml of 10% TCA was used to stop the reaction after incubation. A 0.1 ml solution containing 0.01% FeCl3 was included to the upper part of the solution (1 ml), which had already been combined with 1 ml of distilled water. After allowing the reaction mixture to sit at room temperature for 10 minutes, the absorbance at 700 nm was measured in comparison to the suitable blank solution. Three duplicates of each test were run (n = 3). A positive control was ascorbic acid. A blank solution made of phosphate buffer (PH 6.6) was utilized.

Statistical Analysis
GraphPad Prism 6 was used to analyze duplicate data, and results were given as mean ± SD. Invitro Antioxidant data was presented as percentage activity.

Table 1: Phytochemical distribution in the different fraction of *J. carnea*.

Phytochemicals	Aqueous JCE	Methanol JCE	Ethyl acetate JCE	n-Hexane JCE
Phenol	++	+++	+	++
Saponin	++	+	++	+
Tannin	+++	+++	+	++
Flavonoid	+	++	++	+++
Alkaloids	+	+	-	++
Cyanogenic Glycosides	-	+	-	+
Sterols	-	+	-	-

-    = Absent
+ = Low ++ = Moderate +++ = High

Table 2: Total Phenolics and Total Flavonoids content of different fraction of *J. carnea*.

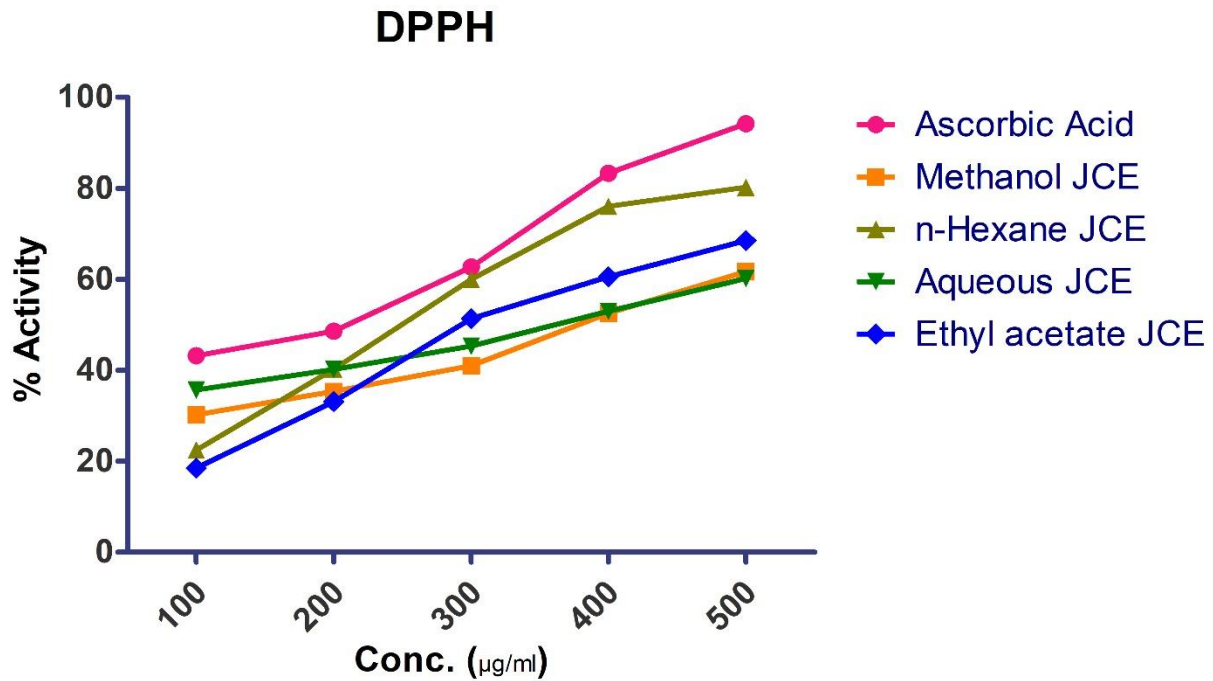|	Residual Aqueous JCE	Crude Methanol JCE	Ethyl acetate JCE	n-Hexane JCE
Total Phenolics (mg GAE/g)	20.86 ± 0.019	31.28 ± 0.020	10.19 ± 0.133	21.40 ± 0.020
Total Flavonoids (mg QE/g)	9.55 ± 0.032	18.30 ± 0.015	11.32 ± 0.032	19.29 ± 0.023

Fig 1: Showing the % DPPH Activity of the different fraction of *J. carnea*.
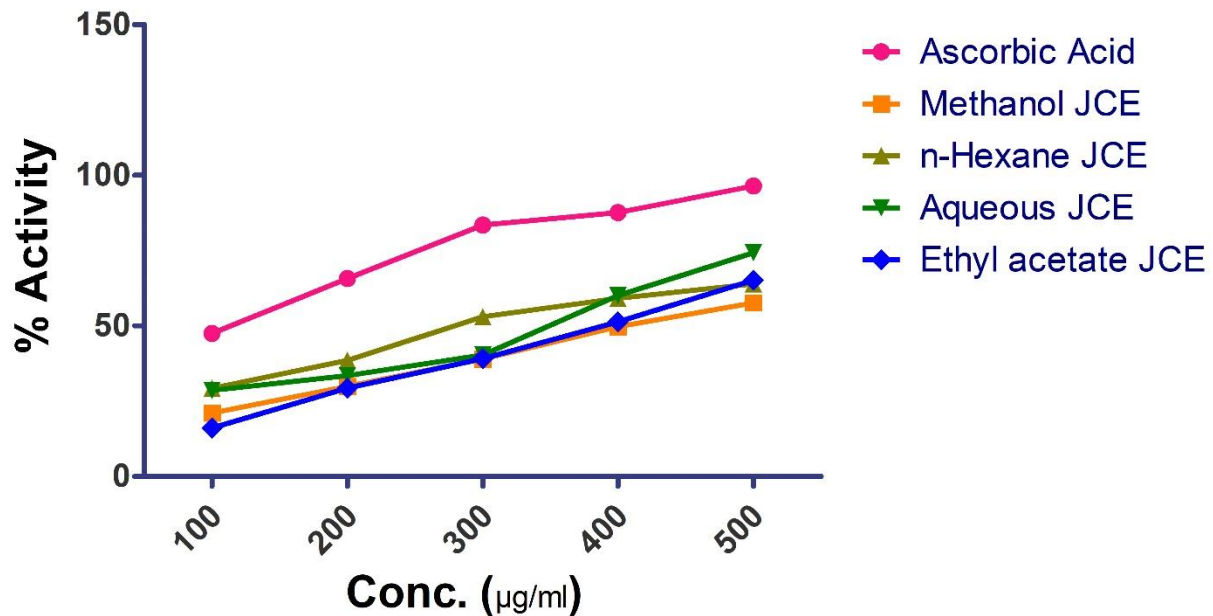

Fig 2: Showing the % FRAP Activity of the different fractions of *J. carnea*.

3.0 DISCUSSION

Numerous plants have demonstrated a variety of health advantages, notably green vegetables, which have been shown to promote excellent health and wellness due to the presence of phytochemicals. Phytochemicals have a wide range of activities which help the immune system fight against diseases and their abundance in a plant could be a pointer to its pharmacological activity (Yadav, Khare, & Singhal, 2017). This may also contribute significantly to the antioxidant capacity. The phytochemical analysis of the methanolic extract of *J. carnea* and its fractions of n-hexane, ethyl acetate and the residual aqueous fraction showed that phenol, flavonoid, saponin, tannins, alkaloids were present in the crude methanol fraction which agrees with research carried out by (Ajuru, Kpekot, Robinson, & Amutadi, 2022). These compounds have been observed to have various pharmacological activities. Saponins have been established to have antifungal, cytotoxic, bacterial, and antiviral activities (Kregiel et al., 2017), tannins can also act as an antioxidant with free radical scavenging activity, antibacterial, anti-cancer, and

cardio-protective qualities (Smeriglio, Barreca, Bellocco, & Trombetta, 2017). The total phenolic and total flavonoid content showed that the crude methanolic JCE and n-Hexane fraction of JCE had the highest phenolic content with 31.28 ± 0.020 and 21.40 ± 0.020 respectively, this agrees with the work by (Mehmood, Javid, Khan, Ahmad, & Mustafa, 2022) their report showed that methanolic fraction of some selected medicinal plants all had total phenolic and total flavonoid rich methanolic fraction. Flavonoids are polyphenolic chemicals with pharmacological effects such as antioxidative, hepatoprotective, antibacterial, anti-inflammatory, anticancer, and possible antiviral activities, in addition to their well-known antioxidant activity (Kumar & Pandey, 2013). n-Hexane fraction had the most flavonoid content at 19.29 ± 0.023, the residual Aqueous JCE had the lowest flavonoid concentration at 9.55 ± 0.032.

In vitro antioxidant activity may be measured using a variety of techniques, including FRAP and DPPH tests. The DPPH radical scavenging test, which is commonly used to assess a compound's capacity to operate as a hydrogen source and free-radical scavenger, is quick, simple, and affordable for determining antioxidant capabilities. The DPPH test is based on the elimination of DPPH, a stabilized free radical (Baliyan et al., 2022). Fig 1 shows the % scavenging activity of the different fractions of *J. carnea* equated with the standard. The result shows that all fractions showed a concentration-dependent increase in activity with the n-Hexane fraction displaying the highest activity at $80.21\% \pm 0.015$. The n-Hexane activity can be attributed to the rich flavonoid content of the fraction (Mehmood et al., 2022). Free radicals have been linked to several illnesses, including cancer, diabetes, and neurological disorders. Antioxidant-rich plant sources continue to be a source of free radical prevention, and the antioxidant activity reported in different fractions of *J. carnea* suggests that it may have medicinal value as a chemopreventive.

CONCLUSION
In the present study, several fractions of *J. carnea*'s methanol crude extract were analysed to assess phenolic and flavonoid content, as well as antioxidant potential. Our data indicate that the methanol and n-hexane fractions of *J. carnea* are high in TPC, and hence have strong antioxidant activity, implying that the bioactive component contained in *J. carnea* may be in the n-hexane and methanol fractions. Further fractionation might be performed on the fraction to isolate the bioactive component. In vivo, investigations on the anti-cancer and cardioprotective properties of *J. cornea's* n-hexane fraction can be conducted to broaden its biological uses.

REFERENCES

Ani, O. N., Udedi, S. C., Akpata, E. I., Onyishi, C. K., & Nwakudu, E. N. (2020). Effects of Ethanol Leaf Extract of Justicia Carnea on Biochemical Indices of Alloxan-Induced Diabetic Rats. *IOSR Journal of Biotechnology and Biochemistry (IOSR-JBB)*, *6*(2), 39–46. https://doi.org/10.9790/264X-0602013946

Anigboro, A. A., Avwioroko, O. J., Ohwokevwo, O. A., Pessu, B., & Tonukari, N. J. (2021). Phytochemical profile, antioxidant, α-amylase inhibition, binding interaction and docking studies of Justicia carnea bioactive compounds with α-amylase. *Biophysical Chemistry*, *269*, 106529. https://doi.org/https://doi.org/10.1016/j.bpc.2020.106529

Anthonia, O. C., Ikechukwu, U. R., Uzoma, N. O., & Sunday, E. L. U. (2019). Nutritive properties of aqueous extract Justicia carnea leaves and its effects on haematological and some biochemical indices of anaemia induced male wistar albino rats. *Biomedical Research*. Retrieved from https://api.semanticscholar.org/CorpusID:199027983

Baliyan, S., Mukherjee, R., Priyadarshini, A., Vibhuti, A., Gupta, A., Pandey, R. P., & Chang, C.-M. (2022). Determination of Antioxidants by DPPH Radical Scavenging Activity and Quantitative Phytochemical Analysis of Ficus religiosa.

Molecules (Basel, Switzerland), *27*(4). https://doi.org/10.3390/molecules27041326

Gospel Ajuru, M., Anthony Kpekot, K., Ewauma Robinson, G., & Chioma Amutadi, M. (2022). Proximate and Phytochemical Analysis of the Leaves of Justicia carnea Lindi. and Justicia secunda Vahl and its Taxonomic Implications. *Journal of Biomedicine and Biosensors*, *2*(1), 1–12. Retrieved from https://gpub.org/journal/jbb

Hazra, B., Biswas, S., & Mandal, N. (2008). Antioxidant and free radical scavenging activity of Spondias pinnata. *BMC Complementary and Alternative Medicine*, *8*, 63. https://doi.org/10.1186/1472-6882-8-63

Kregiel, D., Berlowska, J., Witonska, I., Antolak, H., Proestos, C., Babic, M., … Zhang, B. (2017). Saponin-Based, Biological-Active Surfactants from Plants. In R. Najjar (Ed.), *Application and Characterization of Surfactants*. Rijeka: IntechOpen. https://doi.org/10.5772/68062

Kumar, S., & Pandey, A. K. (2013). Chemistry and biological activities of flavonoids: an overview. *TheScientificWorldJournal*, *2013*, 162750. https://doi.org/10.1155/2013/162750

Mehmood, A., Javid, S., Khan, M. F., Ahmad, K. S., & Mustafa, A. (2022). In vitro total phenolics, total flavonoids, antioxidant and antibacterial activities of selected medicinal plants using different solvent systems. *BMC Chemistry*, *16*(1), 1–10. https://doi.org/10.1186/s13065-022-00858-2

Oloruntola, O. D., Ayodele, S. O., Adeyeye, S. A., Fasuhami, O. S., Osowe, C. O., & Ganiyu, T. O. (2022). Proximate Composition, Phytochemical Profile, Antioxidant, Antidiabetic and Anti-inflammatory Properties of Justicia carnea Leaf Powder. *Black Sea Journal of Agriculture*. Retrieved from https://api.semanticscholar.org/CorpusID:252083337

Otuokere, I. E., Amaku, A., Igwe, K. K., & Chinedum, G. C. (2016). *Medicinal Studies on the Phytochemical Constituents of Justicia carnea by GC-MS Analysis*. Retrieved from https://api.semanticscholar.org/CorpusID:208781284

Seifu, T., Mehari, B., Atlabachew, M., & Chandravanshi, B. (2017). Polyphenolic content and antioxidant activity of leaves of Urtica simensis grown in Ethiopia. *Latin American Applied Research*, *47*(1), 35–40.

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Methods in Enzymology - Oxidants and Antioxidants Part A. *Methods in Enzymology*, *299*, 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1

Smeriglio, A., Barreca, D., Bellocco, E., & Trombetta, D. (2017). Proanthocyanidins and hydrolysable tannins: occurrence, dietary intake and pharmacological effects. *British Journal of Pharmacology*, *174*(11), 1244–1262. https://doi.org/10.1111/bph.13630

Sofowora, A. (1996). Research on medicinal plants and traditional medicine in Africa. *The Journal of Alternative and Complementary Medicine*, *2*(3), 365–372.

Yadav, R., Khare, R. K., & Singhal, A. (2017). Qualitative Phytochemical Screening of Some Selected Medicinal Plants of Shivpuri District. *International Journal of Life Sciences Scientific Research*, *3*(1), 844–847. https://doi.org/10.21276/ijlssr.2017.3.1.16

ANTICORROSION ACTIVITY OF *LAUNAEA TARAXACIFOLIA* LEAVES ON MILD STEEL IN ACID MEDIUM

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ABSTRACT

The effectiveness of *Launaea taraxacifolia* leaf extract (LTLE), ethanol leaf extract as a green anti-corrosive inhibiting agent for mild steel corrosion in 0.5 mol/dm^3 HCl was investigated using the gravimetric techniques at temperatures ranging from 303 to 333 K. The results demonstrated LTLE's ability to inhibit corrosion in acidic conditions, with higher inhibition efficiency (95.41%) observed at lower temperatures (303K) and higher extract concentrations (5% v/v). For instance, even at a 5% v/v concentration, inhibition rates reached approximately 95.41 % at 303 K and 85.76 % at 333 K. Thermodynamic parameters, including ΔG_{ads}, were determined using the Langmuir adsorption isotherm, confirming a monolayer adsorption of the inhibiting agent on the mild steel surface. The ethanol extract of *L. taraxacifolia* leaves proved to be an effective anti-corrosive inhibiting agent due to its composition rich in essential oils, steroids, triterpenes, and a variety of complex flavonoids, chalcones, and flavones.

Keywords: *Launaea taraxacifolia,* Inhibiting agent, acidic conditions, Corrosion, Mild steel

1.0 INTRODUCTION

Corrosion is the process where a material placed in a specific environment undergoes degradation, which may involve chemical or electrochemical factors and may or may not be coupled with mechanical stresses. In metals, this degradation is linked to their tendency to revert from the natural state of lower internal energy (El-Hajjaji, et al., 2019; Olasunkanmi & Ebenso, 2020). This reversion can lead to the formation of corrosion products, weakening the material's structural integrity and potentially compromising its functionality over time (Dahmani et al., 2021; Olasunkanmi & Ebenso, 2020). Notably, metals and their alloys are highly susceptible to this phenomenon. An example is mild steel, widely employed in various sectors and recognized as one of the most extensively manufactured materials globally (Mo, Luo & Li, 2017; Dahmani et al., 2021). Several methods are used to remove rusting and imperfections of the outermost layer of mild steel (MS), but the most common one is acid washing (Obot, Umoren & Obi-Egbedi, 2011; Lgaz et al., 2019; Mo et al., 2017). Putting mechanisms in place to slow down the rate at which metal dissolves is essential. Among the methods that have been suggested for this purpose are anodic and cathodic protection, corrosion preventatives, and anti-corrosion coatings (Leili & Mohammad, 2018; Mobin, Basik & Shoeb, 2019). In combating corrosion, anti-corrosion agents emerge as a particularly promising approach. These agents are designed to inhibit or slow down the corrosion process by interfering with the chemical or electrochemical reactions that lead to material degradation. They can be applied through various methods such as coatings, and inhibitors added directly to the environment or integrated into the material's composition during manufacturing.

For example, anti-corrosion coatings prevent damage from direct contact and slow down the pace of corrosion by forming a layer of protection between the material and an acidic environment. Conversely, inhibitors function by changing the material's or the corrosive medium's electrochemical characteristics, which lessens the possibility that corrosive reactions will occur.

The effectiveness of anti-corrosion agents is subject to the type of material, the nature of the environment, and the specific mechanisms driving corrosion in that environment. Anti-corrosion includes the development of advanced coatings, environmentally friendly inhibitors, and smart materials capable of self-healing or self-monitoring corrosion. By leveraging anti-corrosion agents, industries can prolong the lifespan of materials, reduce maintenance costs, improve safety, and enhance the overall performance of equipment and structures operating in corrosive environments. To choose an appropriate anti-corrosive inhibiting agent three key parameters must be considered: cost-effectiveness, sustainability, binding efficiency, and shielding proficiency (Palanisamy et al., 2018; El-Hajjaji et al., 2019). Inhibitors that effectively sequester heteroatoms such as P, S, and N, along with multiple bonds in their molecules, hold considerable significance in their binding to the mild steel surface

of the anti-corrosive group, including charge concentration at donor atom, conformational flexibility, solubility, the electron arrangement and so on (Prabakaran et al., 2016; Peimani and Nasr-Esfahani, 2018).

Despite the commendable anticorrosive prowess exhibited by numerous synthetic compounds, a significant drawback surfaces many of them pose elevated toxicity perils to both human safety and ecosystem stability (Prabakaran et al., 2016; Mo et al., 2017; Verma, Olasunkanmi & Ebenso, 2018). This realization has led to constraints on the utilization of chemical inhibitors, primarily propelled by increasingly stringent environmental regulations (Obot & Obi-Egbedi, 2009; Lebrini, Robert & Roos, 2010). The potential to induce transient or irreversible impairment to organ systems, particularly impacting the liver or heart, and interference with biochemical processes or enzyme systems during both the synthesis and application of these compounds, underscores the toxicity concerns (Saleh, Mahmoud & Abd El-Lateef, 2019; Shrestha et al., 2019). Consequently, a heightened awareness of the hazardous effects linked to synthetic corrosion inhibitors has catalyzed a shift toward investigating natural products as promising alternatives for corrosion inhibition (Alibakhshi et al., 2018; Tamalmani & Husin 2020). Synthetic corrosion inhibitor refers to a chemically engineered compound utilized to shield metals against rusting. Its mechanism requires the formation of a protective barrier on the mild steel surface.

More environmentally friendly anti-corrosion agents have recently surfaced as substitutes for conventional hazardous corrosion-inhibiting agents (Prabakaran et al., 2016; Alibakhshi et al., 2018). Plant-based extracts are generally inexpensive, biocompatible, and biodegradable; they are extracted from leaves, fruits, and seeds (Alibakhshi et al., 2018; Tamalmani and Husin 2020). These extracts are likely to exhibit robust corrosion inhibition properties, especially when it comes to protecting metal surfaces in acidic environments because they contain donor electron components including heteroatoms and aromatic groups (Saleh et al., 2019; Singh et al., 2020)

Launaea taraxacifolia, also called "African lettuce" or "wild lettuce," serves diverse purposes. It is a common leafy vegetable in specific African areas, offering nutritional benefits. In traditional medicine, certain plant parts are utilised for potential healing properties, addressing concerns like digestive issues and skin conditions. In this study, our objective was to assess the inhibitory effectiveness of LTL extract in mitigating corrosion for MS immersed in a 0.5mol/dm^{3}HCl medium. Electrochemical techniques, including EIS and polarization, were utilised to examine the rust-inhibiting features of this compound (*L. taraxacifolia*).

2.0 MATERIALS AND METHODS

Collection and Preparation of Plant Extract

L. taraxacifolia, leaves were collected from the botanical garden of the Department of Science Laboratory Technology, Federal Polytechnic Ilaro, Ogun State. After cleaning with distilled water, the leaves were dried at room temperature and subsequently powdered. To make the extract, 500 ml of absolute ethanol was added to the 20g powdered *L. taraxacifolia,* leaves, and the mixture was permitted to stand unaltered for 48 hrs., the mixture was sieved through Whatman filter paper. The liquid obtained was concentrated using a rotary evaporator. (Prabakaran et al., 2016; Leili Rassoulia, Mohammad-Mahdavain, 2018; Benahmed, et al., 2020).

Preparation of Mild Coupon

The study utilised distinctive mild steel coupon specimens with the following composition: Carbon = 0.01 %, manganese = 0.34 %, phosphorus = 0.08 %, and iron = 99.51 %. The mild steel coupons, measuring $15 \times 15 \times 2$ mm, underwent degreasing in absolute ethanol, rinsing in distilled water, and rapid drying in acetone before being stored in a desiccator for further use.

Sample Preparation

Mild steel plates acted as the operative electrode. A solution of 0.5 mol/dm³ HCl was prepared by diluting hydrochloric acid with distilled water. Various grades of silicone carbide paper (400 - 1000) were employed to eliminate surface scales, followed by cleaning with analytical-grade acetone. Subsequently, different concentrations of *L. taraxacifolia,* leaves extract (0, 1, 2, 3, 4 and 5 %v/v) were readied for weight loss measurements, considering the solubility of LT LE.

Weight loss Experiment

Weight loss assessments were conducted in a temperature-controlled water bath at 303–333 K utilizing 500 ml glass beakers filled with 250 ml of 0.5 mol/dm³ HCl solution. The analyses were done under complete immersion. With the use of a rod and hook, the mild steel coupons were weighed and suspended in the beaker. The coupons were gradually extracted every one-hour interval for five hours at 303 - 333 K. They were then extensively cleaned with a bristle brush in distilled water, dehydrated in acetone, and weighed again Prabakaran et al., 2016; Mo et al., 2017; Verma et al., 2018). The variations between the overall weight of the mild steel coupons before and afterwards submerged in various test solutions were calculated employing an electronic weighting device to measure the weight loss, expressed in grammes. The tests were carried out again at various temperatures. To achieve high reproducibility, duplicate experiments were conducted. The current study's parallel triple experiment standard deviation values were determined to be less than 6 %, showing a high degree of reliability. The corrosion rate (C_R) in g/cm²/h was determined using equation 1. (Verma et al., 2018; Benahmed et al., 2020):

$$CR = \frac{\Delta W}{At} \dots\dots\dots\dots \text{Eqn. (1)}$$

A denotes the total area of a single mild steel specimen, t represents the duration of immersion, and W indicates the average weight loss of three mild steel sheets. After calculating the corrosion rate, the inhibition efficiency (%I) was then assessed using Equation 2. (Verma et al., 2018; El-Hajjaji et al., 2019):

$$\eta = \frac{Cr(ab) - Cr(pr)}{Cr(ab)} \times 100 \dots\dots\dots\text{Eqn. (2)}$$

Where Cr (ab) represents the corrosion rate of the mild steel coupons in the absence of *L. taraxacifolia*, and Cr (pr) represents the corrosion rate in its presence.

3.0 RESULTS AND DISCUSSION

The most widely used technique for assessing inhibition is the gravimetric (weight loss) approach (Verma et al., 2018; Feng, Yang & Wang, 2011). The weight loss method's measurement is so straightforward and dependable that it is

frequently used as the standard approach in corrosion monitoring programmes (Verma et al., 2018; Olasunkanmi & Ebenso, 2020). The weight loss method shows a similar agreement with other widely recognized corrosion monitoring techniques., including the polarisation technique (Qiang, Li & Lan, 2020), electrochemical impedance spectroscopy (Varshney, Chen & Li, 2012), gasometric (Singh et al., 2020), thermometric (Zang, Pang & Gao, 2019), and atomic absorption spectroscopy (Tan et al., 2018), has been documented by several researchers.
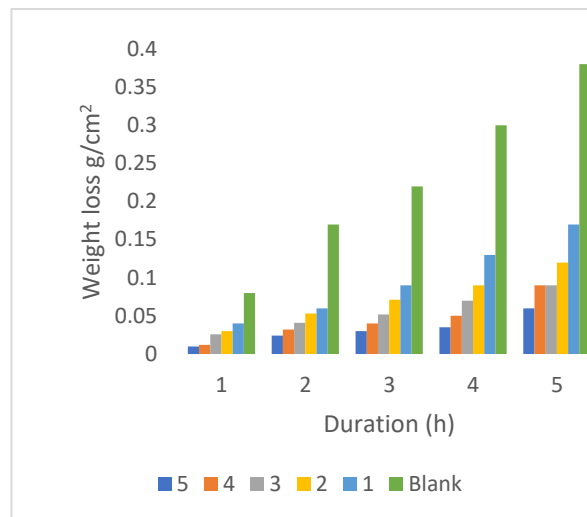

Figure 1. Impact of contact duration on weight loss of mild steel in 0.5 mol/dm³ HCl at 303 K
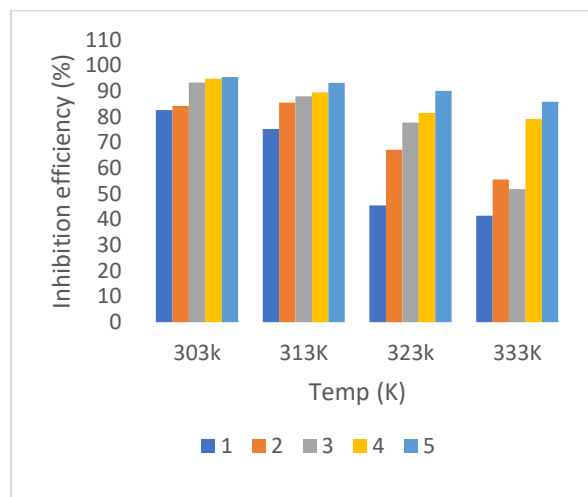

Figure 2. Changes in inhibition efficiency with varying concentrations at varying temperatures.
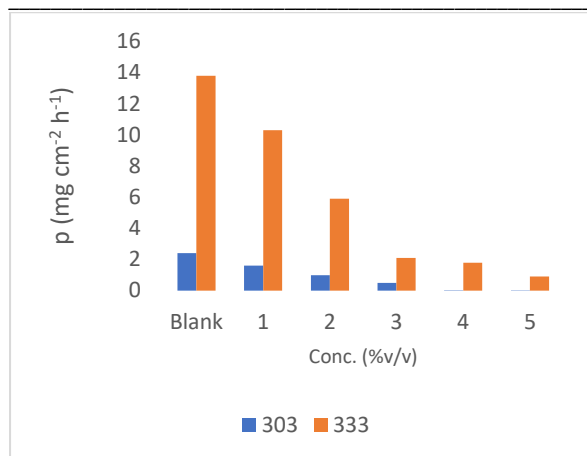
Figure 3. The change in corrosion rate with different concentrations of the inhibiting agent for mild steel in 0.5 mol/dm^3 HCl with *L. taraxacifolia* at temperatures of 303 K and 333 K.

The weight loss method is significant in corrosion studies because it provides direct and tangible evidence of material degradation due to corrosion. By measuring the weight loss of a material over time, researchers can quantify the extent of corrosion and evaluate the effectiveness of corrosion inhibitors or protective coatings (Verma et al., 2018; Shahini, Ramezanzadeh & Ramezanzadeh, 2020). Figure 1 shows the findings from weight loss evaluations regarding the corrosion tendencies of mild steel in a 0.5 mol/dm^3 HCl solution infused with *L. taraxacifolia* across the concentration span of 1% to 5% v/v. Additionally, Figure 2 illustrates the corrosion rate and inhibition effectiveness for mild steel in 0.5 mol/dm^3 HCl, plotted against extract concentration at temperatures of 303 and 333 K. Since there is an overall reduction in the mild steel corrosion rates upon completion of the corrosion monitoring process, these results demonstrate that the tested extract prevents the corrosion of mild steel in 0.5 mol/dm^3 HCl at all concentrations of LTLE utilized in this research. The corrosion-inhibitory impact rises as LTLE concentration rises, demonstrating that the concentration of LTLE in the corroding medium affects the inhibition mechanism (Mo et al., 2017; Verma et al., 2018; Shahini, Ramezanzadeh & Ramezanzadeh, 2020).

According to an analysis of the results, the corrosion rates increased as the temperature rose in the acid (0.5 mol/dm^3 HCl) conditions with and without LTLE. Additionally, a decrease in inhibitory capacity was observed as temperature increased, which suggested that the quantity of material loss was also shown to be dependent on the LTLE by preventing mild steel from corroding in HCl. Figure 3 illustrates the plot of inhibition effectiveness with LTLE concentration for mild steel in 0.5 mol/dm^3 HCl. It shows that inhibition effectiveness increases as extract concentration rises, attaining a maximum value of 95.41 and 85.76% at 303 and 333 K, respectively. The binding and adsorption of the LTLE components onto the steel surface are responsible for the inhibitive activity of LTLE towards the corrosion of mild steel. Initial corrosion inhibition is caused by the adsorbed water molecules being displaced by the type of inhibitor that causes particular adsorption on the metal surface (Varshney, Chen & Li, 2012; Tan et al., 2018). According to reports, *L. taraxacifolia* contains several significant chemical components, including steroids, tannins, alkaloids, and carbohydrates (Prabakaran et al., 2016; Mo et al., 2017; Tan et al., 2018); essential oils, triterpenes, and a variety of complex flavonoids, chalcones, and flavones (Adinortey et al., 2018).

These biochemical molecules are heterogeneous organic compounds that have molecular structures that include nitrogen, oxygen, sulphur, as well as aromatic rings. It has been observed that these elements present in organic heterogeneous compounds contribute to the inhibition of mild steel (Shahini, Ramezanzadeh & Ramezanzadeh, 2020). The suppression of the corrosion

reaction is therefore thought to be primarily brought about by the adsorption of these chemicals on the mild steel surface. Nonetheless, the extract's remarkable inhibitory efficacy might be attributed to the interactions between its phytochemical constituents (Tan et al., 2018; Shrestha, et al., 2019; Olasunkanmi & Ebenso, 2020). It is also evident from Fig. 1 that as temperature rises, inhibition strength decreases. This phenomenon can be elucidated by the physical adsorption of phytochemical molecules onto the mild steel surface, which causes some of the adsorbed phytochemical molecules to desorb from the surface of steel when the temperature increases. However, the interactions among its phytochemical ingredients may account for the extract's exceptional inhibitory activity.

Immersion Time

Using the duration of immersion is vital in corrosion inhibition investigations because it affects how the inhibitor interacts with the mild steel surface over time (Thamaraiselvan, Michael & Oren, 2018; Tan et al., 2019; Olasunkanmi & Ebenso, 2020). In a gravimetric approach, we studied the corrosion response of mild steel in 0.5 mol/dm^3 HCl with and without LTLE across durations ranging from 1 to 5 hours. The goal was to ascertain the impact of immersion duration on the corrosion inhibition impact of LTLE. Figure 1 presents the acquired results. The plot shows that, in the presence and absence of low and high concentrations of LTLE (1 - 5 %v/v) in an acidic medium (0.5 mol/dm^3 HCl) solution, the corrosion rate intensified with prolonged immersion periods. The development of a protective coating on the mild steel surface, which is dependent on time, is responsible for the increase in inhibitory efficiency observed in HCl solution over prolonged immersion times (Verma et al., 2018; Tan et al., 2018; Olasunkanmi & Ebenso, 2020). Prolonged immersion times in inhibitor solutions often lead to the establishment of persistent, two-dimensional films of inhibitor molecules on metal surfaces. This phenomenon, observed and discussed by Tan et al. in 2019, is crucial in understanding the behaviour of corrosion inhibition over extended periods. According to Olasunkanmi and Ebenso, (2020), the decline in inhibitory efficacy during lengthy immersion times can be attributed to several factors. Firstly, the barrier formed by the inhibitor molecules may become unstable over time. This instability could result from the desorption of certain constituents of the inhibitor, weakening the defensive barrier on the mild steel surface. Additionally, the diffusion process passing through the interface protective layer may contribute to its degradation, allowing corrosive agents to reach the mild steel surface more easily.

Adsorption Process

The prevailing opinion in the existing research on corrosion inhibition is that adsorption onto the metal surface is the first stage of an inhibitor's activity in acidic conditions (El-Hajjaji et al., 2019; Olasunkanmi & Ebenso, 2020; Benahmed, et al., 2020). This is predicated on the idea that corrosion reactions are stopped from happening across the portion of the metal surface where inhibitor molecules had been adsorbed, while the inhibitor-free region saw typical corrosion responses (Zahra Sanaei et al., 2019; Singh et al., 2020; Benahmed, et al., 2020). The degree of surface covering (θ) is crucial in elucidating the mechanism of adsorption. Its value was calculated from the weight loss measurements for various LTLE concentrations at the temperatures (303, 313, 323 and 333 K) under investigation. η% = θ × 100 (presuming a direct correlation between inhibition efficacy and surface coverage) and thereafter hypothetically fitted to various adsorption isotherms. The best-matched isotherm was identified using the correlation coefficient (R^2) value (Zhang et al., 2020; Vorobyova & Skiba, 2021). Using the Langmuir adsorption isotherm model, the best outcome was achieved. The graphical representation of C/θ against C is displayed in Figure 4. Linear graphs were produced, demonstrating that the Langmuir adsorption isotherm is followed by the adsorption of LTLE elements onto mild steel surfaces. The Langmuir adsorption isotherm is distinguished by equation 3:

$$\frac{C}{\theta} = \frac{1}{K} + C \ldots\ldots\ldots \quad \text{Eqn. (3)}$$

where C is the concentration, θ is the surface coverage, and K_{ads} is the adsorption process equilibrium constant that is connected to the conventional Gibbs free energy of adsorption by the following equation:

$$K_{ads} = \frac{1}{55.5} \exp\left(\frac{-\Delta G \, ads}{RT}\right) \ldots\ldots\ldots\ldots \text{Eqn. (4)}$$

where T is the absolute temperature, R is the molar gas constant, and 55.5 is the water concentration in mol dm^3.

Table 1. A few variables from the Langmuir isotherm model for mild steel in 0.5 mol/dm^3 HCl in the presence of LTLE.

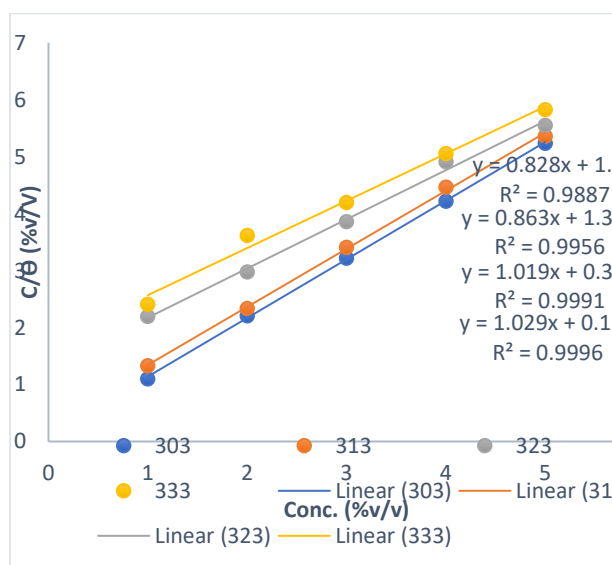| Temperature (K)	R^2 Value	Slope	K (L/ml)	ΔG^o_{ads} (KJ/mol)
303	0.989	0.968	2.98	-12.78
313	0.996	0.985	3.75	-13.89
323	0.999	0.973	2.74	-13.52
333	1.000	1.063	2.86	-13.91

Figure 4. Langmuir adsorption isotherm plots for LTLE on mild steel in 0.5 mol/dm^3 HCl.

Table 1 in the Additional Information presents crucial adsorption parameters derived from the plotted data. A notable trend observed is that as the temperature increases, the K_{ads} values, representing the inhibitor's binding affinity to the metal surface, tend to decrease. This trend provides valuable insights into the impact of temperature on corrosion inhibition mechanisms.

The influence of elevated temperatures on corrosion inhibition can be understood through the phenomenon of desorption, where certain adsorbed components from the extracts detach from the mild steel surface. This aligns with the principles of the physisorption mechanism, where molecules attach and detach based on weak physical forces (Zahra Sanaei et al., 2019; Zhang, Hou & Zhang, 2017). The driving force behind this desorption process is the free energy of adsorption, typically ranging from –

10.0 to –19.72 kJ/mol under such conditions. This range indicates that the extracts predominantly act by physically adhering to the metal surface to inhibit corrosion (Mo et al., 2017; Verma et al., 2018; Vorobyova & Skiba 2021).

Analyzing adsorption energies provides further clarity. Values up to –20 kJ/mol generally indicate physical adsorption or electrostatic interactions between charged molecules and the mild steel surface. Conversely, values exceeding –40 kJ/mol suggest chemisorption, a more intricate interaction involving charge transfer to form coordinate bonds with the mild steel surface, thereby enhancing corrosion inhibition (Olasunkanmi & Ebenso, 2020; Benahmed, et al., 2020; Singh et al., 2020).

The data in Table 1 also reveals a significant deviation from unity in the slope observed during mild steel corrosion in 0.5 mol/dm^3 HCl. This deviation implies potential deviations from strict adherence to the isotherm, highlighting the complexity of interactions and mechanisms involved in corrosion inhibition processes. These findings underscore the need for a comprehensive understanding of the interplay between temperature, adsorption energies, and corrosion inhibition mechanisms to develop effective strategies for corrosion control (Qiang et al., 2020; Singh et al., 2020).

4.0 CONCLUSION

It has been found that LTLE effectively prevents mild steel corrosion in a 0.5 mol/dm^3 HCl solution, with the inhibition impact dependent on concentration. The highest inhibitory efficiency in 0.5 mol/dm^3 HCl was achieved at a 5.0% v/v extract concentration. Additionally, immersion time impacts corrosion inhibition, with increased extract concentration leading to improved inhibitory efficacy. This improvement is attributed to LTLE components adsorbing onto mild steel surfaces, following the Langmuir adsorption isotherm and inhibiting corrosion. The trend of increasing inhibitory efficiency with rising temperature, supported by kinetic parameter values from experimental data, aligns with the theory of physical adsorption.

References

Adinortey, M. B., Sarfo, J. K., Kwarteng, J., Adinortey, C. A., Ekloh, W., Kuatsienu, L. E., & Nyarko, A. K. (2018). The ethnopharmacological and nutraceutical relevance of *Launaea taraxacifolia* (Willd.) Amin ex C. Jeffrey. *Evidence-Based Complementary and Alternative Medicine*, 46, 1-13**.**

Alibakhshi, E., Ramezanzadeh, M., Bahlakeh, G., Ramezanzadeh, B., Mahdavian, M., & Motamedi, M. (2018). *Glycyrrhiza glabra* leaves extract as a green corrosion inhibitor for mild steel in 1 M hydrochloric acid solution: Experimental, molecular dynamics, Monte Carlo and quantum mechanics study. *Journal of Molecular Liquids*, 255, 185–198.

Ansari, K. R., Chauhan, D. S., Quraishi, M. A., & Saleh, T. A. (2020). Bis(2-aminoethyl) amine modified graphene oxide nanoemulsion for carbon steel protection in 15% HCl: Effect of temperature and synergism with iodide ions. *Journal of Colloid and Interface Science,* 564, 124–133.

Benahmed, M., Selatnia, I., Djeddi, N., Akkal, S., & Laouer, H. (2020). Adsorption and corrosion inhibition properties of butanoic extract of *Elaeoselinum thapsioides* and its synergistic effect with *Reutera lutea* (Desf.) Maires (Apiaceae) on A283 carbon steel in hydrochloric acid solution. *Chemistry Africa*, 3, 251–261.

El-Hajjaji, F., Messali, M., Martinez de Yuso, M. V., Rodriguez-Castellon, E., Almutairi, S., Bandosz, T. J., & Algarra, M. (2019). Effect of 1-(3-phenoxypropyl) pyridazin-1-ium bromide on steel corrosion inhibition in acidic medium. *Journal of Colloid and Interface Science*, 541, 418–424.

Gunasekaran, G., & Chauhan, L. R. (2004). Eco-friendly inhibitor for corrosion inhibition of mild steel in phosphoric acid medium. *Electrochimica Acta, 49*(25), 4387–4395.

Lebrini, M., Robert, F., & Roos, C. (2010). Experimental and theoretical study for corrosion inhibition of mild steel in normal hydrochloric acid solution by some new macrocyclic polyether compounds. *International Journal of Electrochemical Science, 5,* 1698.

Rassoulia, L., & Mahdavain, R. N. (2018). Study of the impact of sequence of corrosion inhibitor doping in zeolite on the self-healing properties of silane sol-gel film. Journal of Industrial and Engineering Chemistry, 66, 221–230.

Lgaz, H., Chung, I.-M., Salghi, R., Ali, I. H., Chaouiki, A., El Aoufir, A. Y., & Khan, M. I. (2019). On the understanding of the adsorption of Fenugreek gum on mild steel in an acidic medium: Insights from experimental and computational studies. Journal of Applied Surface Science, 463, 647–658.

Mo, S., Luo, H. Q., & Li, N. B. (2017). Study on the influences of two thiazole flavour ingredients on Cu corrosion caused by chloride ion. Journal of Colloid and Interface Science, 505, 929–939.

Mobin, M., Basik, M., & Shoeb, M. (2019). A novel organic-inorganic hybrid complex based on *Cissus quadrangularis* plant extract and zirconium acetate as a green inhibitor for mild steel in 1 M HCl solution. Journal of Applied Surface Science, 469, 387–403.

Obot, I. B., & Obi-Egbedi, N. O. (2009). Inhibitor effect and adsorption characteristics of 2,3-diaminonaphthalene at aluminium/hydrochloric acid interface: Experimental and theoretical study. Surface Review and Letters, 15, 903.

Obot, I. B., Umoren, S. A., & Obi-Egbedi, N. O. (2011). Corrosion inhibition and adsorption behaviour for aluminium by extract of Aningeria robusta in HCl solution: Synergistic effect of iodide ions. *Journal of Materials and Environmental Science, 2*(1), 60–71.

Olasunkanmi, L. O., & Ebenso, L. O. (2020). Experimental and computational studies on propanone derivatives of quinoxalin-6-yl-4,5-dihydropyrazole as inhibitors of mild steel corrosion in hydrochloric acid, *Journal of Colloid Interfacial Science,* 561 104–116.

Pustaj, G., Kapor, F., & Jakovljević, S. (2017). Carbon dioxide corrosion of carbon steel and corrosion inhibition by natural olive leaf extract. *Journal of Material science and engineering Technology,* 48, 122–138

Palanisamy, S. P., Maheswaran, G., Selvarani, A. G., Kamal, C., & Venkatesh, G. (2018). Ricinus communis – A green extract for the improvement of anti-corrosion and mechanical properties of reinforcing steel in concrete in chloride media. *Journal of Building Engineering*, 19, 376–383.

Peimani, A. M., & Nasr-Esfahani, M. (2018). Application of anise extract for corrosion inhibition of carbon steel in CO$_2$ saturated 3.0% NaCl solution. *Protection of Metals and Physical Chemistry of Surfaces,* 54, 122–134.

Prabakaran, M. Kim, S.-H. Kalaiselvi, K. Hemapriya, V. & Chung, I. M. (2016). Highly efficient *Ligularia fischeri* green extract for the protection against corrosion of mild steel in acidic medium: electrochemical and spectroscopic investigations. *Journal of the Taiwan Institute of Chemical Engineers,* 59, 553–562.

Pustaj, G., Kapor, F., & Jakovljević, S. (2017). Carbon dioxide corrosion of carbon steel and corrosion inhibition by natural olive leaf extract. *Journal of Materials Science and Engineering Technology, 48*(2), 122–138.

Qiang, Y., Li, H., & Lan, X. (2020). Self-assembling anchored film based on two tetrazole derivatives for application to protect copper in a sulfuric acid environment. *Journal of Material Science and Technology, 52*, 63–71.

Saleh, M. M., Mahmoud, M. G., & Abd El-Lateef, H. M. (2019). Comparative study of synergistic inhibition of mild steel and pure iron by 1-hexadecyl pyridinium chloride and bromide ions. *Journal of Corrosion Science, 154*, 70–79.

Shahini, M. H., Ramezanzadeh, M., & Ramezanzadeh, B. (Year). Effective steel alloy surface protection from HCl attacks using Nepeta Panspermia plant stem extract. *Colloid and Surface A: Physicochemical and Engineering Aspects, 634,*

Shrestha, P. R., Oli, P. R., Thapa, B., Chaudhary, Y., Gupta, D. K., Das, A. K., Nakarmi, K. B., Singh, S., Karki, N., & Yadav, A. P. (2019). The bark extract of Lantana Camara in 1 M HCl as a green corrosion inhibitor for mild steel. *Engineering Journal, 23,* 205–21.

Singh, A., Ansari, K. R., Chauhan, D. S., Quraishi, M. A., Lgaz, H., & Chung, I. M. (2020). A comprehensive investigation of steel corrosion inhibition at macro/micro level by eco-friendly green corrosion inhibitor in 15% HCl medium. *Journal of Colloid and Interface Science, 560,* 225–236.

Tamalmani, K., & Husin, H. (2020). Review on corrosion inhibitors for oil and gas corrosion issues. *Applied Science, 10*(3389).

Tan, B., Zhang, S., Qiang, Y., Guo, L., Feng, L., Liao, C., Xu, Y., & Chen, S. (2018). A combined experimental and theoretical study of the inhibition effect of three disulfide-based flavouring agents for copper corrosion in 0.5 M sulfuric acid. *Journal of Colloid and Interface Science, 526,* 268–280.

Thamaraiselvan, C., Michael, N., & Oren, Y. (2018). Selective separation of dyes and brine recovery from textile wastewater by nanofiltration membranes. *Chemical Engineering & Technology, 41*(2), 185–293.

Vorobyova, V., & Skiba, M. (2021). Peach pomace extract as novel cost-effective and high-performance green inhibitor for mild steel corrosion in NaCl solution: experimental and theoretical research. *Waste and Biomass Valorization, 12*(10), 4623–4641.

Varshney, R. K., Chen, W., & Li, Y. (2012). Draft genome sequence of pigeon pea, an orphan legume crop of resource-poor farmers. *Nature Biotechnology, 30*(1), 83–89.

Verma, C., Olasunkanmi, L. O., Ebenso, E. E., & Quraishi, E. E. (2018). Substituents effect on corrosion inhibition performance of organic compounds in aggressive ionic solutions: a review. *Journal of Molecular Liquids, 251*, 100–118.

Vorobyova, V., & Skiba, M. (2021). Peach pomace extract as novel cost-effective and high-performance green inhibitor for mild steel corrosion in NaCl solution: experimental and theoretical research. *Waste and Biomass Valorization, 12*(10), 4623–4641.

Sanaei, Z., Ramezanzadeh, M., Bahlakeh, G., & Ramezanzadeh, B. (2019). Use of Rosa canina fruit extract as a green corrosion inhibitor for mild steel in 1 M HCl solution: a complementary experimental, molecular dynamics and quantum mechanics investigation. *Journal of Industrial and Engineering Chemistry, 69*, 18–31.

Zhang, Q. H., Hou, B. S., & Zhang, G. A. (2020). Inhibitive and adsorption behaviour of thiadiazole derivatives on carbon steel corrosion in CO$_2$-saturated oilfield produced water: effect of substituent group on efficiency. *Journal of Colloid and Interface Science, 572,* 91–106.

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BLOOD PROFILE AND INTESTINAL MICROBES OF PULLET CHICKENS FED *PHYLLANTHUS NIRURI* LEAF MEAL

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ABSTRACT

The use of chemical growth promoters as additives despite their adverse effects on animal and public health has compelled researchers to source natural alternatives such as plant-based or phytogenic feed additives. This study assessed the impact of *Phyllanthus niruri* leaf meal (PNLM) on the caecum microbial population and layers chicken's blood profile during the growth stage. The collected *P. niruri* leaves were milled after being air-dried at room temperature (25ºC) for ten days and then added to the pullets' diet. 360 pullets were randomly allotted to 6 treatments (T) of 4 replicates each in a completely randomised manner with 60 and 15 birds per treatment and replicate respectively. Treatments (T) 1 to T6 had 0%, 0% +antibiotics, 0.2, 0.3, 0.4 and 0.5% inclusion levels of PNLM respectively. Some haematological and serum parameters including caecum microbial populations were investigated using standard procedures. Data were subjected to one-way ANOVA while significant differences were determined using Duncan's multiple range test in SAS ($P<0.05$). The inclusion of PNLM significantly ($P<0.05$) influence the white blood cell, Lymphocyte and creatinine. The highest WBC (17.23 ± 4.50 x 10^9/L) and creatinine values (4.63 ± 2.64 mg/dL) were recorded in T2. T5 had the highest Lymphocyte value (70.50 %). Inclusion of PNLM also improved beneficial bacteria in the caecum especially *Pseudomonas* and *Bacillus spp*. The study concluded that PNLM enhanced the beneficial microbes of the caecum without adverse effects on the blood profile.

Keywords: Blood, Health, Microbes, *Phyllanthus niruri* leaf meal, Pullets

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1.0. INTRODUCTION

Antibiotic growth promoters (AGPs) are generally added to the animal ration to enhance immunity, reduce stress, boost nutrient absorption in the intestinal wall and prevent illness, increasing feed efficiency and the quality of poultry products. According to Kulkarni, Gaghan, Gorrell, Sharif, and Taha-Abdelaziz (2022), AGPs contribute to the decrease of harmful bacteria in the intestine, which promotes the growth of good microbiota (like *Lactobacillus spp.*) and improves bird performance. Manyi-Loh, Mamphweli, Meyer, and Okoh (2018) reported the negative impacts of AGPs in poultry production which include; the development of germs resistant to antibiotics, the presence of leftover effects in meat and eggs, and the rise in production costs.

Researchers have looked for ways to reduce the cost of poultry production, addition or supplementation of a conventional feedstuff with agro-industrial byproducts and plants or forages in the poultry diet became a viable solution (Sugiharto et al., 2019; Unigwe et al, 2022). Incorporating leaf meal into rations can lower feed costs while improving hens' health (Sugiharto et al., 2019).

Phyllanthus niruri has been utilised in many nations to cure various human medical ailments, including fever, jaundice, liver and kidney diseases, and prostate issues (Nguyen, Brian and Nguyen, 2012). Research on the pharmacological properties of this plant's bark and leaves demonstrates strong antibacterial activity (Meena, Bibwe, Bhushan, Jalgaonkar, & Mahawar, 2018), anti-inflammatory function, antioxidant (Endang et al., 2020) and antiviral activities (Meena et al., 2018; Endang et al., 2020; Perera et al., 2021).

Haematological factors are associated with blood and organs that generate blood, and they serve as reliable markers of an animal's physiological state (Khan, and Zafar, 2005). According to Olafedehan et al. (2010), blood serves as a pathological reflector of an animal's condition after exposure to toxins and other factors. Animals with a healthy blood composition are likely to perform effectively (Okpe et al., 2016). An organism's physiology, nutrition, and pathological state can all be greatly impacted by the analysis of blood, which provides the chance to look into the existence of many metabolites and other substances in animal bodies (Doyle, 2006).

The makeup of the gut microbiota can influence growth parameters, including growth rate. Research has been done on the connection between production performance and microorganisms like *Enterobacteria*, *Lactobacilli*, *Escherichia coli*, and *Campylobacter* (Iqbal, Cottrell, Suleria, & Dunshea, 2020).

According to some research, phytobiotics influence the population of gut microbes by interfering with their metabolic processes, whereas gut microbes convert phytobiotics into simpler metabolites to make them into absorbable metabolites (Iqbal et al., 2020; Skoufos, Bonos, Anastasiou, Tsinas, & Tzora, 2020; Ahmed, Elwakeel, El-Zarkouny, & Al-Sagheer, 2024).

To reduce the cost of poultry production, and prevent the development of antibiotic-resistant pathogens and AGP residue in poultry products, the addition or supplementation of conventional feedstuff and drugs with agro-industrial byproducts and plants or forages in poultry diet became a viable solution. Thus, the current investigation looked into how *P. niruri* leaf meal will affect pullet hens' gut morphology, serum biochemistry, and haematology in comparison with conventional AGP.

2.0 Materials and Methods

2.1. Description of Experimental Location

The study was conducted at The Federal Polytechnic Ilaro Teaching and Research Farm's poultry unit in Ogun State, which is situated in the South-Western rainforest belt of Nigeria, with an average daily temperature of 28°C, an annual rainfall of 1500 mm, and longitudes of 3.7187^0E and $6.8940º$N relative to the equator (World Weather Online, 2024).

2.2. Collection and Preparation of Experimental Plant Material

A botanist verified *P. niruri* fresh leaves that were taken in and around the experiment location. The harvested *P. niruri* leaves were thoroughly rinsed to remove sand and debris after which they were dried at room temperature (25ºC) for ten days in the open air (Kamran, Hamlin, Scott, & Obied, 2015). The leaves were afterwards ground into powder using a blender (Pyramid® PM-B999) (Akinlade, Okusanya, & Okparavero, 2021). The resulting *P. niruri* leaf meal (PNLM) was then added to the birds' basal diets at various quantities during the experiment.

Table 1: Proximate composition of *Phyllanthus niruri* leaf (PNL)

Nutrients	% Dry Matter
Dry matter	91.06
Crude fibre	16.90
Ether extract	7.55
Crude protein	14.74
NFE	44.54
Ash	7.33

Key: NFE: Nitrogen Free Extract,

Experimental Animal Management and Design

In a fully randomized design, 360 growing pullets (Isa Brown) at nine weeks old were divided into six (6) treatments, with four duplicates of 60 and 15 birds, respectively. The following were the dietary interventions:

i)　　　T1 = (without any additive)

ii)　　　T2 = Antibiotics (Tylosin as tartrate 10 g, Doxycycline as hyclate 10 g)

iii)　　　T3 = 0.2% PNLM

iv)　　　T4 = 0.3% PNLM

v)　　　T5 = 0.4% PNLM

vi)　　　T6 = 0.5% PNLM

Table 2: Composition of Experimental Diet (Basal Diet)

Ingredients	Growers
Maize	50.00
Wheat offal	28.00
Oyster shell	2.00
Soybean meal	16.00
Bone Meal	1.25
Oyster Shell	1.00
Limestone	1.00
Salt	0.25
Methionine	0.25
Premix	0.25
Total	100.00
Analyzed Result	%
Crude fibre	4.24
Crude protein	20.55
Ash	4.26
Ether Extract	4.54
Metabolizable Energy	2967 (Kcal/kg)

2.3 Data Collection

Data were collected on haematological parameters, serum biochemistry and gut microbes.

Determination of Haemato-Biochemical Parameters

In the twentieth week, 2 birds from each replicate were selected for blood evaluation, blood sample was collected through the wing web vein into bottles containing Ethylene Diamine Tetra-Acetic acid (EDTA) for haematological parameters. Parameters that were evaluated include: red blood corpuscles (RBC), packed cell volume (PCV), Haemoglobin (Hb), white blood cells (WBC), heterophils lymphocyte and differential counts (lymphocyte, heterophil, eosinophil, basophil, monocyte) ratio were calculated (Bordoloi, Jas, and Ghosh, 2012). Additionally, blood samples were drawn into sterile sample bottles devoid of anticoagulants to assess serum biochemical characteristics. Using commercial diagnostic kits, each serum sample was tested for cholesterol, total protein, albumin, globulin, low-density lipoprotein (LDL), high-density lipoprotein (HDL), aspartate aminotransferase (AST), alanine transaminase (ALT), and alkaline phosphatase (ALP) (Ogunbajo, Alemede, Adama, & Abdullahi, 2009; Alagbe et al., 2023).

Determination of Bacterial Count in the Gastro-intestinal Tract

Two randomly selected birds from each replicate were chosen and slaughtered, the caecum was extracted, preserved in peptone water, and stored at 40°C for additional examination. Before being used, glassware was allowed to cool after being sterilized in the oven for two hours. The autoclave was used to sanitize all of the media for 15 minutes at 121°C. Each caeca content was homogenized for three minutes after being combined with nine millilitres of sterile dilution blank solution. One millilitre (ml) of each dilution was inoculated into different mediums, such as MacConkay agar for coliforms and MRS agar for LAB. After that, the inoculation plates were incubated for 24 to 48 hours at 37 to 40°C. Using an upgraded bacteria colony counter, the total number of bacterial colonies was counted after each incubation period (Gill, Penney and Nottingham, 1978; Siva, Subha, Bhakta, Ghosh, & Babu, 2012).

2.4. Statistical Analysis

A one-way analysis of variance (ANOVA) was performed on the collected data. Duncan's Multiple Range Test was used to identify significant differences between treatments as contained in SAS (SAS Institute, 1999)

3.0 Results and Discussion

3.1 Effect of PNLM inclusion on haematological parameters of pullets

Table 1 shows the impact of *PNLM* as an addition on the experimental birds' haematological parameters during the growing phase. Packed cell volume showed numerical differences (P>0.05),

ranging from 28.50% (T1) to 37.75% (T2). The range of hemoglobin percentages was 9.70% to 12.03%. Moreover, T6 had the lowest red blood cell count (2.75×10^{12}/L) and T4 had the greatest (3.43×10^{12}/L). On the other hand, PNML significantly ($p<0.05$) influence the values of white blood cells and lymphocytes. T1 (control) had the lowest white blood cell value (13.18×10^9/L) and T2 had the highest value (17.23×10^9/L). T5 had the highest lymphocyte value of 72.5% while T4 had the lowest value of 68.00%.

Table 3: Haematological parameters of pullets fed PNLM

Parameters	T1	T2	T3	T4	T5	T6	SEM±
Pack Cell Volume (%)	28.50	37.75	32.25	31.25	32.25	28.75	3.58
Haemoglobin (g/dl)	9.70	12.03	11.00	10.10	10.18	9.70	2.51
Red Blood Cell ($\times 10^{12}$/L)	2.78	2.93	3.25	3.43	2.78	2.75	0.22
White Blood Cell ($\times 10^9$/L)	13.18[b]	17.23[a]	15.45[ab]	15.50[ab]	14.28[ab]	14.43[ab]	4.50
Lymphocyte (%)	70.50[ab]	70.25[ab]	69.50[ab]	68.00[b]	72.50[a]	70.00[ab]	4.65
Heterophils (%)	28.75	29.25	29.50	30.00	26.75	28.75	4.78
Monocytes (%)	0.50	0.25	0.50	1.00	0.25	0.50	0.25
Eosinophil (%)	0.25	0.00	0.25	0.25	0.25	0.25	0.21

Alphabetic superscript shows that Mean within the same row were significantly different (P<0.05)

3.2 Serum biochemical parameters of pullets fed PNLM

The effect of PNLM as an additive on serum biochemical parameters of the experimental birds at the growing phase is presented in Table 2. The lowest cholesterol value (9.00mg/dl) was recorded for birds fed 0.2% PNLM (T3). Numerical differences (P>0.05) were observed for aspartate aminotransferase (AST)

(118.15μ/l) in T5 and for alkaline phosphatase (ALP) (87.00μ/l) in T6 (500g PNLM). The lowest values in AST (97.18μ/l), ALP (64.50μ /l) and ALT (97.58μ/l) were observed in T2. In birds given T6, the highest ALT value (134.95μ/l) was observed (500g PNLM). There was a significant difference ($p<0.05$) in the value of creatinine. T2 had the highest value (4.63 mg/dl) while T1 had the lowest value (1.50 mg/dl) for creatinine, respectively.

Table 4: Serum biochemical parameters of pullets fed PNLM

Parameters	T1	T2	T3	T4	T5	T6	SEM±
Cholesterol (mg/dl)	20.00	15.00	9.00	12.25	14.25	10.00	5.19
Aspartate aminotransferase (U/L)	113.23	97.18	100.00	112.18	118.15	106.78	3.55
Alanine transaminase (U/L)	102.38	97.58	97.60	115.88	112.70	134.95	1.82
Total Protein (g/dl)	4.78	4.65	4.70	4.55	4.20	4.03	0.46
Albumin (g/dl)	2.95	2.90	3.10	2.95	2.48	2.58	0.27
Globulin (g/dl)	1.85	1.70	1.60	1.58	1.75	1.45	0.25
Alkaline phosphatase (U/L)	85.75	64.50	80.75	73.50	72.00	87.00	5.53
Creatinine (mg/dl)	1.50[b]	4.63[a]	2.10[ab]	2.63[ab]	2.53[ab]	1.60[b]	2.64

Alphabetic superscript shows that Mean within the same row were significantly different (P<0.05)

3.3 Effects of PNLM inclusion on the intestinal microbial population of pullets

The intestinal bacterial count of pullets fed diets with varying amounts of *Phyllanthus niruri* leaf meal (PNLM) as a supplement throughout the growing period is displayed in Table 3. The findings revealed that, except T1, none of the treatment groups had any Bacillus species in the caecum. There was no significant difference

($p<0.05$) in the caecum total bacteria count. The highest numerical value was observed in diet containing 0.5% PNLM (T6) (2.0×10^6 cfu/g) when compared to T1 control (1.20×10^6 cfu/g) but almost closer to T2 treated with antibiotics (1.70×10^6 cfu/g). However, the results showed a numerical increase ($p>0.05$) in the total bacteria count (1.6×10^6 cfu/g, 1.8×10^6 cfu/g, 2.00×10^6 cfu/g) as the levels of PNLM increased (0.3%, 0.4%, 0.5g).

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Table 5: Intestinal microbial population of pullets fed PNLM

Treatment	TBC Caecum (10^6cfu/g)	*Staphyloccocus aureus*	*Bacillus Spp*	*Escherichia Coli*	*Streptococcus faecalis*	*Pseudomonas Spp*
1	1.2	+	+	-	+	-
2	1.7	+	-	+	-	+
3	1.6	+	-	+	-	+
4	1.6	-	-	+	+	-
5	1.8	+	-	+	_	+
6	2.0	-	-	+	_	+

TBC: Total Bacteria Count, Spp: Specie, P-value: 0.23

3.4. Discussion

Major indicators for assessing circulatory erythrocytes and important in the diagnosis of anaemia include packed cell volume (PCV), and haemoglobin, (Peters, Gunn, Imumorin, Agaviezor, & Ikeobi). According to Chineke, Ologun, and Ikeobi (2006), they also function as helpful indicators of a mammal's ability to manufacture red blood cells in the bone marrow. The whole condition of chickens is influenced by their erythrocyte (RBC) count (Mitruka, Rawnsley, & Vadehia, 1977). PCV, haemoglobin, and red blood cell counts in the birds increased, suggesting that the blood's ability to carry oxygen was improved. According to Chineke et al. (2006), there has been a proposition that a high PCV reading, or polycythemia, signifies either a decrease in circulating plasma volume or an increase in red blood cell count. This could potentially be attributed to a physiological adjustment to a high pathological response to a chronic respiratory or circulatory illness. Most birds show signs of dehydration when their PCV value is higher than 56% (Pendl, 2001). The results obtained in this study, however, were within the reference ranges for layers of 25–45% (Al-Nedawi, 2018).

White blood cells levels in birds have phagocytic activity and are utilized as sensitive biomarkers essential to immune function as well as a sign of stress response. Low white blood cell counts put animals at high risk of contracting diseases. In contrast, moderate counts allow for the production of antibodies during phagocytosis, increase disease resistance, and improve adaptation to both local environmental conditions and disease-prevalent conditions (Soetan, Akinrinde,& Ajibade, 2013). The result of WBC in this study points to the treatment groups had a relatively lower WBC than those reported by Pewan et al. (2019), though, within the range reported by (Pewan et al., 2019), this may mean that the birds were stressed hence the significant (p<0.05) reduction in WBC. This tends to confirm the report of Talebi, Asri-Rezaei, Rozeh-Chai, and Sahraei, (2005) that nutrition affects the blood profiles of birds and this implies that up to 2.5% inclusion of leaf meal had a positive effect on the relative quantity of blood cell as well as the total volume of blood. Lymphocytes are mediator cells of the adaptive immune response and play a crucial part in the body's defence against infection. The maturation process takes place in the bursa of fabricius and thymus in birds and mammals. The observed values are consistent with normal ranges reported for healthy birds (Lee et al., 2011).

It should be mentioned that the liver is prone to different degrees of chemical and biological damage because it is the hub of several metabolic, digestive, and productive processes. Serum levels of particular liver-derived enzymes indicate such damage. Liver function and damage can be bio-indicated by the blood levels of the enzymes AST, ALP, and ALT. (Yildirim, Yalchinkaya, Kanbur, & Oruc, 2011). The body's reaction to stress is linked to elevated levels of these enzymes, which might cause damage to the liver or muscles (Lumeij, 2008). There were notable variations (P<0.05) in the value of metabolites creatinine among the treatment groups. This shows

that feed supplements with P. *ninuri* had a substantial (P<0.05) impact on the levels of creatinine. The cationic amino acid-derived nephrotoxic effect of accumulated antibiotics can cause damage to the kidney's proximal tubular epithelial cells by binding phosphoinositides. Consequently, the filter process is inhibited and levels of creatinine rise (Pazhayattil & Shirali, 2014). The high levels of creatinine seen in the control group indicate that antibiotics tend to impair kidney function. The reason for this is that antibiotics not only eradicate all bacteria but also combat infectious ones, which negatively impact poultry birds' health, particularly the liver and kidneys (Śliżewska, Cukrowska, Smulikowska, and Cielecka-Kuszyk, 2019). Probiotics, prebiotics, enzymes, organic acids, immunostimulants, bacteriocin, bacteriophage, carotenoids, phytoncides, nanoparticles, and essential oils are examples of frequent feed additives that are advised to be used instead. According to Mehdi et al. (2018) and Habibu, Dzenda, Ayo, Yaqub, and Kawu, (2018), the alternative feed additives are safer because they enhance chicken performance without interfering with kidney function or leaving behind residue in the meat, and liver, kidneys, skin, and fat. This suggests that using PNLM as a supplement for antibiotics in layers chicken production is both safe and healthy. The findings showed that the beneficial bacteria (*Pseudomonas spp.* and *Escherichia coli*) in T6 were enhanced by the addition of 0.5%PNLM. The presence of *Bacillus spp* in T2-T6 at the caecum and in T1 and T5 respectively, was not detected by PNLM supplementation. The microbiome contains useful, innocuous bacteria called *Bacillus* species. By growing the good bacteria and pushing out the bad bacteria, phytobiotics have demonstrated beneficial effects. According to Yildirim et al. (2011), the colonization of the gastrointestinal tract by helpful bacteria such as *Bacillus*, *Escherichia coli*, and *Pseudomonas spp.* inhibits the growth and presence of potentially harmful species. The findings imply that the phytobiotics found in *Phyllanthus niruri* leaf meal work in a bacteriostatic manner, which lessens the pathogenic bacteria's pathogenicity and aids in the colonization of the GIT by good bacteria. The findings of Murugesan, Syed, Haldar, and Pender (2015), who found that a phytogenic feed additive boosted the gut microbiota with beneficial bacteria and reduced the coliform population in the cecum are consistent with this work. Because of their quick colonization, rapid growth, and ability to cause acidity in the GIT, *Bacillus* species have the potential to selectively prevent pathogens from sticking once they become established (Alagbe et al., 2023).

4.0. Conclusion

This study's findings indicate that PNLM in layer chicken diet does not negatively impact the birds, suggesting that the product from such birds is safe for human consumption without risk of health problems. Furthermore, PNLM helps in the proliferation of beneficial microbes in the caecum. Therefore to enhance the health

status of layer chickens, the addition of *Phyllanthus niruri* leaf meal is recommended because it has no negative effect on the blood profile and enhances the proliferation of beneficial microbes in the caecum.

References

Ahmed, M. G., Elwakeel, E. A., El-Zarkouny, S. Z., & Al-Sagheer, A. A. (2024). Environmental impact of phytobiotic additives on greenhouse gas emission reduction, rumen fermentation manipulation, and performance in ruminants: an updated review. *Environmental Science and Pollution Research*, 1-20. https://doi.org/10.1007/s11356-023-25220-4

Akinlade, O. O., Okusanya, P. O. & Okparavero, O. O. (2021). Effect of Aqueous Blend of Three Herbs on Haematobiochemical Indices of Broiler Chicken at Starter Phase. *Journal of Pure and Applied Sciences (FEPI-JOPAS) 3*(2), 34-39. *https://fepi-jopas.federalpolyilaro.edu.ng*

Alagbe, J. O., Agubosi, O. C. P., Oluwafemi, R. A., Akande, T. O., Adegbite, A. E., & Emiola, I. A. (2023). Haemato-biochemical indices and intestinal microbial population of broiler chickens fed diet supplemented with Prosopis africana (African mesquite) essential oil. *Brazilian Journal of Science*, *2*(9), 98-110.

Al-Nedawi, A. (2018). Reference hematology for commercial Ross 308 broilers. *Online Journal of Veterinary Research*, *22*(7), 566-570.

Bordoloi, G., Jas, R., & Ghosh, J. D. (2012). Changes in the haemato-biochemical pattern due to experimentally induced haemonchosis in Sahabadi sheep. *Journal of Parasitic Diseases*, 36, 101-105.

Chineke, C. A., Ologun, A. G., & Ikeobi, C. O. N. (2006). Haematological parameters in rabbit breeds and crosses in humid tropics. *Pakistan Journal of Biological Sciences*, *9*(11), 2102-2106.

Doyle, D. (2006). The father of haematology. *British Journal of Haematology, 133*(4), 375-381.

Endang, D., Lin, N., Siti, F. F., Ira, A. W., Ria, P. S. & Dzulhaifa, D. (2020). The sub-chronic toxicity test of Meniran (*Phyllanthus niruri* L.) and Pegagan (*Centella asiatica*) extract in Wistar strain rats on liver and kidney function. *Journal FarmasiSains Dan Komunitas*, *16*(2), 86-95.

Gill, C. O., Penney, N., & Nottingham, P. M. (1978). Tissue sterility in uneviscerated carcasses. *Applied and Environmental Microbiology*, *36*(2), 356-359.

Habibu, B., Dzenda, T., Ayo, J. O., Yaqub, L. S., & Kawu, M. U. (2018). Haematological changes and plasma fluid dynamics in livestock during thermal stress, and response to mitigative measures. *Livestock Science*, *214*, 189-201.

Iqbal, Y., Cottrell, J. J., Suleria, H. A. R. & Dunshea, F. R. (2020). Gut microbiota-polyphenol interactions in chicken: a review. *Animals*, *10*, 1391. doi: 10.3390/ani10081391.

Kamran, M., Hamlin, A. S., Scott, C. J., & Obied, H. K. (2015). Drying at high temperature for a short time maximizes the recovery of olive leaf bisphenols. *Industrial Crops and Products*, *78,* 29-38.

Khan, T. A., & Zafar, F. (2005). Haematological Study in Response to Varying Doses of Estrogen in Broiler Chicken. *International Journal of Poultry Science, 4*(10), 748-751.

Kulkarni, R. R., Gaghan, C., Gorrell, K., Sharif, S. & Taha-Abdelaziz, K. (2022). Probiotics as alternatives to antibiotics for the prevention and control of Necrotic enteritis in chickens. *Pathogens*, *11*, 1-20. doi: 10.3390/pathogens11060692.

Lee, S. H., Lillehoj, H. S., Jang, S. I., Lee, K. W., Bravo, D., & Lillehoj, E. P. (2011) Effects of dietary supplementation with phytonutrients on vaccine-stimulated immunity against infection with *Eimeria tenella*. *Veterinary Parasitology*, *181*, 97–105. doi: 10.1016/j.vetpar.2011.05.003.

Lumeij, J. T. (2008). Avian clinical biochemistry in Clinical Biochemistry of Domestic Animals. 6th ed. J. J. Kaneko, J. W. Harvey, and M. L. Bruss, ed. *Academic Press, Burlington*, 839–872.

Manyi-Loh, C., Mamphweli, S., Meyer, E. & Okoh, A., (2018). Antibiotic use in agriculture and its consequential resistance in environmental sources: Potential public health implications. *Review Molecules*, *23*, 1-48. doi:10.3390/molecules23040795.

Meena, V. S., Bibwe, B., Bhushan, B., Jalgaonkar, K., & Mahawar, M. K. (2018). Physicochemical characterization of selected Pomegranate cultivars. *Turkish Journal of Agricultural Engineering Research, 2(2),* 425-433.

Mehdi, Y., Létourneau-Montminy, M.P., Gaucher, M.L., Chorfi, Y., Suresh, G., Rouissi, T., Brar, S.K., Côté, C., Ramirez, A.A. and Godbout, S., (2018). Use of antibiotics in broiler production: Global impacts and alternatives. *Animal Nutrition*, *4*(2), 170-178.

Mitruka, B. M., Rawnsley, H. M., & Vadehia, B. V. (1977). Clinical biochemical and haematological reference values in normal experimental animals. *Masson Publishing USA Inc.* 272.

Murugesan, G. R., Syed, B., Haldar, S., & Pender, C. (2015). Phytogenic feed additives as an alternative to antibiotic growth promoters in broiler chickens. *Veterinary Science, 2*(21), doi: 10.3389/fvets.2015.0002.

Nguyen, H. P., Brian, O. P., & Nguyen, Q. T. (2012). Detoxifying effects of a commercial additive and *Phyllanthus amarus* extracts in pigs fed *fumonisins*-contaminated feed. *Livestock Research for Rural Development, 24(6), 22-27*.

Ogunbajo, S. O., Alemede, I. C., Adama, J. Y., & Abdullahi, J. (2009). Haematological parameters of Savannah brown does fed varying dietary levels of flamboyant tree seed meal (p. 88-91). *Proceedings of 34th Annual Conference of Nigerian Society for Animal Production*. http://nsap.org.ng/index.php/proceedings/2009 -conference- proceedings/category/3-conference-proceedings

Okpe, O., Habila, N., Ikwebe, J., Upev, V. A., Okoduwa, S. I., & Isaac, O. T. (2016). Antimalarial potential of *Carica papaya* and *Vernonia amygdalina* in mice infected with *Plasmodium berghei*. *Journal of Tropical Medicine*, *6*(91), 146-151.

Olafedehan, C. O., Obun, A. M., Yusuf, M. K., Adewumi, O. O., Oladefedehan, A. O., Awofolaji, A. O., & Adeniji, A. A. (2010). Effects of residual cyanide in processed cassava peal meals on haematological and biochemical indices of growing rabbits *Proceedings of 35th Annual Conference of Nigerian Society for Animal Production, p*212. http://nsap.org.ng/index.php/proceedings/2010-conference-proceedings/category/3-conference-proceedings

_____

Pazhayattil, G. S., & Shirali, A. C. (2014). Drug-induced impairment of renal function. *International Journal of Nephrology and Renovascular Disease*, 457 -468

Pendl, H. (2001). Avian hematology for practitioners. *Proceeding of Association of Avian Veterinarians*, 387-400.

Perera, W. P. R. T., Janitha, A. L., Dissanayake, K. G. C., Hiruni, G., Weerakoon, W. M. T. D., Wanigasekara, D. N., Fernando, W. S. K., Rajapaksha, R. M. H., Liyanage, R. P., & Bingun, T. P. (2021). Antiviral potential of selected medicinal herbs and their isolated natural products. *Biomedical Research International*, *4*(2), 22-27.

Peters, S. O., Gunn, H. H., Imumorin, I. G., Agaviezor, B. O., & Ikeobi, C. O. N. (2011). Haematological studies on frizzled and naked neck genotypes of Nigerian native chickens. *Tropical Animal Health Production*, *43*(3), 631- 638.

Pewan, S. B., Yibis, G. G., Danbirni, S., Nyam, P. P., Tahir, I., & Mbap, S. T. (2019). Effects of seasons on haematologic and serum biochemical profiles of indigenous chickens in Shendam, Plateau State, *Nigeria. Nigerian Journal of Animal Science*, *21*(2), 77-84.

Siva, R., Subha, K., Bhakta, D., Ghosh, A. R., & Babu, S. (2012). Characterization and enhanced production of prodigiosin from the spoiled coconut. *Applied Biochemistry and Biotechnology*, *166*, 187-196.

Skoufos, I., Bonos, E., Anastasiou, I, Tsinas, A., & Tzora, A. (2020). Effects of phytobiotics in healthy or disease-challenged animals. *Feed Additives*, 311-337.

Śliżewska, K., Cukrowska, B., Smulikowska, S., & Cielecka-Kuszyk, J. (2019). The effect of probiotic supplementation on performance and the histopathological changes in liver and kidneys in broiler chickens fed diets with aflatoxin B1. *Toxins*, *11*(2), 112.

Soetan, K. O., Akinrinde, A. S., & Ajibade, T. O. (2013). Preliminary studies on the haematological parameters of cockerels fed raw and processed guinea corn (*Sorghum bicolor*). *In Proceedings of 38th Annual Conference of Nigerian Society for Animal Production, Nigeria, pp. 49-52.* http://nsap.org.ng/index.php/proceedings/2013-conference-proceedings/category/3-conference-proceedings

Sugiharto, S., Yudiarti, T., Isroli, I., Widiastuti, E., Wahyuni, H. I. & Sartono, T. A. (2019). Recent advances in the incorporation of leaf meals in broiler diets. *Livestock Research and Rural Development*, *31(7), Article #109.Retrieved July 7, 2020, from http://www.lrrd.org/lrrd31/7/sgu_u31109.html.*

Talebi, A., Asri-Rezaei, S., Rozeh-Chai, R. & Sahraei, R. (2005). Comparative studies on hematological values of broiler strains. *International Journal of Poultry Science*, *4*(8), 573 – 579. doi: 10.3923/ijps.2005.573.579.

Unigwe, C. R., Esan, O. O., Egwu, U. L., Enibe, F., Njoku, P. C. & Onyeachonam, F. O. (2022). Haematology and serum biochemistry evaluations of broiler chickens inoculated with *Salmonella enteritis* and treated with *P. amarus* leaf extract. *Journal of Applied Science and Environmental Management, 26(*3), 495-503

World Weather Online (2024). https://www.worldweatheronline.com/ilaro-weather-averages/ogun/ng.aspx

Yildirim, E. I., Yalchinkaya, M., Kanbur, M. Ç., & Oruc, E. (2011). Effects of yeast lucomannan on performance, some biochemical parameters and pathological changes in experimental aflatoxicosis in broiler chickens. *Révue de Médicine Vétérinaire*, *162*, 413–420

STUDY OF QUALITY ASSESSMENT OF FLOUR AND AMALA PRODUCED FROM WHITE YAM (*DIOSCOREA ROTUNDATA*), UNRIPE PLANTAIN (*MUSA PARADISIACA*) AND SWEET POTATO (*IPOMOEA BATATAS*)

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ABSTRACT

Traditionally to the Nigerian southwestern culture, amala is exclusively obtained from yam or cassava flours. Enhancing the availability of amala and making different varieties available to consumers, will require the comparison of amala produced from other sources. Therefore, yam, unripe plantain and sweet potato flours were produced using standard methods, and subjected to analysis for their proximate composition, functional properties, and pasting characteristics. Amala produced from the flours using the standard method was sensorially evaluated by 30 member panellists using a 9-point hedonic scale. The proximate values of flour samples were moisture content (7.26-8.38%), protein (4.33-5.13%), fat (2.56-4.10%), fibre (2.56-4.10), ash (1.36-3.04%), and carbohydrate (73.75-81.36), with energy ranging from 302.10 to 311.40kcals, respectively. Functional analysis revealed varying bulk density, swelling capacity, and water absorption index, ranging from 0.45 to 0.59 g/cm^3, 1.35 to 1.71 g/cm^3, and 2.34 to 6.93 g/cm^3, respectively. The peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time, and pasting temperature ranged from 4315.50 to 6613.00 cP, 2786.00 to 4385.00 cP, 45.00 to3827.00 cP, 3926.50 to 6474.5 cP, and 4.13 to 6.93 minutes, respectively. All amala samples produced received high likeness ratings in all sensory attributes while the overall likeness was for unripe plantain amala. Considering, the comparative nutritional and sensory properties of all flour samples studied, the utilisation of yam, unripe plantain and orange-fleshed sweet potato flours for amala preparation would provide variety and enhance food security.

Keywords: Amala, sweet potato, plantain, pasting, sensory

1.0 INTRODUCTION

Amala, a traditional Nigerian dish, is a gelatinised product usually produced from yam flour (CF) or other flours from fermented and sundried yam tubers; and is widely consumed in the Western part of Nigeria. Amala preparation from yam or cassava flour involves reconstituting the flour in boiling water until a stiff smooth paste is formed(Oluwamukomi & Lawal, 2020). A wide variety of roots and tubers plays a major role in the human diet (Chandrasekara, 2018), however, amala's large consumer base due to their cultural attachment has necessitated the need to evaluate alternatives that can serve food security purposes and nutritionally adequate composition.

Sweet potato remains an underutilized crop because its cultivation to harvest is a short period of about four months and the dry matter yield is high(Osunrinade et al., 2023). As such, sweet potato is a food crop that is increasingly being recognized as having an important role to play in improving household and national food security, health and livelihoods of poor families in sub-Saharan Africa. Sweet potatoes play an immense role in the human diet and are considered the second staple food in developed and underdeveloped countries(Alam, 2021). Sweet potatoes are vegetable crops which have been grossly underutilised in Nigeria, and therefore efforts at promoting their utilisation are being continuously researched. Nutritional profiling of sweet potato showed that it is rich in vitamins B6 and C, beta carotene and dietary fibre (Jenfa et al., 2024).

Plantain (*Musa paradisiacae*) serves as a significant carbohydrate source in various regions of Africa, Asia, and South America (Oyeyinka & Afolayan, 2019). Its consumption is primarily attributed to its rich vitamin and mineral contents. Plantain flour, whether used alone or in combination with yam flour, can yield a quality stiff dough known as amala (Adenekan et al., 2021). Unripe plantain has been reported to be used for amala preparation,

especially for diabetic patients(Ajiboye & Shodehinde, 2022). However, a comparative assessment of its stiff dough has not been compared with other sources of flour samples used to produce amala.

Traditionally to the Nigerian southwestern culture, amala is exclusively obtained from yam or cassava flours(Oluwamukomi & Lawal, 2020), there is a need to explore other sources such as unripe plantain and sweet potato to compare with the commonly used raw materials (yam). This could help in enhancing the availability of the product and make different varieties available to consumers. The present study endeavours to produce yam, plantain, and sweet potato flours, with a focus on conducting proximate analysis, evaluating functional properties, and ultimately preparing amala from these flours to assess their sensory attributes.

2.0 Materials and Methods

2.1 Raw material and source of procurement.

Freshly harvested samples of sweet potato and unripe plantain fruits were sourced from the Oke-Ogun Polytechnic farm community in Saki, Oyo State, Nigeria. Botanical identification was conducted at the International Institute of Tropical Agriculture (IITA) in Ibadan, Oyo State, Nigeria. Subsequent processing of the samples was carried out at the Food Science Technology laboratory of The Oke-Ogun Polytechnic, Saki (TOPS).

2.2 Samples preparation

2.2.1 Preparation of sweet potato and yam flour.

Fresh roots of flesh sweet potato and yam, free from any signs of infection or infestation, were thoroughly washed under running tap water to eliminate any adhering soil, dirt, or dust. Subsequently, the roots were peeled, washed, and sliced into water containing 0.01% sodium

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metabisulphite, where they were left to soak for approximately 10 minutes. Following this, the slices were sun-dried for a week. The dried chips were milled into flour. The flour samples were passed through a sieve of 200 μm mesh size to obtain fine consistency (Osunrinade et al., 2023). Finally, the flour was carefully packed into airtight plastic packages and stored at ambient temperature for further analysis and preparation of amala for sensory evaluation.

2.2.2 Preparation of unripe plantain flour.

The plantain fruits were carefully separated from their bunches, thoroughly washed with clean water, and then peeled using a sharp knife. The peeled plantain fruits were sliced manually with a sharp knife to an average thickness of 1cm, and the slices were laid out on stainless trays for sun drying. Dried chips were milled using a locally fabricated hammer mill and then sieved through a mesh (200 μm mesh size) to achieve a fine particle size flour texture. The resulting flour was meticulously packed into air-tight plastic containers, labelled, and stored at ambient conditions for future use.

2.3 Analytical method.

2.3.1 Determination of proximate composition of flour

The ash, crude fat, crude fibre, moisture, and protein contents were analysed using the standard methods outlined in AOAC (2005)by the Association of Analytical Chemists. Carbohydrate content was determined by the difference method, wherein the sum of ash, fat, protein, crude fibre, and moisture contents was subtracted from 100. Additionally, the energy value (in kcals) was calculated using factors of 2.44, 8.37, and 3.47 to multiply the percentages of crude protein, crude lipid, and carbohydrate, respectively, following the methodology specified for vegetable analysis (Ijarotimi et al., 2013).

2.3.2 Determination of functional properties of flour

Bulk density was determined following the procedure outlined by Agume Ntso et al.(2017), while water absorption capacity was assessed using the method detailed by Chandra et al. (2015). For the determination of oil absorption properties, the method described by Joshi et al. (2015) was employed. Additionally, the swelling index of flour samples was determined according to the method outlined by (Tharise et al., 2014)

2.3.3Flour pasting property determination

Pasting properties were determined using a rapid visco-analyser (RVA). Initially, 2.5g of the flour was precisely weighed into a dried empty canister. Subsequently, 25 ml of distilled water was dispensed into the sample canister, and the suspension was thoroughly mixed. The canister was then fitted into the rapid visco-analyser. Each suspension underwent a temperature regime starting at 50°C for 1 minute, followed by heating up to 95°C at a rate of 12.2°C per minute, and held at 95°C for 2.5 minutes. Subsequently, it was cooled to 50°C at a rate of 11.8°C per minute and maintained at 50°C for 2 minutes.

2.3.4 Sensory Evaluation.

The sensory characteristics of the amala samples produced from flour samples were assessed by a panel of thirty semi-trained panellists. Before the evaluation process, all panellists received a briefing outlining the sensory attributes to be evaluated, including appearance, taste, texture, flavour, and overall acceptability. A nine-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely) was used for rating. It's worth noting that all panellists were regular consumers of amala and water was provided to rinse the mouth between evaluations.

3.0 RESULTS AND DISCUSSION
3.1 Proximate analysis of potato flour, plantain flour and yam flour.
The moisture content of each sample ranged from 7.26 to 8.38%, with significant differences observed among them at $p<0.05$. This falls within the maximum level of 10% recommended for flour and flakes indicating favourable storage conditions (Sujitha et al., 2018). Regarding protein content, results ranged from 3.13 to 4.83%, showing significant differences among the samples (Table 1). Sample 532 exhibited a significantly higher value than the average content of 2% for plantain flour, while sample 352's value surpassed the typical 1.5%. The crude fibre composition varied from 2.43 to 4.10% and showed significant differences among the samples. Dietary fibre is known to reduce the risk of cardiovascular diseases, with increased consumption contributing to a decline in the incidence of conditions such as diabetes, coronary heart disease, colon cancer, and various digestive disorders (Reynolds et al., 2022)

Ash content ranged from 3.02 to 3.78%, with all three samples significantly differing at p<0.05. This indicates that the samples could serve as good sources of nutritionally essential minerals and trace elements. All samples exhibited high carbohydrate content values ranging from 73.27 to 75.50%. This is typical of root and tuber crops, which are naturally rich in carbohydrates compared to other crops. Sample 352 had the lowest energy value at 302.10 kcal, while samples 532 and 523 had 306.48 and 311.40 kcal, respectively.

Table 1: Result for the proximate analysis of potato flour, plantain flour and yam flour

Sample code	Moisture Content(%)	Crude protein(%)	Crude fat(%)	Crude fiber(%)	Total ash(%)	Carbohyd rate (%)	Energy value (kcal)
352	7.26[c]± 0.07	5.13[a] ± 0.06	3.77[b]±0.31	3.13[b]±0.24	1.36[c]±0.08	81.36[a]±0.49	302.10± 0.15
532	8.38[a]± 0.10	4.83[b]± 0.06	2.56[c]±0.04	2.43[c]±0.13	3.04[a]±0.12	73.75[b]±0.10	306.48 ± 0.03
523	7.74[b]± 0.30	4.33[c] ± 0.21	3.87[a]±0.25	4.10[a]±0.18	2.61[b]±0.02	77.36[c]±0.81	311.40± 0.01

*Values are Means±StandardDeviation (SD) of triplicate samples; means with different superscripts in the same column were significantly different (p< 0.05).
Sample 352: orange flesh sweet potato flour; Sample 532: Plantain flour; Sample 523: Yam flour

3.2 Functional properties of flours of yam, plantain and orange-fleshed sweet potato

The functional properties of yam, plantain and orange-fleshed sweet potatoflour derived from various cultivars are presented in Table 2.The bulk density (g/cm^3) of the yam flour, potato flour, and plantain flour exhibited significant variation ($p<0.05$). Ranging from 0.45 to 0.59 g/cm^3, the bulk density of the flour samples plays a crucial role in determining packaging requirements, material handling, and application in the wet-processing food industry (Km & Veteran, 2021). Flour with lower bulk density offers advantages in bulk storage and transportation.

Water absorption capacity (WAC), which measures the flour's ability to retain water, significantly differed among the produced flours. The WAC ranged from 2.34 to 6.93 g/cm^3, this property influences the flour's ability to form a paste and impacts physicochemical properties in various food products such as soup, dough, and baked goods

(Awuchi et al., 2019). Low water absorption capacity suggests a compact molecular structure, while a high value indicates a loose structure of starch polymers, making it suitable for composite flour in bread making (Cornejo-Ramírez et al., 2018)

The swelling index of the flours varied significantly ($p<0.05$), with results ranging from 1.35 to 1.71 g/cm^3. Sample 523 exhibited the lowest swelling index (1.35 g/cm^3), while the highest was recorded for sample 532. This aligns with findings reported by Ukom et al.(2018), on the effect of processing on cocoyam flour which ranged from 1.26 to 2.00 g/ml. The swelling index reflects the extent of associative forces within the granules which indicate the presence of amylase influencing the quantity of amylase and amylopectin present in the flour (Awuchi et al., 2019). Therefore, higher swelling power implies higher associative forces.

Table 2: Result for the Functional Properties of the flour

Sample code	Bulk density(g/cm^3)	Swelling capacity(g/cm^3)	Water absorption index (g/cm^3)
352	$0.59^a \pm 0.01$s	$1.47^b \pm 0.01$	$2.34^c \pm 0.01$
532	$0.45^c \pm 0.01$	$1.71^a \pm 0.01$	$6.93^a \pm 0.15$
523	$0.50^b \pm 0.01$	$1.35^c \pm 0.01$	$4.89^b \pm 0.01$

*Values are Means ± standard deviation (SD) of triplicate samples; means with different superscripts in the same column were significantly different ($p< 0.05$).Sample 352: orange flesh sweet potato flour; Sample 532: Plantain flour; Sample 523: Yam flour

3.3 Sensory Evaluation
The sensory evaluation results are summarized in Table 4. sample 532 (plantain flour) received the highest ratings across all parameters, indicating superior sensory characteristics. Notably, sample 532 was particularly favoured for its colour, with significantly higher ratings compared to the other samples. Conversely, sample 523 received the lowest rating for colour, likely due to the darkness of the 'amala' attributed to the yam variety used.

Regarding taste, panellists showed a preference for sample 532 (plantain flour 'amala') over the other samples, with

significant differences observed only for this sample. The processing method and cultivar type likely influenced these variations.Texture ratings for the 'amala' ranged from 8.20 to 7.40, while sample 532 consistently received the highest ratings. While no significant difference was observed between samples 352 and 523, sample 532 stood out for its superior texture.

In terms of overall acceptability, sample 532 (plantain flour) emerged as the preferred choice, receiving the highest rating. Samples 352 and 523 were not significantly different from each other, both receiving favourable ratings.

Table3: Sensory EvaluationAmala Samples

Sample code	Appearance	Colour	Taste	Texture	Overall
352	$7.70^a \pm 1.26$	$7.20^b \pm 1.24$	$7.75^a \pm 1.02$	$7.40^a \pm 1.19$	$7.60^a \pm 1.35$
532	$7.90^a \pm 1.07$	$8.05^a \pm 0.89$	$7.95^a \pm 1.36$	$8.20^a \pm 0.95$	$8.35^a \pm 0.88$
523	$7.15^a \pm 1.53$	$6.80^b \pm 1.58$	$7.55^a \pm 1.61$	$7.50^a \pm 1.47$	$7.70^a \pm 1.17$

Values are mean ± standard deviation (SD) of triplicate samples; means with different superscripts in the same column were significantly different ($p< 0.05$).Sample 352: orange flesh sweet potato flour; Sample 532: Plantain flour; Sample 523: Yam flour

4.0 Conclusion
Since 'Amala' from yam were the commonly accepted one, the research work 'Amala' made from plantain and sweet potato has no significant difference in the nutritional compositions, functional properties and sensory evaluation. Plantain and sweet potato were generally underutilized in this part of the world but were beneficial for individuals with diabetes, offering comparable functionality to yam flour ('amala'), a commonly consumed staple. Notably, the presence of fibres in sweet potatoes offers various health benefits, including a reduced risk of diabetes and improved gut health. Therefore, incorporating these flours into diets can contribute to overall health and well-being, especially for individuals

managing diabetes or seeking to enhance their dietary fibre intake.

REFERENCES
Adenekan, M. K., Odunmbaku, L. A., & Lawal, O. A. (2021). Effect of Pre-Treatment Conditions on the Anti-Nutrients of Dried Unripe Plantain (Musa Parasidiaca) and the Application in Dough Making. *International Journal of Advances in Engineering and Management (IJAEM)*, *3*(8), 1268–1274.

Agume Ntso, A. S., Njintang, Y. N., & Mbofung, C. M. F. (2017). Physicochemical and pasting properties of maize flour as a function of the interactive effect of natural-fermentation and roasting.

Journal of Food Measurement and Characterization, 11, 451–459.

Ajiboye, A. O., & Shodehinde, S. A. (2022). Diet supplemented with boiled unripe plantain (Musa paradisiaca) exhibited antidiabetic potentials in streptozotocin-induced Wistar rats. *Journal of Food Biochemistry*, 46(12), e14431.

Alam, M. K. (2021). A comprehensive review of sweet potato (Ipomoea batatas [L.] Lam): Revisiting the associated health benefits. *Trends in Food Science & Technology*, 115, 512–529.

AOAC. (2005). *Official method of Analysis.* (18th ed.). Association of Official Analytical Chemists, Washington DC.

Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The functional properties of foods and flours. *International Journal of Advanced Academic Research*, 5(11), 139–160.

Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology*, 52, 3681–3688.

Chandrasekara, A. (2018). Roots and tubers as functional foods. *Bioactive Molecules in Food. Reference Series in Phytochemistry. Springer, Cham. 10,* 978–3.

Cornejo-Ramírez, Y. I., Martínez-Cruz, O., Del Toro-Sánchez, C. L., Wong-Corral, F. J., Borboa-Flores, J., & Cinco-Moroyoqui, F. J. (2018). The structural characteristics of starches and their functional properties. *CyTA-Journal of Food*, 16(1), 1003–1017.

Jenfa, M. D., Adelusi, O. A., Aderinoye, A., Coker, O. J., Martins, I. E., & Obadina, O. A. (2024). Physicochemical compositions, nutritional and functional properties, and color qualities of sorghum–orange-fleshed sweet potato composite flour. *Food Science & Nutrition*, 12(4), 2364–2378.

Joshi, A. U., Liu, C., & Sathe, S. K. (2015). Functional properties of select seed flours. *LWT-Food Science and Technology*, 60(1), 325–331.

Km, R. K., & Veteran, J. (2021). The physicochemical properties of white sorghum (Sorghum bicolor L.) flour in various particle sizes by soaking the seeds before and after dehulling. *Food Research*, 5(3), 129–143.

Oluwamukomi, M. O., & Lawal, O. S. (2020). Textural characteristics of Nigerian foods. *Textural Characteristics of World Foods*, 361–383.

Osunrinade, O., Phillips, A., & Alabi, A. (2023). Physical properties, proximate composition and sensory acceptability of gluten-free cookies from sweet potato using shea butter as shortening. *Acta Periodica Technologica*, 54, 165–175. https://doi.org/10.2298/APT2354165O

Oyeyinka, B. O., & Afolayan, A. J. (2019). Comparative evaluation of the nutritive, mineral, and antinutritive composition of Musa sinensis L.(Banana) and Musa paradisiaca L.(Plantain) fruit compartments. *Plants*, 8(12), 598.

Reynolds, A. N., Akerman, A., Kumar, S., Diep Pham, H. T., Coffey, S., & Mann, J. (2022). Dietary fibre in hypertension and cardiovascular disease management: Systematic review and meta-analyses. *BMC Medicine*, 20(1), 139.

Sujitha, J., Muneer, M. R., Mahendran, T., & Kiruthiga, B. (2018). *Influence of storage temperature on the quality parameters of wheat flour during short-term storage*.

Tharise, N., Julianti, E., & Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. *International Food Research Journal*, 21(4).

Ukom, A. N., Richard, C. P., & Abasiekong, S. K. (2018). Effect of processing on the proximate, functional and anti-nutritional properties of cocoyam (Xanthosoma Maffa (Scoth)) flour. *Nigerian Food Journal*, 35(2), 9–17.

ANTHROPOMETRIC INDICES AND COGNITIVE PERFORMANCE OF SCHOOL-AGE CHILDREN IN SAGAMU, OGUN STATE, NIGERIA.

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ABSTRACT
This study examined the anthropometric status and cognitive performance of school-age children in Sagamu, Ogun State, Nigeria. A descriptive cross-sectional survey with multistage sampling approaches was carried out on 250 school children, to gather data on their socio-demographic characteristics. The World Health Organization's Anthro Plus software was used to calculate body mass index for age, height for age, and nutritional status using the anthropometric assessment approach. Additionally, the respondent's academic performance was evaluated through the use of a cognitive questionnaire, which included questions about drawing the human figure, thinking patterns, numerical recall, and sentence structure. Results showed that the respondents' mean weight, height, age, and gender did not differ significantly. The nutritional state of the respondent showed that, while 65.2% had a normal BMI-for-age, (28.4%), (5.6%), and (0.8%) were mildly, moderately, and severely thin respectively. Of the respondents, a majority had a normal nutritional status, 36, 11.2, and 1.2% were mildly, moderately, and severely stunted. In addition, nearly all the respondents performed well academically in terms of number recall; around 90% are very excellent at pattern reasoning. In conclusion, anthropometric indices were found to be significantly correlated with students' cognitive ability.

Keywords: Anthropometric indices, Academic performance, School-age children, Nutritional status, Health

1.0 INTRODUCTION

Worldwide, it is estimated that over 200 million school-age children are overweight and stunted, making malnutrition in this population a major public health concern (UN-IGME, 2019). It is believed that malnutrition is a pathological condition caused by an inconsistent diet. Based on the quantity of energy and other nutrients ingested, it can be roughly classified as either under or over-nutrition. Inadequate consumption of foods high in energy and other essential nutrients for growth, survival, and reproduction leads to undernutrition (Ngo, Ortiz-Andrellucchi & Serra-Majem, 2016).

Amare, Benson, Fadare, and Oyeyemi (2018) reported that the prevalence of stunting in Nigeria differs by geopolitical zone, with the North-West reporting a 55% prevalence and the South-East reporting a 16% prevalence. School-age children (SAC) who eat diets high in starchy staples and low in fresh produce, meat, and dairy products are more vulnerable to undernutrition and its effects. This is due to the possibility of vitamin deficits brought on by such diets (Moursi, Arimond & Dewey, 2008).

According to Grantham-McGregor, Walker, and Chang (2007), about 200 million children under the age of five do not reach their full potential in terms of cognitive development because of a combination of malnourishment, diseases, poverty, and poor care. Cognitive performance is the mental process through which an individual applies perception, reasoning, memory, learning, and attentional skills to process information (Udani, 1992).

Poorer academic performance is associated with both hunger and undernutrition, which both impact cognitive function (Zerga, Tadesse, Ayele & Ayele, 2022). Children who endure malnutrition during the most developmental years of their brains score substantially worse on reading, vocabulary, mathematics, and general knowledge assessments (Brown & Pollitt, 1996). Research has shown that undernourishment throughout the school-age period has a significant impact on children's cognitive and motor skills (De Onis & Branca, 2016; Adedeji, John, Okolo, Ebonyi, Abdu & Bashir, 2017).

Protein-energy malnutrition (PEM) has several impacts on SAC, one of which is decreased physical and mental development. This has to do with students enrolling in school late or not at all (Gibson, Manger, Krittaphol, Pongcharen, Gowachirapa, Bailey &

Winichagoon, 2007**;** Lodhi, Rahman, Lodhi, Wazir, Taimor, &Jadoon, 2010)**.** It's also important to keep in mind that children who seem to be eating well and getting enough calories for their daily activities may nevertheless be suffering from "hidden hunger" brought on by vitamin inadequacies. Stunting, a decreased IQ, and even death are risks associated with deficiency in certain micronutrients, such as iodine, zinc, iron, and vitamin A (WHO, 1999).

Furthermore, because many children in less developed countries do not complete their primary education, and those who completed did not perform as well as children in developed countries, many researchers are interested in the relationship between nutrition, health, and educational achievement of the school-age population in these countries Several studies in developing countries found out that height- for -age, which is an indicator for stunting, is related to educational achievement (Adepoju & Cooker, 2019)**.**

Thus, the current study aims to determine the anthropometric indices and cognitive performance of school-age children in Sagamu, Ogun state, Nigeria.

2.0 MATERIALS AND METHODS

Research design and sampling techniques
The study's design was descriptive and cross-sectional. The research population was selected using a multi-stage sampling technique that included a purposive selection of Sagamu, a random selection of five out of the fifteen political wards, and a systematic selection of pupils (respondents) from primary four through primary six at regular intervals.

Sample Size Determination
Gibson's 2007 formula was used to calculate the sample size;

$$N = \frac{Z^2 P(1-P)}{d^2}$$

Where N= sample size

Z= the standard normal variable for a 95% confidence level is: 1.96

P= prevalence of stunting in Ogun state is 17.4% (Idowu et al., 2011).

Q= 1-P (1-0.174) = 0.826

D = the desired level of precision at 5% (0.05)

$$N = \frac{1.96^2 X 0.174 X 0.826}{0.05^2} = \frac{3.8416 X 0.144}{0.0025} = 220$$

10% was added to account for non-response

0.10 x 220 =22

220 + 22 = 242, it was rounded off to 250.

The total number of respondents that were assessed during the research was 250.

Data collection

Data collection was done with the aid of a semi-structured questionnaire with the following sections; socio-demographic characteristics where information on respondent's age, sex, family structure, religion, and other personal data of the respondents was obtained, academic performance, and Anthropometric measurement.

Anthropometric measurements

The participant was told to stand with their backs to the height metre and their heads resting on it to measure the pupil's height barefoot using a height metre. It was requested of the respondent to look straight. The meter's headpiece was pressed flat or lowered to the level of the hair before the measurement was taken and recorded, with a precision of 0.1cm. A digital bathroom scale, calibrated regularly to ensure accuracy, was used to measure weight. Readings were taken twice to ensure precision. The weight was measured in kilograms (kg). Thereafter, height-for-age, weight-for-age, and BMI-for-age indices were derived from anthropometric parameters.

Academic performance.

The respondents' grades from prior promotion exams were used to evaluate the student's academic achievement. A questionnaire covering numerical recall, pattern recognition, and human anatomy drawing was also given out. The student's overall performance was divided into three categories: poor, good, and very good.

Statistical/Data analysis

The data collected was subjected to both descriptive and inferential statistics. Descriptive statistics such as percentage, frequency, chart, mean and standard deviation were used. The chi-square test was used to test for the statistically significant association between the anthropometric indices and cognitive performance of the pupils using Statistical Package for Social Science (SPSS) version 20.0. Z-score for Height-for-age (HAZ) Weight-for-age, (WAZ), and Body mass index-for-age (BMIZ) were used to define stunting, underweight, and thinness, respectively using a cut-off value of <-2 standard deviations from the median value of the references, using WHO-Anthroplus software.

3.0 RESULTS AND DISCUSSION
Results

Table 1 shows the socio-demographic characteristics of the respondents. The majority of the respondents (51.6%) were between the ages of 8-10 years, most (56.4%) were male, while 56.8% were in primary 4-6. The result also shows that more than half (56%) of the respondents were Christian, 31.2% of the respondents occupied third position in the family while 16% of the respondents belonged to other birth ranges other than first and second.

Table 1: Socio-demographic characteristics (SDC) of respondents

Variables	Frequency	Percentage (%)
Age range		
6-7 years	17.0	6.8
8-10 years	129.0	51.6
11-12	104	41.6
TOTAL	**250.0**	**100**
Sex		
Male	140.0	56.0
Female	109.0	43.6
NR	1.0	4.0
TOTAL	**250.0**	**100**
Class		
Primary 1-3	107.0	42.8
Primary 4-6	142.0	56.8
NR	1.0	4.0
TOTAL	**250.0**	**100**
Religion		
Christianity	140.0	56.0
Islam	106.0	42.4
Others	4	1.6
TOTAL	**250.0**	**100**
Position of the child		
First born	55.0	22.0
Second born	77.0	30.8
Third born	78.0	31.2
Others	40.0	16.0
TOTAL	**250.0**	**100**

The mean weight, height, and age of the respondents were 31.25±5.89, 133.25±6.73 and 116.12±15.91 respectively for males while females had a mean weight, height, and age of 30.61±5.29, 132.42±7.59 and 114.80±16.31 respectively. There was no significant difference (P>0.05) between the mean weight, height, age, and gender of the respondents as evident in table 2 below.

Table 2: Mean and standard deviation of anthropometric measurements

Gender	Average Weight Mean ±SD	Average Height Mean ±SD	Average Age Mean ±SD
Male	31.25±5.89	133.25±6.73	116.12±15.91
Female	30.61±5.29	132.42±7.59	114.80±16.31
F	0.78	0.80	0.41
P-value	0.38	0.37	0.52

Significant at (P<0.05)

Table 3 below show the cognitive performance of the respondents. In number recall, almost all the respondents (99.6%) were very good, regarding pattern reasoning, the majority (90%) were very good, 92.4% were very good in sentence arrangement while for drawing the human body, (56.4%) were good and 38.6% of the respondents were very good respectively.

Table3: Cognitive performance of the respondents

Variable (score)	Frequency	Percentage (%)
Number Recall		
Very good (**8-10**)	249	99.6
Good (**5-7**)	0	0
Poor (**< 5**)	1	0.4
Total	250	100.0
Pattern Reason		
Very good (**8-10**)	225	90.0
Good (**5-7**)	11	4.4
Poor (**< 5**)	14	5.6
Total	250	100.0
Sentence arrangement		
Very good (**8-10**)	231	92.4
Good (**5-7**)	6	2.4
Poor (**< 5**)	13	5.2
Total	250	100.0
Drawing human body		
Very good (**8-10**)	94	37.6
Good (**5-7**)	141	56.4
Poor (**< 5**)	15	6.0
Total	250	100.0

With regard to cognitive performance, more than half of the respondents (76.8%) were good, 14.4% were very good and 8.8% were poor respectively as shown in Figure 3.

The table 4 below shows the association between nutritional status and academic performance of respondents. No significant association (P>0.05) was observed between nutritional status and the academic performance of respondents.

Table 4: Association between Nutritional Status and Academic Performance

	Height for age					
	Normal	Mildly Stunted	Moderately Stunted	Severely Stunted	χ²	P-Value
Academic performance						
Excellent/very good	39 (15.6)	24(9.6)	5(2.0)	0(0.0)		
Good	69(27.6)	46(18.4)	20(8.0)	2(0.8)	6.24	0.40
Fair/average	21(8.4)	20(8.0)	3(1.2)	1(0.4)		
	BMI for Age					
	Normal	Mildly Thin	Moderately Thin	Severely Thin	χ²	P-Value
Academic performance	X²	Df	P-value			
Excellent/very good	49(19.6)	17(6.8)	1(0.4)	1(0.4)		

Good	88(35.2)	38(15.2)	10(4)	1(0.4)	5.62	0.47
Fair/average	26(10.4)	16(6.4)	3(1.2)	0(0.0)		

In table 5 below, a significant association (P<0.05) was observed between nutritional status (height for age and socio-demographic characteristics such as age. Also, a significant relationship was observed between BMI for age status, class and position in the family.

Table5: Association between nutritional status and socio-demographic characteristics

	Height for Age			BMI for age		
Socio-demographic	χ^2	df	P- value	χ^2	df	P-value
Age	14.37	6	0.03*	7.03	6	0.32
Sex	5.72	3	0.13	4.78	3	0.12
Class	12.91	9	0.13	22.26	9	0.01*
Religion	5.93	6	0.43	5.63	6	0.47
Position in the family	23.23	6	0.08	18.14	15	0.4*

Statistically significant (p<0.05) *
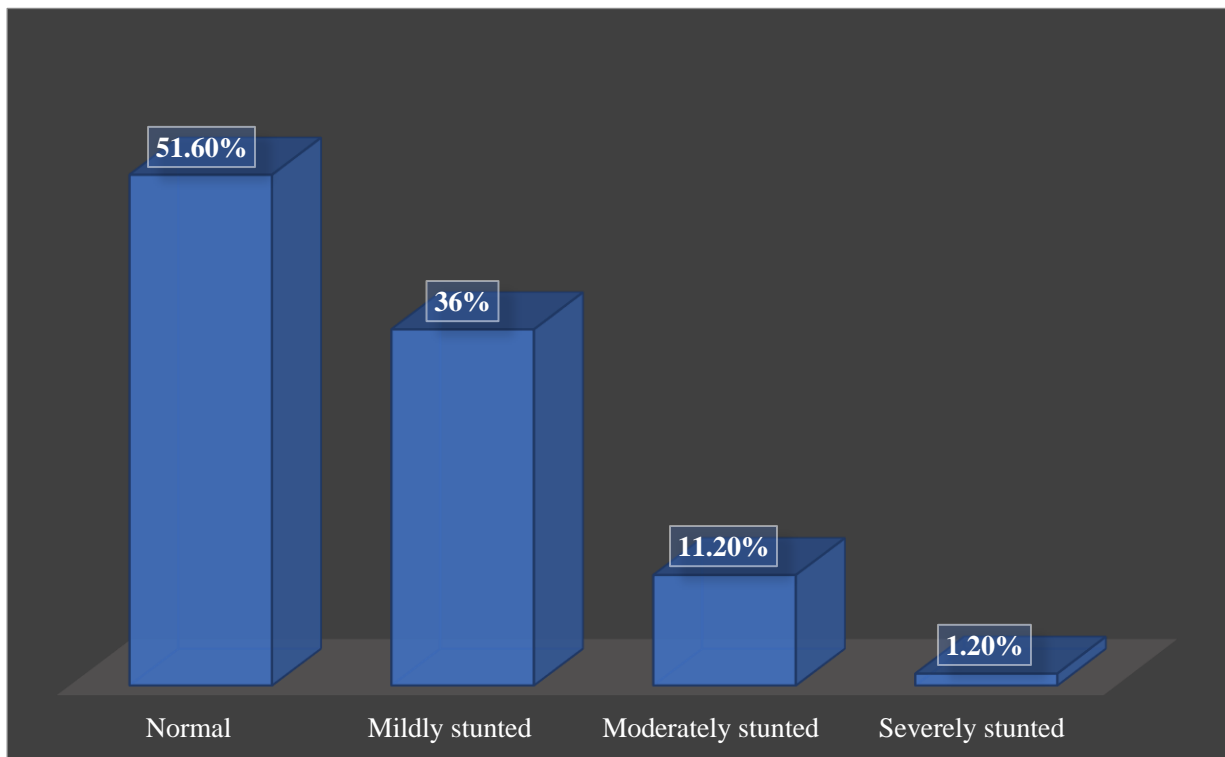
Nutritional status of the respondents

Figure 1: Height for Age status of the respondents

Figure 1 shows the height for age status of the respondents. It revealed that half (51.6%) of the respondents had normal height for their age, while 36% were mildly stunted, 11.2% were moderately stunted and 1.2% were severely stunted.
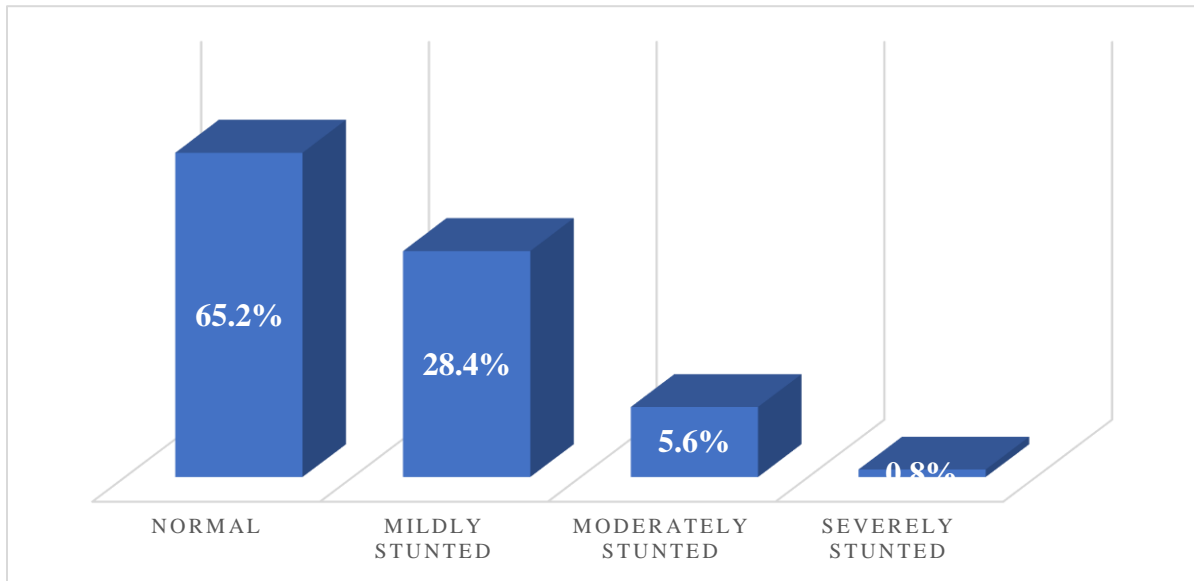
Figure 2: BMI for age of respondents

Figure 2 shows the BMI (Body Mass Index) for the age status of respondents. It revealed that the majority (65.2%) of the respondents had normal body mass index for age, while 28.4% were mildly thin, 5.6% were moderately thin and 0.8% were severely thin.
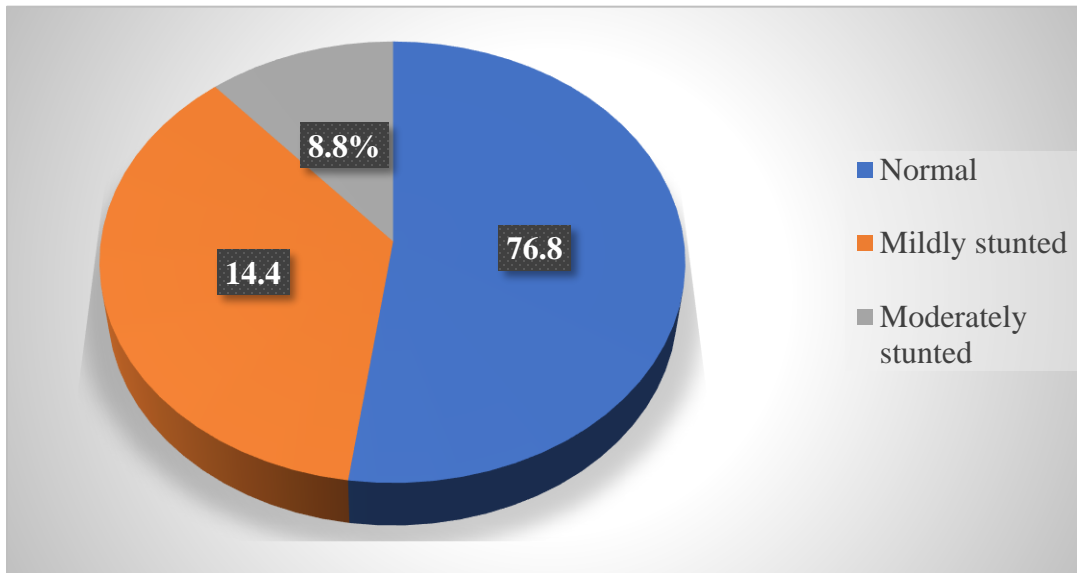
Figure 3: Shows the overall cognitive performance of the respondents

DISCUSSION

The school-age group has higher nutritional needs than the preschool years since it is a dynamic time of active growth and mental development in childhood. To maintain the need, malnutrition among this age group continues to be a serious public health issue in developing nations (Fontanilla. Catza. Nano, & Adaya, 2023). Over the years, several studies have been carried out in different parts of Nigeria to investigate the connection between childhood malnutrition and cognitive performance; however, none

of them have been carried out in Sagamu, Ogun state, Nigeria. Therefore, there is no information available about childhood malnutrition in this area.

According to the SDC results, the majority of respondents (56.0%) were male and between the ages of 8 and 9; most were in primary 4 to 6 (56.8%) and 56.2 percent identified as Christians. These findings are consistent with the study of Olwedo, Mworozi, Bachou, & Orach, (2008). In a study conducted by Adepoju and Cooker

(2019), 99.3% of the respondents were between the ages of 6 and 10 years old, and more than half (61.7%) of the respondents identified as Christians. The bulk of respondents in this survey were the family's second (30.8%) and third (31.2%) born children, which aligns with a study by Acham, Kikafunda, Malde, Oldewage-Theron, and Egal (2012).

Male mean weight, height, and age (31.25±5.89, 133.25±6.73, and 116.12±15.91) were found to be substantially closer to female mean values (30.61±5.29, 132.42±7.59, and 114.80±16.31) respectively according to the respondents' mean anthropometry. The respondents' mean weight, height, age, and gender did not differ significantly (P>0.05). Similar results were obtained in the study undertaken in Southern Nigeria by (Omuemu & Ogboghodo, 2020). Stunting is a sign of past or long-term undernutrition, wasting is a sign of present undernutrition, and being underweight is a convenient synthesis of both past and present undernutrition. Stunting, wasting, and underweight prevalence were shown to be indicators of undernutrition in the current investigation. The respondents' height concerning their age was measured. The data showed that 51.6% of the participants had normal height for their age, 36% had mild stunting, 11.2% had moderate stunting, and 1.2% had severe stunting. This suggests that nearly half of the respondents assessed in this study were stunted. Nevertheless, this data still reveals a significant number of nutritional status departures from the norm. This is at odds with a study by Acham et al. (2012) in Ghana, where a higher number of respondents (56.7%) were stunted. Furthermore, a 2019 study by Adepoju and Cooker among a similar population in Ilaro revealed that the respondents had a high prevalence of stunting, with an overall reported percentage of moderate stunting of 50.7% and severe stunting of 3.7%. Variations in location, socioeconomic background, and nutritional consumption may be the cause of the discrepancy. In addition, the respondent's body mass index was determined; it was found that the majority of the respondents (65.2%) had a body mass index that was normal for their age, with the remaining respondents (28.4, 5.6, and 8%) being mildly, moderately, and severely thin, respectively. The study's conclusions represent the nutritional condition of the participants in the research area; eating habits, inadequate nutrition during pregnancy, and a lack of access to food are the main causes of undernourished infants.

When comparing mean cognitive test scores to anthropometric indices, children who are stunted (HAZ < -2SD) and underweight (WAZ < - 2SD) had lower scores than normal. The cognitive test scores were assessed using number recall, pattern reasoning, sentence arrangement, and drawing the human body.

Stunted children showed significantly lower scores in pattern reasoning and number recall when compared to normal children. Underweight children showed significantly lower mean scores in sentence arrangement and school performance, indicating short-term memory.

This adds to the body of evidence demonstrating how poor nutrition negatively influences schoolchildren's cognitive development and academic ability. This result is in line with studies conducted in other developing countries (Taras, 2005). A comparable study from Malaysia that looked at the effects of gender and nutritional status on academic achievement and cognitive function among primary school pupils revealed a negative correlation between stunting and cognitive function (Hanks, Just, Smith, & Wansink, 2012). Undernutrition and

schoolchildren's psychological exam scores were found to be negatively correlated in an Indian cross-sectional study (Kleinman, Hall, Green, Korzec-Ramirez, Patton, Pagano, & Murphy 2002).

CONCLUSION

This study concludes that Stunting was more common among school-age children in Sagamu, Ogun state, Nigeria than other anthropometric indices (underweight and thinness), and the stunted pupils showed significantly lower scores in cognitive evaluation when compared to school-aged children with normal nutritional status**.**

REFERENCES

Acham, H., Kikafunda, J., Malde, M., Oldewage-Theron, W., & Egal, A. (2012). Breakfast, midday meals and academic achievement in rural primary schools in Uganda: implications for education and school health policy. *Food and Nutrition Research*, *56*(1), 11217.

Adepoju, A., & Cooker, O.J. (2019) Nutritional status and academic performance of school-age children in Ilaro. *FEPI-JOPAS*, *1*(1), 1-9.

Adedeji, I.A., John, C., Okolo, S.N., Ebonyi, A.O., Abdu, H., & Bashir, M.F. (2017). Malnutrition and the intelligence quotient of primary school pupils in Jos, Nigeria. *British Journal of Medicine and Medical Research 21*(2), 1-13

Amare, M., Benson, T., Fadare, O., & Oyeyemi, M. (2018). Study of the determinants of chronic malnutrition in Northern Nigeria: quantitative evidence from the Nigeria Demographic and Health Surveys International Food Policy Research Institute (IFPRI) working paper 45 (September 2017). *Food and Nutrition Bulletin*, *39*(2), 296-314.

Brown, J. L., & Pollitt, E. (1996). Malnutrition, poverty, and intellectual development. *Scientific American*, *274*(2), 38-43.

De Onis, M., & Branca, F. (2016). Childhood stunting: a global perspective. *Maternal and Child Nutrition*, *12*, 12-26.

Fontanilla, R. C., Catuiza, F. L., Nano, A. B., & Adaya, A. V. (2023). Nutritional status to academic performance of the school-aged children: a basis for inter-collaborative extension services program. Article in Seybold Report. *18(6):1668-1684 DOL:10.17605/OSF.IO/26F89*

Gibson, R.S., Manger, M.S., Krittaphol, W., Pongcharoen, T., Gowachirapant, S., Bailey, K.B., & Winichagoon, P. (2007). Does zinc deficiency play a role in stunting among primary school children in NE Thailand? *British Journal of Nutrition*, *97*(1), 167-175.

Grantham-McGregor, S. M., Walker, S. P., & Chang, S. (2000). Nutritional deficiencies and later behavioural development. *Proceedings of the Nutrition Society*, *59*(1), 47-54.

Hanks, A.S., Just, D.R., Smith, L.E., & Wansink, B. (2012). Healthy convenience: nudging students toward healthier choices in the lunchroom. *Journal of Public Health*, *34*(3), 370-376.

Idowu, O.S, Kazeem, A.O, Olumuyiwa, O.O, & Olisamedua, F.N (2011)Prevalence of and risk factors for stunting among school children and adolescents in Abeokuta, Southwest

Nigeria. *Journal of Health Population and Nutrition ,29(4):364-370*

Kleinman, R.E., Hall, S., Green, H., Korzec-Ramirez, D., Patton, K., Pagano, M.E., & Murphy, J.M. (2002). Diet, breakfast, and academic performance in children. *Annals of Nutrition and Metabolism*, *46 Suppl 1*(01), 24–30. https://doi.org/10.1159/000066399

Lodhi, H.S., Rahman, M., Lodhi, F.S., Wazir, S., Taimor, A., &Jadoon, H. (2010) Assessment of nutritional status of 1-5-year-old children in an urban union council of Abbottabad. Journal of Ayub Medical College Abbottabad 22(3):124-7

Moursi, M. M., Arimond, M., Dewey, K.G., Treche, S., Ruel, M. T., & Delpeuch, F. (2008). Dietary diversity is a good predictor of the micronutrient density of the diet of 6-to 23-month-old children in Madagascar. *The Journal of Nutrition*, *138*(12), 2448-2453.

Ngo, J., Ortiz-Andrellucchi, A., & Serra-Majem, L. (2016). Malnutrition: Concept, classification, and magnitude. Encyclopedia of Food and Health, 1610-1630 https://doi.org/10.1016/B978-0-12-384947-2.00439-6

Omuemu, V. O., & Ogboghodo, E. O. (2020). Nutritional factors and academic performance of primary school children in an urban city in Southern Nigeria. *Journal of Health and Medical Sciences*, *3*(3).

Olwedo, M. A., Mworozi, E., Bachou, H., & Orach, C. G. (2008). Factors associated with malnutrition among children in internally displaced person's camps, northern Uganda. *African Health Sciences*, *8*(4), 244-252

Taras, H. (2005). Nutrition and student performance at school. *Journal of School Health*, *75*(6), 199-213.

Udani, P.M. (1992). Protein-energy malnutrition (PEM), brain, and various facets of child development. *The Indian Journal of Pediatrics*, *59*, 165-186.

UNICEF-IGME (2019). Levels and trends in child mortality. *New York: UNICEF*. UN-IGME-child-mortality-report-2019.pdf (unicef.org) Retrieved 24 June 2024
World Health Organization. (1999). Management of severe malnutrition: a manual for physicians and other senior health workers (who. int)

Zerga, A. A., Tadesse, S. E., Ayele, F. Y., & Ayele, S. Z. (2022). Impact of malnutrition on the academic performance of school children in Ethiopia: A systematic review and meta-analysis. *SAGE Open Medicine*, *10*, 20503121221122398.

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DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A WALK-BEHIND DRIVEN MONO WHEEL AGRO-CHEMICAL BOOM SPRAYER.

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ABSTRACT

The rural subsistence agricultural farmers require a technologically improved boom sprayer for spraying agro-chemicals. This will protect crops from pests and disease attacks to improve yield. Farmers use ordinary knapsack sprayers for spraying by pushing the lever up and down to create the needed pressure for spray. This is time-consuming, accompanied by the operator's drudgery leading to a small area of farmland being covered. This research aimed at increasing field performance capacity with minimal man-hour input to reduce drudgery. The designed equipment was constructed using a 20-litre capacity tank and four (4) precision nozzles for breaking liquid into droplets of effective sizes, distributing them uniformly over the surface to be applied using a slider crank mechanism. This was regulated using a hand-operated pressure regulator to avoid excessive application that might prove harmful and wasteful. At an average forward travel speed of 4 km/hr, the equipment TFC calculated was 1.04 ha/hr. For every 0.31 hectare of field coverage after 18 minutes, only 4 times of refilling was required; the AFC evaluated was 0.89 ha/hr while the FE of the equipment calculated was 86 % having an optimal uniformity of coverage.

Keywords: Agriculture, Boom sprayer, Agrochemicals, Subsistence, Farmer.

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1.0   INTRODUCTION

We are living in a world of energy saving. It is easy to predict that energy saving will be of interest in the application of agrochemicals on agricultural fields where chemicals are widely used for controlling plant diseases, insects and weeds on crops because they can save crops from insects and pest attack when applied timely and efficiently. Agro-chemicals, a man-made or natural preparation are used to kill insects, pests, rodents, fungi and weeds. Farmers can save an agricultural crop from their attacks by improving the growing of crops with agrochemical applications. These agrochemicals are applied to crops with the help of a special device known as a sprayer which provides optimum performance with minimum efforts (Angadi et al., 2017). Also, agrochemicals are costly, therefore, the design of equipment with lower cost for Small and Medium Scale (SMS) farmers with a uniform and effective application becomes essential. The new invention of a sprayer brings a revolution in the agriculture or horticulture sector, this enables farmers to obtain the maximum agricultural output.

According to Gandhare et al. (2015), the main function of a sprayer is to break the liquid into droplets of effective size and distribute them uniformly over the surface or space to be protected. Another function is to regulate the amount of insecticide to avoid excessive application that might prove harmful or wasteful. A sprayer that delivers droplets large enough to wet the surface readily should be used for proper applications.   Subbarayudu et al., (2017) stated that there are many advantages of using sprayers such as easy to operate, maintain and handle, it facilitating the uniform spread of the chemicals, capability of throwing chemicals at the desired level, precision made nozzle tip for adjustable stream and capable of throwing foggy spray, light or heavy spray, depending on the requirement. Most SMS farmers use the backpack knapsack sprayer to apply these chemicals on their crops. This is time-consuming with associated human fatigue as a major concern. According to Deshpande *et al.*, (2017); farmers generally use the traditional way of spraying crops with backpack sprayers. These requires carrying the heavy tank at the back and oscillating the lever which requires more effort. The major concern of it operation on farmland is usually time-consuming and accompanied by human fatigue. The conventional sprayer has some difficulties such as it needs a lot of effort to push the liver up and down to create the pressure to spray. For the Nigerian SMS farmers' overcome these difficulties, there exists a need to design and fabricate an economically affordable single-wheel boom sprayer to encourage the mechanization of Small

and Medium Scale (SMS) farming activities within the Nigerian agricultural productive sector. This 20–litre tank boom sprayer was designed to be energy-efficient and easy to operate and maintain. The single-wheel boom sprayer is an improvement on the manual knapsack sprayer using a simple technology of non-conventional mechanical energy that minimizes human energy application, increases operators' self-reliance, and reduces weight impact on the soil by the use of a single wheel. The equipment utilizes the slider crank mechanism for it operation. The rotary wheel motion is transmitted by chain and sprocket arrangement to the slider-crank. The slider crank moves in a reciprocating order to generate an in-built pressure within the tank with the aid of a piston. This pressure is released as a force required for agrochemical spraying operations on vegetable and forage, cereal and grains, and root and tuber crop fields with accessible walkways. The specific objective of this research work is to design, construct and evaluate the performance of a fuelless boom sprayer, capable of discharging a boom of agrochemicals of effective sizes with minimal total volume utilization at high operational efficiency for agricultural farm applications.

2.0 MATERIALS AND METHOD cost and time effectiveness

2.1 Design Considerations

a. The following were taken into consideration when designing the walk-behind mono-wheel operated boom sprayer:
b. Capacity of the agro-chemical storage tank.
c. Agro-chemical wastage minimization using precision nozzles.
d. Adjustable height and width of boom spray to suit various field crop heights.
e. Size and number of nozzles to determine the extent of spray boom (field coverage)
f. The relative effect of sprocket diameter to high-pressure creation inside nozzles
g. Ease of maintenance and availability of original equipment manufacturers' (OEM) spares were adequately considered.

To enhance the reliability, work-ability, and stability of equipment on agricultural fields, the following were considered while designing the equipment:

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a.   The cost of designed equipment should be low.

b.   The Materials of construction should be durable, readily available and efficient.
c.   Mode of operation and adjustment of the equipment should be comparatively simple.
d.   The equipment should be portable to handle.

e.   The equipment should be easy to maintain.

2.2 Component Parts

The main components of the walk behind single wheel agro-chemical boom sprayer are as follows:

a.   A 16B – 1 inch 18 size teeth sprocket gear on which the chain passes over.
b.   No. 50 size sprocket chain made of steel was used to transmit the rotary tyre wheel motion to the crank mechanism
c.   A 3.00 – 17 rim size rotary tyre wheel was used for the motion of the equipment from one place to another.
d.   The pump consisted of a piston and cylinder arrangement with a lever which generated a pressure of 2 bar delivered to the spray nozzles.
e.   The four (4) spray nozzles converted the pump-generated pressure energy in chemical fluid into kinetic energy for distribution over the desired farmland area.
f.   An assembly frame with dimension of 1,200 to 600 mm long and wide respectively, was designed and constructed using an angular iron bar and a $1\frac{1}{2}$ circular hollow steel. This was strong enough to withhold the entire weight of the assemblage without any failure.
g.   A 20 litres capacity high density polyethylene plastic chemical tank, were utilized for the purpose of this research work.

2.3 Working Principle

The working principles of this equipment were as follows:

a.   Motion transmission by chain and sprockets arrangement.

b.   Slider crank mechanism.

c.   Rotary motion converted into reciprocating motion
The operator grabs the handle and pushes the rotary tyre wheel forward which in turn rotates the mounted gear sprocket at equal speed through a chain connection. The corresponding rotary motion of the gear sprocket was converted into an oscillating motion by a crank mechanism arrangement and the tank pump lever to generate an in-built fluid pressure inside the agrochemical tank with the aid of the pump. The in-built pressure sucked in the fluid inside the pump with the aid of the piston and cylinder arrangement. This was forced out to the arranged number of nozzles on the boom shaft through a connected hose line to spray the chemical. The pressure required for spraying was regulated with the aid of a special arrangement at the operator's handle for the equipment. By using this, pumping was stopped while the wheel rotated freely when boom spraying of chemicals was not required. Also, the height, position and angle of the nozzles were adjustable.

2.4 Design Analysis

2.4.1 Selection of Pinion

Minimum no. of teeth available on pinion = 18

Outer dia. Of pinion = 0 mm

Inner dia. Of pinion = 5 mm

Pitch circle diameter (Dp) = $\frac{D0-Di}{2}$ + (Di) …………………... (1) (Ajit, K. 2012)

= $\frac{80-65}{2}$ + (65)

Dp = 72.5mm

Gear Ratio = 1:3

On rotation of the gear sprocket gives three rotations of the pinion sprocket, we required three strokes to generate an adequate amount of pressure.

2.4.2 Selection of Gear Sprocket

Plate 1 Gear sprocket

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$$\frac{1}{3} = \frac{tp}{tg}$$

$$\frac{1}{3} = \frac{18}{tg} = tg = 18 \times 3$$

$$tg = 54$$

$$\frac{tp}{tg} = \frac{Dg}{Dp} = \frac{3}{1} = \frac{Dg}{72.5} \quad \ldots\ldots\ldots\ldots\ldots \text{ (2) (Ajit, K. 2012)}$$

Dg = 218mm

$$\text{Pitch} = \frac{number\ of\ teeths\ on\ pinion}{pitch\ circle\ diameter\ of\ pinion} = \frac{18}{72.5} = 0.25\text{mm}$$

2.4.3 Selection of Chain

Chain type: roller chain with ISO Chain no. 05B pitch = 0.25 mm

Length of chain, L = K.P

Where:

K is the No. of chain and P represents the pitch of the chain teeth

No. of chain, $K = \frac{T1+T2}{2} + \frac{2x}{P} + \frac{T2-T1}{2\pi} \times \frac{P}{X}$ … (3)   (Ajit, K. 2012)

$$\frac{18+54}{2} + \frac{2 \times 478}{0.25} + \frac{54-18}{2\pi} \times \frac{0.25}{478}; \; K$$
$$= 36 + 3824 + 0.00299$$

K = 3860 mm

L = K × P

L = 3860 × 0.25; L = 965 mm;

L = 96.50 cm

2.4.4 Design of structural frame

Plate 2. Dimensioned structural frame

The total Discharge of pesticide through four nozzles is 36.73lit/hour

Length of Frame = 1200 mm

Width of Frame = 600 mm

Height of Frame = 775mm

2.4.5 Nozzle Selection

Design consideration

A_2 = cross sectional area of outlet nozzle, m^2

d_2 = diameter of outlet nozzle in mm

N = speed of the small sprocket in, rpm

V_2 = outlet velocity/s

Q = discharge, m^3/s

2.4.6 Area of the nozzle required:

$A_2 = \frac{\pi}{3} (d_1{}^2 - d_2{}^2)$ ………… (4) (Ajit, K. 2012)

$= \{(10 \times 10^{-3})^2 - (1 \times 10^{-3})^2\}$

$= 7.77 \times 10^{-5} \text{ m}^2$

2.4.7 Required inlet velocity of fluid (chemical)

$V_1 = \frac{\pi d_1 N}{60}$ ……………………….. (5)

$= \frac{3.14 \times 10 \times 10^{-3} \times 250}{60}$

$= 0.130$m/s

2.4.8 Required outlet velocity of fluid (chemical)

$A_1 V_1 = A_2 V_2$ …………………... (6) (FAO, 2004)

$= 7.8 \times 10^{-5} m^2 \times 0.130 = 7.77 \times 10^{-5} \times V_2$

$V_2 = 77.5$m/s

2.4.9 Required outlet velocity per nozzle

$\frac{V_2}{4} = \frac{77.5}{4} = 19.37$m/s

2.4.10 Required maximum discharge volume per nozzle

Q = $A_1 V_1$ …………………….. (7)   (FAO, 2004)

$= 7.8 \times 10^{-5} m^2 \times 0.130$

$= 1.43 \times 10^{-5}$m^3/s

$= 0.01020$ lit/sec

$= 0.612$ lit/min

$= 36.73$ lit/hr

Discharge of one nozzle is 9.18 litres/hour

2.5 Machine Capacity

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While calculating the actual and Theoretical Field capacities (TFC) of the equipment, the sum of the time consumed for real work done and lost time during turning between seedbeds rows, and refilling of the tank, maximum forward travel speed and the width of the monowheel boom sprayer were taken into consideration according to (Sharma, *et al.,* 2010) to determine the field efficiency of the equipment.

2.5.1 Actual Field Capacity (AFC) $= \frac{A}{T}$ ha/hr ……………….. (8)

Where;

A = total area of land covered is 0.31 ha

T = Total time taken

T $_=$ time for turning + time for refilling + time for actual work

 = 3 sec × 20 + 30 sec × 4 + 1080 sec = 0.35 hr

AFC $= \frac{0.31}{0.35} = 0.89$ ha/hr

2.5.2 Theoretical Field Capacity (TFC) ha/hr

This was calculated by (Sharma, et al., 2010).

$$TFC = \frac{Speed \times boom\ width}{10} \text{…………………} (9)$$

= 1.04 ha/hr

Where;

Average forward travel speed = 4 km/hr

Boom width = 3 m

2.5.3 Field Efficiency (FE) %

This represented the ratio of AFC to TFC expressed in % according to (Sharma, et al., 2010).

$$FE = \left(\frac{0.89\frac{ha}{hr}}{1.04\frac{ha}{hr}}\right) \times 100 \text{……………………} (10)$$

FE = 86 %.

3.0   RESULTS AND DISCUSSION

Table 1. Boom Sprayer Total Nozzles Discharge Output per Mililitre in   One Minute (ml/min)

Replicates	Nozzles Discharge (ml)				Average discharge Per Nozzle (ml)	Total Discharge (ml)	Discharge per nozzle (ml/min)
	N1	N2	N3	N4			
R1	610	608	609	611	610	2.438	0.610
R 2	612	610	611	610	611	2.443	0.611
R 3	611	611	612	611	611	2.445	0.611
R 4	612	611	611	612	612	2.446	0.612
R 5	611	612	612	611	612	2.446	0.612

The rate of discharge from each nozzle was measured to determine the amount of chemical discharged while spraying. This was done for each 5-meter interval of 30-meter forward distance covered to determine variations that would occur between the discharge rates for each nozzle at each 5 m interval, the discharge from each nozzle was collected using a bag and measured using a measuring cylinder.

The time taken to cover each interval was recorded, this was used to calculate the discharge rate for each nozzle. The trial for each interval was replicated five times. Results obtained revealed that the total volume of agrochemical discharged and calculated in litres by each nozzle for all trials falls within the range of the calculated required maximum discharge volume as given in equation 7.

Table 2. Swath Widths and Nozzle Adjustment Angles at Different Boom Heights

Replicates	Boom Heights (cm)	Swath width (m)	Nozzle angle (°)
1	125	0.97	44.25
2	105	0.88	43.06
3	85	0.66	41.83
4	65	0.57	38.25
5	35	0.44	31.70
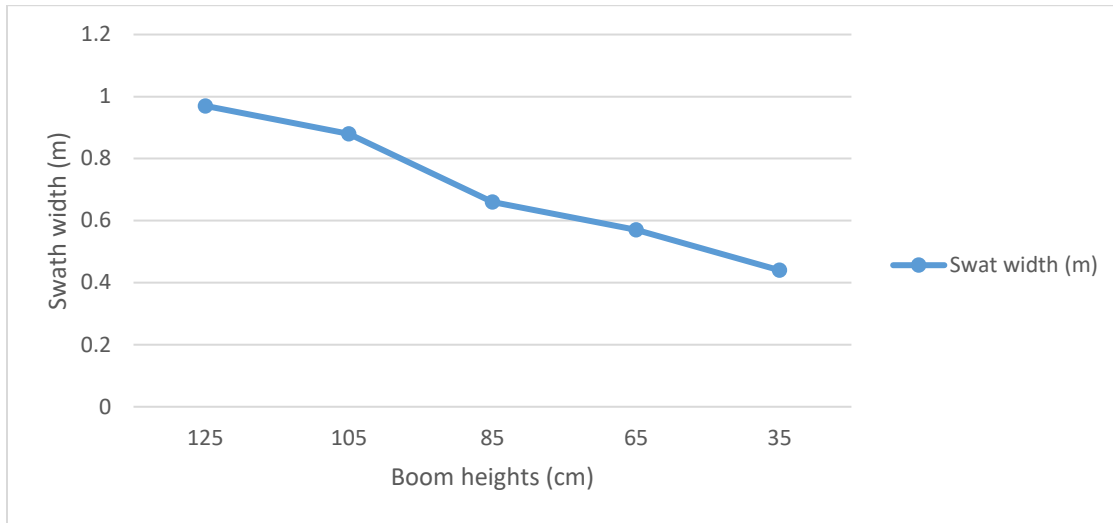
Figure 1: Variation Swath Width with Boom Height

From figure 1, the swath width of the spray increases with increasing boom heights of the equipment. The increase in swath width covered as experienced was directly dependent on the height of the boom spray.
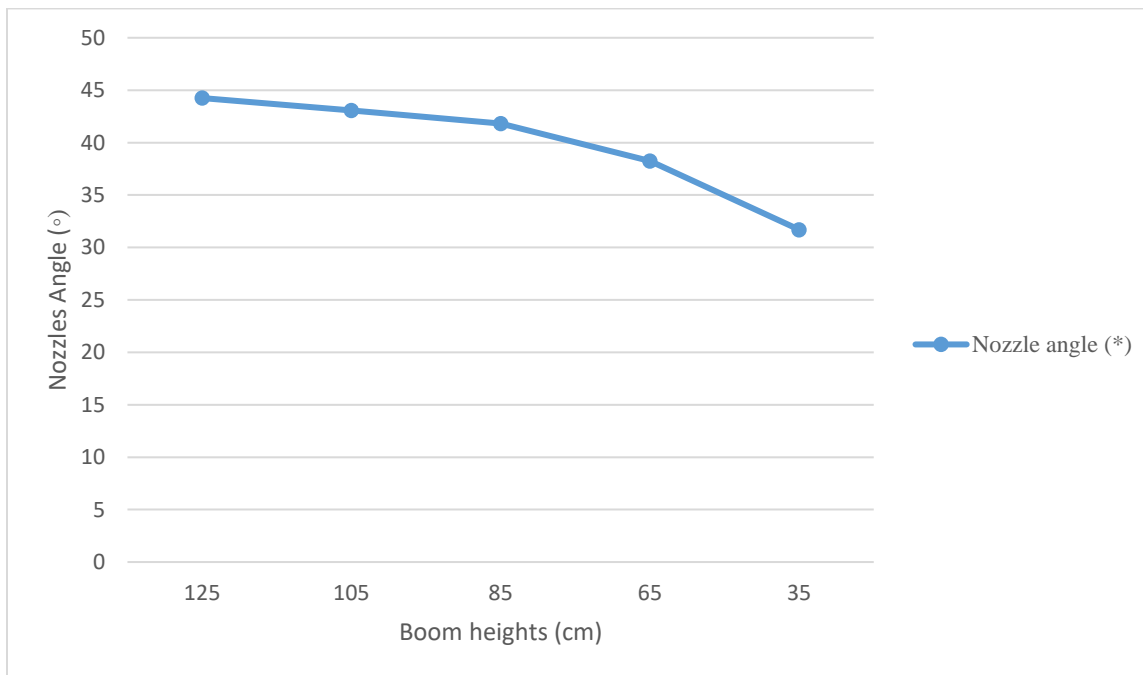
Figure 2: Variation of Nozzle Angles with Different Boom Heights

From Figure 2, the nozzle angle varies with the boom height of the equipment. These variations in angular inclinations of nozzles for every corresponding varying height of the boom ensured optimum swath width spray coverage. According to Sravan (2015), nozzles having boom spray angles less than 110° could reduce the risk of spray drift when using boom nozzle heights of greater than 50 cm. As the spray angles of the mono wheel boom sprayer was less than 110°, the effect of drifts experienced were minimum at height greater than 50 cm.

The mono-wheel boom sprayer nozzle performances were evaluated based on the uniformity of its boom coverage and spray patterns over a maximum area of 0.31 ha. With a TFC of 1.04 ha/hr, the AFC of the equipment was evaluated to be 0.89 ha/hr, while the FE was calculated to be 86 % based on the sum of times consumed for real work done, lost time during turnings between seedbeds rows, refilling of tank, maximum forward travel speed and the width.

4.0 CONCLUSION

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Based on the result achieved, the single wheel boom sprayer when operated at an average speed of 4 km/hr forward travel speed, the average nozzle discharge rate variation along travel distance and attained an optimum discharge rate among the nozzles within 15-20 m distance. With a tank capacity of 20 litres, only 4 times of refilling

RECOMMENDATIONS

Based on the research work carried out and it obtained result from field performance evaluations, the following recommendations were given. The monowheel boom sprayer worked satisfactorily under evaluated field conditions and it can also be used for row crops. The equipment's operational drudgery was minimal making it suitable for subsistence agro-farmers. Owing to its adjustable boom height, it has useful applications in vegetable crop fields, groundnut, and soya-bean and oilseed crops at varying heights. It can only be successively used for spraying agrochemicals of water-soluble formulations.

REFERENCES

Ajit, K. (2012). Engineering Principles of Agricultural Machines, 2nd Edition, American Society of Agricultural and Biological Engineers: 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

Rajashekhargoud, A., Rohit L.G., Changond, S., & Kagale, S. (2017). Cam Operated Agrochemical Pesticide Sprayer*; International Journal of Engineering Research & Technology (IJERT),* 6(01), 278-287.

Deshpande, S.V, Mayur, D., & Swapnil, D. (2017). Agricultural Reciprocating Multi Sprayer. 7th International

was required during it field operation of 18 minutes with an optimal uniformity of coverage. The sprayer's forward speed and spray application were synchronized such that when the sprayer attained the optimal uniform discharge along all nozzles it maintained its uniformity till the next tank refilling operation.

Conference on recent trends in Engineering, science and management. www.conferenceworld.inc.

Food and Agriculture Organization (2004) Agriculture Pesticides Sprayers. FAO technical standards: Sprayer specifications and test procedures: pp 7-8.

Gandhare, S.N, Moon, A., Wairagade, A., Kakade, C., Pathak, N., Moreshiya, R., & Giradkar, V. (2015). Design and fabrication of paddle operated multi-point pesticide spraying machine. *International Journal of Advances in Engineering & Scientific Research,* 2(2), 01-07 ISSN: 2349 –3607.

Sharma, D.N., & Mukesh S. (2010). Farm machinery design principles and problems. Sunikumarjani for Jani brothers, New Delhi.

Kumar, S. (2015). Development and Performance Evaluation of Single Wheel Driven Boom Sprayer. *International Journal of Agricultural Science and Research (IJASR);* 5(5), 277-286.

Subbarayudu, T., & Venkatachalapathi, N. (2017). Modeling and Development of Pedal Operated Agricultural Sprayer. *Australia Journal of Basic and Applied Science (AJBAS)*; 11(11), 122-131.

SPECIES DIVERSIFICATION, A POSITIVE TREND TOWARD NIGERIA'S AQUACULTURE SUSTAINABILITY: A REVIEW.

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ABSTRACT
With its large population of approximately 150 million people, Nigeria has a significant fish demand, estimated at 2.66 million metric tons in 2012. However, local fish production only meets a portion of this demand, producing 1.32 million metric tons annually, of which 0.62 million metric tons come from aquaculture. Though critical for food security and economic diversification, this sector is currently underdeveloped, producing only 200,000 metric tons against a potential of 2.5–4.0 million metric tons. Aquaculture development is essential to meet Nigeria's fish demand and promote economic growth. Nigeria's aquaculture output has increased significantly, with tilapia and catfish being the predominant species. However, further growth and diversification are needed to close the supply-demand gap. Introducing exotic species like Rohu, Pangasius, climbing perch, and common carp presents a viable solution to enhance productivity. These species exhibit favourable traits such as fast growth, high nutritional value, adaptability to diverse environments, and efficient feed conversion. The integration of these species into Nigeria's aquaculture sector could substantially improve fish production, support food security, and provide economic opportunities. This review highlights the current state of aquaculture in Nigeria, the challenges faced, and the potential benefits of diversifying fish species. By leveraging existing infrastructure and addressing key challenges, Nigeria can enhance its aquaculture sector, reduce its fish import dependency, and improve the livelihoods of its citizens.

Keywords: Diversification, species, sustainability, productivity

1.0 INTRODUCTION

FISH FARMING IN NIGERIA

With an estimated 150 million people, Nigeria is the most populous black nation in the world. The anticipated fish demand of its population as of the end of 2012 was 2.66 million tons of fish (Adewumi, 2015). The amount of fish supplied throughout the specified time frame was 1.32 million tons, this amount included 0.62 million tonnes from aquaculture and 0.7 million tonnes from imports. Fish makes for around 40% of Nigerians' annual protein intake, with annual fish consumption ranging from 11.2 to 13.3 kg/person (WorldFish, 2018). Nigeria consumes less protein per person than the average for Sub-Saharan Africa. Significantly, fish is less expensive than other animal protein sources (Sheeska & Murkin, 2002). Fish production has increased to one million metric tons annually. 805,210 metric tons come from fisheries, while 275,645 metric tons come from aquaculture (WorldFish, 2018). The world's fastest-growing food production industry, according to Ayinla (2012), is aquaculture. As a result of wild fisheries reaching their biological limits and the growing demand for cultured fish worldwide, he said, aquaculture production has quadrupled globally over the past 20 years and is expected to treble over the next 15 years. Fish supplies are just 1.32 million metric tonnes annually, compared to Nigeria's 2.66 million metric tons of demand as of 2012. 0.7 million metric tonnes of this total are imported, and 0.62 million metric tonnes are the result of local production.

Nigeria has made significant strides in the development of fish farming and aquaculture over several decades (1950–1992). The second phase of the National Development Plan placed a strong emphasis on removing the main obstacles to the rapid development of aquaculture (Ezenwa, 1994). During the early stages of Nigeria's aquaculture growth, extension programs offered by the government demonstration fish farms at Itu and Opobo in the 1960s and 1970s increased technology adoption and awareness (Ajenifuja, 1998). The ensuing zeal led to a notable individual involvement in fish farming in Nigeria's Niger Delta region (Inyang, 2001). Fish farming has been shown to have the ability to significantly reduce poverty, unemployment, and protein deficiency, however, despite these claims, the region's output has been declining. According to Aina, Kaniki and Ojiambo (1995), information is essential to maintaining and enhancing any country's aquaculture output.

The demand for fish has consistently outpaced the availability over time. The annual national fish demand, estimated in 2005 at 1.5 million metric tons, is significantly greater than the domestic supply, which stands at 0.55 million tons (Dada, 2003). The average annual domestic fish supply, including fish from far-off waters, has never been able to meet demand. Imports have always been used to make up the shortfall. Fish imports made up 27.2% of the total fish supplied in 1990. This has increased to 57.1 % by 2022. Forecasts indicate that the deficit will keep rising. The severity of the mismatch between supply and demand, according to the 2005 report by the Presidential Committee on Fisheries and Aquaculture Development, if the Nigerian EEZ fisheries potential is fully utilized for tuna and deep sea demersal and pelagic resources, it is possible to significantly increase the sector's current contribution to domestic fish production from 27,000 MT to well over 200,000 MT (Raji, 2007). The yearly yield potential of aquaculture is estimated to be 2.5 million metric tons, but according to Musa, Oguntade and Atahiru (2005), the subsector's average contribution to domestic production is 25.2%.

STATE OF AQUACULTURE IN NIGERIA
Aquaculture has grown to be a significant industry in Nigeria for the provision of food, revenue, and jobs. Nigeria is well-positioned to become one of Africa's leading aquaculture-producing nations thanks to its extensive coastline, copious water resources, and pleasant climate. Nigeria has not been exempted from the global trend of rising demand for fish and seafood in recent years. In addition to being important providers of protein and other critical nutrients, fish and seafood also contribute significantly to economic

growth and food security. Unfortunately, overfishing, habitat degradation, and falling fish stocks are just a few of the issues facing Nigeria's capture fishery industry, which has historically provided the majority of the country's fish supply. The production of fish through aquaculture has become more popular as a substitute source of fish due to this. Over the past ten years, Nigeria's aquaculture output has increased at an average yearly rate of 10%, according to the Food and Agriculture Organization of the United Nations (Food

and Agriculture Organisation [FAO], 2021). Nigeria ranked among the top producers of farmed fish in Africa in 2019 with an estimated 136,000 tons of fish generated from aquaculture. Tilapia and catfish, the two most widely cultivated species in Nigeria, account for the majority of the country's aquaculture production. Alongside Nile perch (*Heterotis niloticus*) which is among the other species that are farmed in Nigeria, as indicated in the figure below.
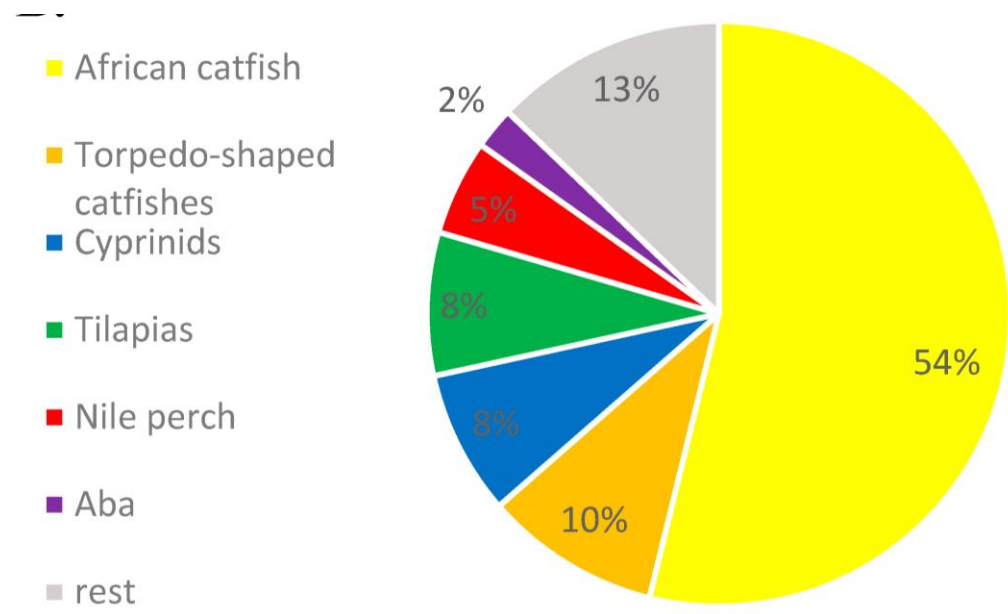

Figure 1: Contribution of the six most relevant species to the total production.
Source: Diversity of the Aquaculture Sector (Fish Statistics, 2006)

The Nigerian government, researchers, and foreign organisations have all contributed to the expansion of the aquaculture industry by giving farmers access to infrastructure, training, and support. Nevertheless, a number of issues still need to be resolved in spite of the aquaculture industry's expansion and promise in Nigeria. These consist of low infrastructure, a shortage of skilled workers, a lack of funding, and restricted market access. The industry has also suffered from the economic recession, which has resulted in high cost of feed, lower demand, lower revenue, and supply chain interruptions. The government and development partners must support and finance the industry, encourage the growth of value chains and market connections, and help the sector overcome these obstacles. The production of aquaculture in Nigeria is still behind. With production just over 1,000 tons, Zambia, Madagascar, Togo, Kenya and Sudan lag behind. This shows how far behind the rest of the African continent is in terms of aquaculture.

DEMAND AND SUPPLY OF FISH IN NIGERIA
According to FAO (2021), an individual Nigerian consumes an estimated 13 kg of fish yearly on average; however, the ECOWAS Commission's Directorate of Agriculture and Rural Development (2020) published a lower estimate of 8.33 kg. Over 74.09% of Nigeria's total domestic fish production was produced by artisanal small-scale fishers, primarily from coastal, inshore, Niger Delta

creeks, lagoons, inland rivers and lakes. In contrast, aquaculture and industrial fisheries contributed only 24.91% and 1%, respectively, of the total fish produced in 2018 (Subasinghe *et al.,* 2021), This suggests that the seafood sector in Nigeria is underdeveloped and underutilized. The main capture is the tiny migratory Bonga (*Ethmalosa fimbriata*) (FAO, 2021). Although there has been some initial effort in creating an industrial fisheries sector, the infrastructure and fleet are ageing. The National Bureau of Statistics (2017) report on fish production in Nigeria states that out of the 5.79 million tonnes of fish produced between 2010 and 2015, Nigeria produced barely 204,403 metric tons of fish and shrimp industrially. Compared to the fish produced by aquaculture and artisanal fishing, industrial fishing made up only 4% of the total. The aquaculture subsector's overall fish production began to decrease in 2015. The production from capture fisheries began to decline after 2017, while the production from aquaculture was 316,727 metric tons in 2015, 289,543 metric tons in 2021, and 325,550 tons in 2020 (FAO, 2021; DARD-ECOWAS Commission, 2020). The data indicates a significant discrepancy between the increase in fish production and the population growth observed between 2015 and 2019. The decrease in the aquaculture subsector's fish production is extremely concerning because the nation needs more fish from this subsector to supplement its wild fish harvest to be able to meet its needs.

Nigeria's per capita fish intake has fluctuated and began to decline in 2011, despite the global trend of increasing fish eating since 1984. The world's per capita consumption of fish and fishery products was 18.9 kg in 2011; in contrast, Nigeria's per capita consumption was 15.2 kg. However, by 2018, Nigeria's per capita consumption had dropped to 13 kg (FAO, 2020, WorldFish, 2018).

POTENTIAL EXOTIC SPECIES FOR AQUACULTURE DIVERSIFICATION IN NIGERIA

The demand-supply gap for fish is expected to be closed and consumer demand for aquatic food is unlikely to be met in the next ten years by tilapia and catfish farms alone. This makes it essential to investigate and introduce potential exotic and/or native species diversification in Nigerian aquaculture. The days of importing fish will come to an end if we can accept that these breeds make suitable replacements for the varieties that are often imported. With a 95–98% survival rate, market acceptance, low production costs, and the ability to be cultivated in both monoculture and polyculture systems, some of these potential fish may be cultivated and might flourish in Nigeria. Our ability to fulfil future supply and demand will depend on our ability to leverage these breeds, as catfish alone will not suffice. These varieties offer a lot of potential to support fish farmers and provide the nation with food security, investment opportunities, and exports to boost Nigeria's economy.

This review looks at some foreign fish species that can be domesticated in Nigeria to determine which ones are suitable for Nigeria's Aquaculture sector. The review focuses on freshwater fish species, while there is still much to learn about the farming potential of fish species that can be farmed in brackish and marine environments.

ROHU (*LABEO ROHITA*)

Rohu is a huge fish with a noticeable arched head that is silver in colour and resembles a typical cyprinid. Although they average about 1.2 m (1.6 ft), adults can weigh up to 45 kg (99 lb) and reach a maximum length of 2 m. The species is an omnivore with distinct dietary preferences depending on the stage of life. In the early phases of its life cycle, it mostly consumes zooplankton; but, as it grows, it consumes an increasing amount of phytoplankton. Eventually, as an adult or adolescent, it becomes a herbivorous column feeder, consuming mostly phytoplankton and submerged vegetation. Its adapted gill rakers, which resemble fine hairs, indicate that it feeds by filtering the water. One of the best fish species for aquaculture is rohu. Rohu holds great potential for development and flexibility, which could revolutionize fish farming in Nigeria. Furthermore, our productive spawning method guarantees a steady and dependable supply of Rohu juveniles, making them more accessible to fish growers throughout the nation. With the right nutrition, this freshwater bony fish can grow to weigh 1 kg in just three months, with a documented 80% survival rate. It has good seedling output for induced spawning; supports monoculture and polyculture systems, and it's a freshwater fish native to South Asia. Rohu is highly promising for aquaculture because of its robust growth qualities and capacity to adapt to a variety of environmental circumstances. The following are some of the main factors that make Rohu an outstanding option for aquaculture in Nigeria:

Quick Growth: Rohu is a widely sought-after species for commercial aquaculture operations due to its well-known rapid growth as it exhibits a low feed conversion ratio. When grown in ideal conditions, rohu can reach marketable size in a comparatively short amount of time, giving farmers prompt returns on their investment.

High nutritional value: Rohu has a high nutritional value and is a good source of protein, vital amino acids, and omega-3 fatty acids. Due to its flavour and texture, which appeal to consumers' tastes both in Nigeria and abroad, its meat is highly valued. Fish from rohu has a high omega-3 fat content and less saturated fat, which helps prevent heart disease. It also aids in lessening osteoarthritis and rheumatoid arthritis symptoms. For those experiencing age-related macular degeneration, rohu fish is useful.

PANGASIUS HYPOTHALAMUS

Pangasius is one of the very few exotic species that can be diversified in Nigeria, one of the freshwater species in aquaculture with the quickest growth rates worldwide is the pangasius catfish (Jeyakumari, George, Ninan, Joshy, Parvathy, Zynudheen & Lalitha, 2016). Nowadays, pangasius is transported to more than 100 countries worldwide in the form of skinless and boneless fillets, portions, steaks, and other products with added value (Thi, Noseda, Samapundo, Nguyen, Broekaert, Rasschaert & Devlieghere, 2013). In terms of trade and output, the industry has grown in just six months. Pangasius can quickly reach a body weight of 1.2 to 1.3 kg. However, depending on marketability, harvesting often occurs after 8 months (Gurung, Shrestha & Karki, 2016). Due to its firm cooked texture, white, soft flesh, lack of fishy smell, high nutritional content, and superior sensory qualities, pangasius has become more and more popular among consumers (Rao, Murthy & Prasad, 2013). Since pangasius has a mild flavour, white flesh colour, firm cooked texture, low-fat content (Orban, Nevigato, Di Lena, Masci, Casini, Gambelli & Caproni, 2008), easily digestible protein (Thammapat, Raviyan & Siriamornpun, 2010), and nutritional qualities that are good for human health (Usydus, Szlinder-Richert, Adamczyk & Szatkowska, 2011), there is a lot of room to grow consumption by creating different value-added products from them. Fish-based products are in high demand, particularly value-added and ready-to-eat "convenience" items because of recent social and cultural shifts (Rathod, Pagarkar, Pujari, Gokhale & Joshi, 2012). Significant quantities of head, bone, scrap meat, and skin by-products are produced by the filleting industry (Thuy, Lindberg & Ogle, 2010). These by-products can be processed correctly to provide a variety of high-value products with strong economic efficiency. More than 30% of a fish's weight is made up of its skin and bones, making fish processing waste a good possible source of gelatin. Additionally, waste can be decreased by using garbage as a source for prospective products with additional value (Atma, 2017).

CLIMBING PERCH (*ANABAS TESTUDINEUS)*

The euryhaline climbing perch, scientifically known as *A. testudineus*, is a freshwater fish species belonging to the family Anabantidae. This fish species is native to Asia, and are often harvested commercially for food. The fish is well-known for its remarkable ability to survive out of water for extended periods, earning it the name 'climbing perch'. Typically, climbing perches grow to about 25 centimetres (10 inches) in length. They have a laterally compressed body that aids in their movement through narrow spaces. Their colouration ranges from olive to brownish-green on the back, with lighter, often yellowish or whitish, underbellies. Some may have faint dark stripes along their sides.

They possess strong and spiny dorsal and anal fins which can be used for defence and mobility. The pectoral fins are rounded and facilitate movement in water and on land. Their head is covered with large, bony scales that give it a turtle-like appearance, which is likely the origin of their name 'testudineus'. They thrive in a variety of freshwater habitats, such as rivers, lakes, swamps, and even stagnant waters. The species is distributed across South and Southeast Asia, including countries like India, Bangladesh, Myanmar, Thailand, Malaysia, Indonesia, and the Philippines. The climbing perch is a remarkable example of an aquacultural species, with a catchy potential due to its unique survival strategies which include;

Presence of Labyrinth Organ: One of their most distinctive features is the labyrinth organ, which allows them to breathe atmospheric oxygen. This adaptation enables them to survive in oxygen-poor waters and even out of water for extended periods. Their capacity to endure prolonged periods out of the water has increased its marketability

Amphibious Behavior: They are known for their ability to "climb" out of water and move across land. Using their gill covers and pectoral fins, they can wriggle and propel themselves over moist surfaces. This ability helps them escape predators, find new habitats, or survive when their water bodies dry up.

Diet and Feeding: Climbing perches are omnivorous, with a varied diet that includes small invertebrates, crustaceans, plant matter, and detritus. Their diet flexibility is another reason for their survival in diverse environments. It is fed with a floating pelleted feed having 30-35% protein or chopped fish. The fish being primarily an insectivore, fixing a hanging light just above the tank/pond/cage is a really good way to attract insects, which provide an additional source of food (Department of Fisheries, 2022).

Resilience: Their resilience to harsh conditions and adaptability make them a species of interest for studies on environmental stress and adaptation.

In many regions, they are considered a valuable food source and are caught for local consumption. They are also sometimes sold in the aquarium trade due to their unique characteristics. It is commonly consumed as food and believed by the Thais that this species of fish helps ward off disease, the reason why it is called *pla mo* (translated as *"physician fish"*) (Ahmad, Hadiaty, de Alwis Goonatilake, Fernado & Kotagama, 2019). This might be so because the fish contains a high amount of iron and copper which are essential for hemoglobin synthesis (Kumar & Mohanty, 2023). It also contains all the essential amino acids

COMMON CARP (*CYPRINUS CARPIO*)

Presently, carp is one among the four most cultured species in the world and account for 8% of total fish produced in 2016 by aquaculture (FAO, 2017). The potential culture of this species is yet to be fully optimized in Nigeria. The wide adoption of common carp (*Cyprinus carpio*) for aquaculture in Nigeria presents a significant opportunity due to several factors, including the species' biological characteristics, adaptability, and economic benefits. Common carp is highly adaptable to a wide range of environmental conditions, including varying temperatures and water quality, making it suitable for Nigeria's diverse aquatic environments (FAO, 2020). The species has a fast growth rate and can reproduce easily in captivity, which is beneficial for maintaining sustainable fish populations and continuous production (Beveridge & Phillips, 1993). Carp farming can be a lucrative business for small-scale farmers, contributing to poverty alleviation and improving livelihoods (FAO, 2020). Common carp is a popular fish for consumption due to its taste and nutritional value. It has high protein, fat, minerals and vitamin contents. The protein content is between 15.9-18.5%. There is a significant market for it in both local and regional contexts (Gabriel, Akinrotimi, Bekibele, Onunkwo, & Anyanwu, 2007).

Nigeria has established aquaculture practices, particularly with species like tilapia and catfish. The infrastructure and knowledge from these practices can be adapted for common carp farming (Fagbenro & Adebayo, 2005). Common carp can be easily cultured in ponds, which are commonly used in Nigeria. Techniques such as polyculture, where carp are farmed alongside other species, can enhance productivity and resource use efficiency (Oladosu, Ayinla, & Ajana, 1990). Common carp can be integrated into existing farming systems, such as rice-fish culture, enhancing resource use and providing multiple outputs from the same area of land (Gabriel et al., 2007). Carp are efficient converters of feed into biomass, and they can utilize a variety of feed sources, including agricultural by-products, which can reduce feed costs and improve sustainability (FAO, 2020).

The major challenge to carp production is scarcity of seed supply. Establishing reliable hatcheries to provide high-quality carp fingerlings is crucial. Investment in hatchery infrastructure and training for hatchery management is needed (Fagbenro & Adebayo, 2005), while at the same time implementing effective biosecurity measures with regular monitoring that can mitigate disease risks, ensuring healthy fish populations (Beveridge & Phillips, 1993). Developing efficient market channels and improving processing and storage facilities can help farmers get better prices and reduce post-harvest losses (FAO, 2020).

Although, *C. carpio* is already under culture in Nigeria, its wide adoption is still far beyond that of catfish and tilapia. Common carp farming can be economically viable and beneficial for smallholder farmers, with the potential for scaling up to meet larger market demands (Gabriel et al., 2007). The adoption of common carp for aquaculture in Nigeria holds considerable promise due to the species' adaptability, economic benefits, and compatibility with existing farming practices. By addressing challenges such as seed supply and disease management and leveraging existing aquaculture infrastructure, Nigeria can significantly enhance its aquaculture sector and improve food security and rural livelihoods.

Rohu Fish

Pangasius

Climbing perch

Common Carp
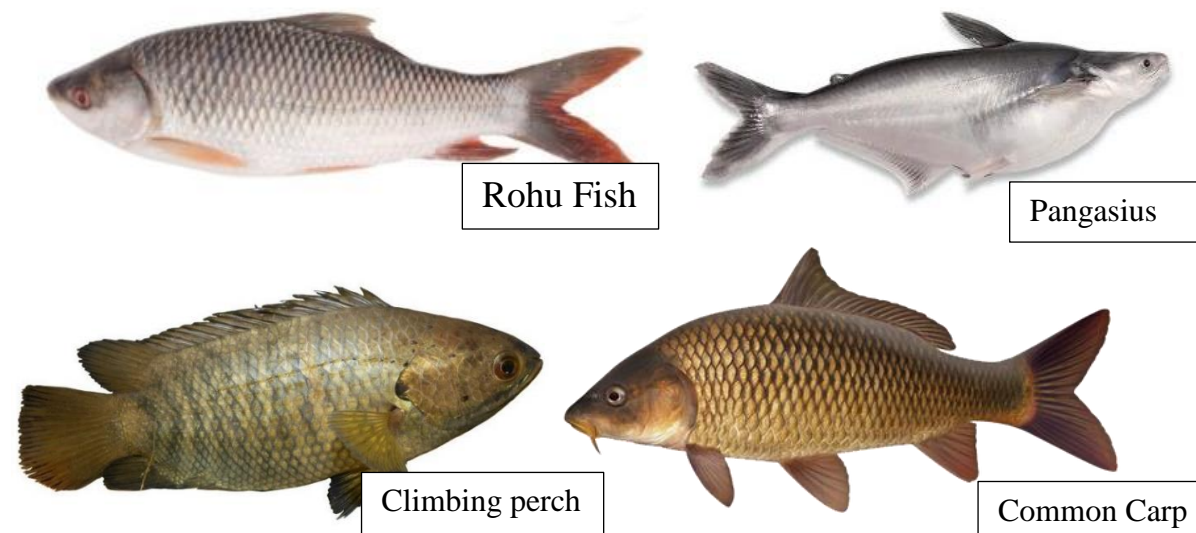
Source: Online Pictures (https://stock.adobe.com, June 3rd, 2024)

CONCLUSION

Diversification of fish species in Nigeria aquaculture sector will help enhance productivity, sustainability and profitability. Nigerian farmers can make use of a range of farming settings and methods by cultivating a diversity of species. Diversifying the different fish species cultivated in Nigeria might improve fish output, food security, and livelihoods in the nation—despite the tough, time-consuming, and costly nature of domesticating a species for aquaculture. Funding research institutes and universities to conduct the necessary studies for the development of the culture technologies for certain species should be the government's responsibility in order to promote the sector's growth.

High cost of fish feed is one of the major reasons for encouraging fish species diversification, some of the fish species review in this article require lesser crude protein to attain maturity compared to the indigenous fish species (e.g. catfish) thereby reducing the farmer's total cost of production which will in turn increase productivity of this sector. To fully optimize the blue economy the nation is working towards, there is a need to fund research on diversifying different fish species (indigenous and local). Diversification of fish species will boost aquaculture, encourage foreign exchange, boost local reliance and consumption, and foster value chain addition like filleting, deboning etc. Therefore, for successful domestication of the aforementioned species, there should be intensive research on their breeding, growth and processing method (cold blasting).

REFERENCES

Adewumi, A. A (2015) Aquaculture in Nigeria: Sustainability Issues and Challenges. *Direct Resource Journal of Agriculture and Food* Science *3*(12), 223-231.

Ahmad, A.B., Hadiaty, R.K., de Alwis Goonatilake, S., Fernado, M., Kotagama, O. (2019). "*Anabas testudineus*". IUCN Red List of Threatened Species, **2019**. *Retrieved 20 November 2021 at e.T166543A174787197. doi:10.2305/IUCN.UK.2019-3.RLTS.T166543A174787197.en.*

Aina, L. O., Kaniki, A. M. & Ojiambo, J. B. (1995). *Agricultural information in Africa*, Ibadan, Third World Information Services

Ajayi, O., Akinrinlola, A., Usman, A., Muhammed, A., & Van der Knaap, M. (2022). *Aquaculture Development in Nigeria and FAO's Role*. FAO Aquaculture Newsletter (65), 21-24.

Ajenifuja, Y. F. (1998). Post-independence historical perspectives in fisheries development in Nigeria, P.72.

Atma, Y. (2017). Amino acid and proximate composition of fish bone gelatin from different warm-water species: A comparative study. IOP Conf. Series: Earth and Environmental Science 58:012008, doi: 10.1088/1755-1315/58/1/012008.

Ayinla, O. A. (2012). Aquaculture development and appropriate enterprise combination in the Braced states. High-level meetings of experts and the meeting of Braced States Commissioners for Agriculture. Songhai Farms, Port-Harcourt. Oct 31-Nov. 2, 2012. 1-41.

Babatunde, A., Deborah, R. A., Gan, M., & Simon, T. (2021). A quantitative SWOT analysis of Key aquaculture players in Africa. *Aquaculture International*, *29*(4), 1753-1770.

Beveridge, M. C. M., & Phillips, M. J. (1993). Environmental impact of tropical inland aquaculture. In Pullin, R. S. V., Rosenthal, H., & Maclean, J. L. (Eds.), *Environment and Aquaculture in Developing Countries*. *ICLARM Conference Proceedings 31*.

Canton, H. (2021). Food and Agriculture Organization of the United Nations—FAO. In: *The Europa Directory Of International Organizations 2021* (pp. 297-305). Routledge.

Dada, B. F. (2003). Contribution of fisheries to employment, national economy and food security in Nigeria, A Paper presented at the 2003 FISON Public Lecture, Lagos. December 22nd, 2003.

Department of Fisheries, (2022). Production of Climbing Perch. Department of Fisheries, Government of Kerala. *Retrieved on May 22nd, 2024 at* https://vikaspedia.in/agriculture/fisheries/package-of-aquaculture-practices-fisheries-1/production-of-climbing-perch

Directorate of Agriculture and Rural Development– ECOWAS Commission (2020). "Fishery and Aquaculture: Statistical Factsheets of the ECOWAS Member countries". (10/02/2022).

Ekelemu, J. K., & Irabor, A. E. (2013). A review of aquaculture production in Nigeria: Problems and prospects. *Journal of Northeast Agricultural University (English Edition)*, *3*, 11.

Ezenwa, B. (1994). Aquaculture Development and Research in Nigeria: In Aquaculture Development and Research in Sub-Saharan Africa, National Reviews. CIFA Technical paper, 223 supl. FAO, Rome. Pp 45-79.

Fagbenro, O. A., & Adebayo, O. T. (2005). A review of the animal and aquafeed industries in Nigeria. In Moehl, J., Halwart, M., & Brummet, R. E. (Eds.), *Fisheries and Aquaculture Department, FAO*.

Food and Agriculture Organisation (FAO), (2023). *FAO report: global fisheries and aquaculture production reaches a new high record,* Rome/ San Jose, Costa Rica.

Food and Agriculture Organisation (FAO). (2020). *The state of world fisheries and aquaculture 2020.* Sustainability in action. Rome.

Food and Agriculture Organisation (FAO), (2017). *Fisheries and aquaculture country profiles: Nigeria.* Country Profile Fact Sheets. Rome.

Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N., & Anyanwu, P. E. (2007). Economic benefit and ecological efficiency of integrated fish farming in Nigeria. *Scientific Research and Essays 2*(8), 302-308.

Gurung, S., Shrestha, S. and Karki, J. (2016). Value chain of Pangasius (*Pangasius hypopthalmus*) in Rupandehi and Nawalparasi districts of Nepal. *International Journal of Life. Sci. Scientific Resources 2*(6): 712-728.

Inyang. E. B., (2001). *Factors affecting aquaculture production in Akwa Ibom State*, (Unpublished M.Sc dissertation), Department of Agricultural Extension and Rural Development, University of Ibadan, Ibadan.

Jeyakumari. A., George. Ninan., Joshy. C. G.,Parvathy. U., Zynudheen. A. A. and Lalitha. K. V. (2016). Effect of Chitosan on Shelf Life of Restructured Fish Products from Pangasius (*Pangasianodon Hypophthalmus*) Surimi During Chilled Storage. *Journal of Food Science and Technology. 53*(4):2099–2107.

Kumar, R., & Mohanty, U. L. (2023). Broodstock development, induced breeding, and seed production of climbing Perch *Anabas testudineus*: An alternative aquaculture species for changing environment. In: *Outlook of climate change and fish nutrition* (pp. 367-375). Singapore: Springer Nature Singapore.

Musa, B. 0., Oguntade, O. R. & Atahiru, S. M. (2005). Tilapia culture in Nigeria; status and prospects. *Proceedings of the 20th Annual Conference of Fisheries Society of Nigeria (FISON),* November, 2005. (49-53pp).

National Bureau of Statistics, Nigeria (NBS) (2017). *Nigeria's fish production: 2010-2015.* https://www.nigerianstat.gov.ng/download/509 (10.02.2020).

Oladosu, G. A., Ayinla, O. A., & Ajana, A. M. (1990). Polyculture of Tilapia (Oreochromis niloticus) and Catfish (Clarias gariepinus): Effect of stocking ratio on growth, yield, and fish production economics. *Journal of Aquaculture in the Tropics*, 5(1), 59-64.

Orban, E., Nevigato, T., Di Lena, G., Masci, M., Casini, I., Gambelli, L., & Caproni, R. (2008). New Trends in the Seafood Market, Sutchi Catfish (*Pangasius hypophthalmus*) Fillets from Vietnam: Nutritional Quality and Safety Aspects. *Food Chemistry 110*(2): 383-389.

Rahman, S., Monir, M. S., & Khan, M. H. (2013). Cultural potentials of climbing Perch. Thai Koi, *Anabas Testudineus* (Bloch) under different stocking densities in Northern Regions of Bangladesh. *Journal of Experimental Biology and Agricultural Sciences*, *1*(3), 203-208.

Raji, A. (2007). The Nigerian fisheries and the attainment of the millennium goals. A keynote address at the 22nd Annual Fisheries Society of Nigeria (FISON) Conference held at Birnin Kebbi, November 12th-16th, 2007.

Rao, B. M., Murthy, N. L. & Prasad, M. M. (2013). Shelf life of chill stored Pangasius (*Pangasianodon hypophthalmus*) fish fillets: Effect of vacuum and polyphosphate. *Indian Journal of Fish. 60*(4): 93-98.

Rathod, N. B., Pagarkar, A.U., Pujari, K. H., Gokhale, N. B., & Joshi, V.R. (2012). Standardisation of recipe for fish cutlet product from *Pangasianodon hypophthalmus*. *Ecology, Environment and Conservation,18* (4), 981-986.

Sheeshka, J. & Murkin, E. (2002). Nutritional aspects of fish compared with other protein sources. *Comments on Toxicology, 8.* 375-397

Subasinghe, R., Siriwardena, S. N., Byrd, K., Chan, C. Y., Dizyee, K., Shikuku, K., Tran, N., Adegoke, A., Adeleke, M., Anastasiou, K., Beveridge, M., Bogard, J., Chu, L., Fregene, B. T., Ene-Obong, H., Cheong, K. C., Nukpeza, J., Olagunju, O., Powell, A., Steensma, J., Williams, G., Shelley, C. & Phillip, M. (2021). *Nigeria Fish Future, Aquaculture in Nigeria: Increasing Income, Diversifying Diets and Empowering Women.* Report of the scoping study, Penang, Malaysia: WorldFish Program Report 2021-16

Thammapat, P., Raviyan, P., & Siriamornpun, S. (2010). Proximate and fatty acids composition of the muscles and viscera of

Asian catfish (*Pangasius bocourti*). *Food Chemistry, 122*(1), 223- 227.

Thi, A. N. T., Noseda, B., Samapundo, S., Nguyen, B. L., Broekaert, K.,Rasschaert, G., & Devlieghere, F. (2013). Microbial Ecology of Vietnamese Tra Fish (*Pangasius Hypophthalmus*) Fillets During Processing. *International Journal of Food Microbiology, 167*(2), 144-152

Thuy, N. T., Lindberg, J. E., & Ogle, B. (2010). Digestibility and nitrogen balance of diets that include marine fish meal, catfish (*Pangasius hypophthalmus*) By-product meal and

silage, and processing wastewater in growing pigs. *Asian-Australasian Journal of Animal Sciences, 23*(7), 924-930.

Usydus, Z., Szlinder-Richert, J., Adamczyk, M., & Szatkowska, U. (2011). Marine and farmed fish in the Polish market: comparison of the nutritional value. *Food Chemistry, 126*(1), 78-84.

WorldFish, (2018). *World Fish Nigeria Strategy* 20182022. https://digitalarchive.worldfishcenter.org (19.08.2021)

FOOD PREFERENCES AND FORAGING ECOLOGY OF THE BLACK AND WHITE MANNIKIN BIRD (Spermestes bicolor) FOUND IN ILARO, OGUN STATE, NIGERIA.

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ABSTRACT
This study was conducted in Ilaro, Ogun State, Nigeria, in 2023, aiming to understand the food preferences and feeding behaviours of the Spermestes bicolor, commonly known as the Black and White Mannikin, to support sustainable tourism initiatives. This investigation spanned 12 months and focused on 20 pairs of Black and White Mannikins, ranging in size from one to ten, observed across three distinct areas: Residential zones, Farmland, and Fallowland. Data collection utilised the Direct Observation method, with researchers employing Bushnell 750 binoculars from dawn to dusk to minimize bird disturbance during feeding activities. Throughout the study period, detailed records were maintained regarding foraging locations, feeding techniques, feeding duration, bird population density, types of food consumed, and interactions with other avian species. Analysis of the gathered data revealed that the Black and White Mannikin's diet predominantly comprised plant-based resources, accounting for 70% of their intake. In comparison, insects constituted 27%, and the remaining 3% comprised leaves and flowers. Among plant-based foods, Panicum Maximum seeds were the most commonly consumed at 14.5%, followed by Lawsoniainermis fruits at 10.7%, and Ficus thonningii seeds at 8.6%. Regarding insects, Macrotermes bellicosus exhibited the highest frequency of observation at 16.2%, trailed by Parasysciasudanensis at 13%. Examination of habitat utilization patterns indicated that residential areas constituted 55% of the Black and White Mannikin's habitat, while farmland and fallow areas collectively represented 25%. These findings offer insights into the dietary preferences and habitat usage tendencies of the Black and White Mannikin within the study area, thereby providing valuable information for the development of strategies aimed at sustainable tourism management.

Keywords: Diet, foraging ecology, habitat, utilization, sustainable tourism

1.0 INTRODUCTION
The Black and White Mannikin (*Spermestes bicolor*), also known as the Bronze Munia or Bronze Finch, is a small songbird indigenous to sub-Saharan Africa. This species thrives in diverse open environments throughout the region, including grasslands, savannas, and wooded areas such as forest edges, gallery forests, and acacia woodlands (Aerts, Lerouge & November, 2019). They are frequently observed near water bodies like rivers, streams, or marshes. Black and White Mannikins demonstrate adaptability to human-modified landscapes, commonly found in locations such as gardens, parks, farmlands, and even urban areas with appropriate vegetation (Chen& Hsieh, 2019). While the overall conservation status of the Black and White Mannikin is categorised as least concern by the International Union for Conservation of Nature (IUCN), specific populations and regions face distinct threats and conservation challenges. Among the primary threats are deforestation, conversion of land for agriculture, and urban expansion, which result in habitat fragmentation and degradation as human populations grow (Birdlife International, 2016). Moreover, Black and White Mannikins are vulnerable to capture for the pet trade, particularly in areas where they are prized as cage birds (Birdlife International, 2016). Unregulated trapping can lead to declines in local populations. Competition and predation from non-native birds and mammals, especially in areas where they have been introduced, pose significant risks to bird populations (Clement, Harris, & Davis, 1993). Changes in climate patterns, such as alterations in rainfall and temperature, can affect the availability of

suitable habitat and food resources for the Black and White Mannikin. Furthermore, agricultural pesticides and pollutants from urban runoff have the potential to contaminate water sources and food supplies, potentially jeopardizing the health and reproductive success of Black and White Mannikins (Gill, Donsker & Rasmussen, 2021). Understanding the dietary preferences and feeding ecology of birds is crucial for conservation endeavors and ecosystem management, as it offers insights into their ecological roles, habitat needs, and susceptibilities to environmental changes, thereby facilitating the promotion of sustainable tourism.

2.0 MATERIALS AND METHOD
Study area
Ilaro is located within the Yewa South Local Government Area of Ogun State, Nigeria, positioned at coordinates 6.8894° N, 3.0471° E. It serves as the home to notable institutions like the Federal Polytechnic. Ilaro, The rainy season typically spans from March to November in the region, with December through February marking its conclusion, receiving an average annual rainfall ranging between 1700 to 2000 mm (Megistu & Salami, 2007). The mean yearly temperature in the area averages 26°C. The native vegetation of the region comprises a tropical rainforest with emergent growth, numerous canopies, and lianas (Isichei, 1995). However, except for designated farming areas, the natural vegetation has largely been reduced to grassland and secondary regrowth forest thickets (Manu, 2005).
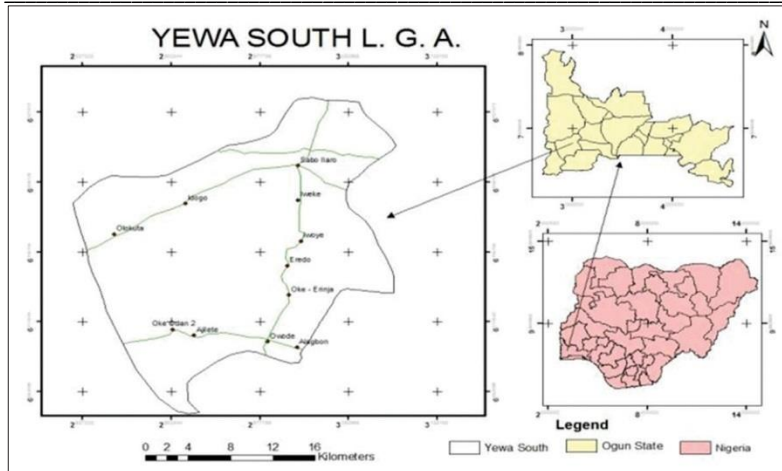
Firgure1, Map of the study area

Data Collection

For the purpose of this investigation, the study area was segmented into three sections: The Residential block, The Forest/Fallowland block, and The Farmland block. Over a continuous 12-month period from January to December 2023, data concerning the diet and feeding behavior of 20 pairs of Northern Grey Headed Sparrows, each consisting of one to three individuals, were compiled. The Direct Observation technique described by (Okosodo, Orimaye & Odewumi, 2016) was employed for this study. Field observations were conducted from dawn until dusk utilizing binoculars (specifically Bushnell 750) to observe the birds' feeding activities with minimal disruption. Each pair of sparrows was observed for a duration ranging from a few hours to up to five hours during each visit. While it was typically feasible to keep several birds within sight simultaneously, observing the entire flock concurrently was seldom achievable. During each observation session, data regarding the foraging location, feeding method, duration of feeding activity, number of birds present, types of diets consumed, and any interactions with other bird species were recorded. Additionally, seasonal variations in the birds' dietary patterns were examined. Due to the size of the trees and the height of the nests above the ground, further investigation into the birds' pellets was not feasible.

Data Analysis

The data gathered from the observations were analyzed using descriptive statistics. The diversity index of tree species in the study area was analyzed using the computer software PAST Model version 3.

Results

Although the Black and White Mannikin primarily consumes grains, it also incorporates fruits, leaves, flowers, and insects into its diet. The findings reveal that 70% of the Black and White Mannikin's diet is sourced from plant resources, while 27% comes from insects, and 3% from leaves and flowers (Figure 2). Among the plant-based foods, *Panicum Maximum* seeds are the most heavily consumed at 14.5%, followed by *Lawsonia inermis* fruits at 10.7%, and *Ficus Thonningii* seeds at 8.6% (Table 1). Regarding insects, *Macrotermes bellicosus* exhibits the highest frequency of observations at 16.2%, followed by *Parasyscia sudanensis* at 13% (Table 2). The assessment of habitat utilization indicates that the residential block constitutes 55%, while farmland and fallow areas collectively make up 25% (Figure 3). The family composition of the plant species utilized by the Black and White Mannikin shows that Poaceae is the most predominant with 14 species, followed by Apocynaceae with 3 species (Figure 4). Similarly, in terms of insects, the family composition reveals that Formicidae is represented by 3 species (Figure 5).
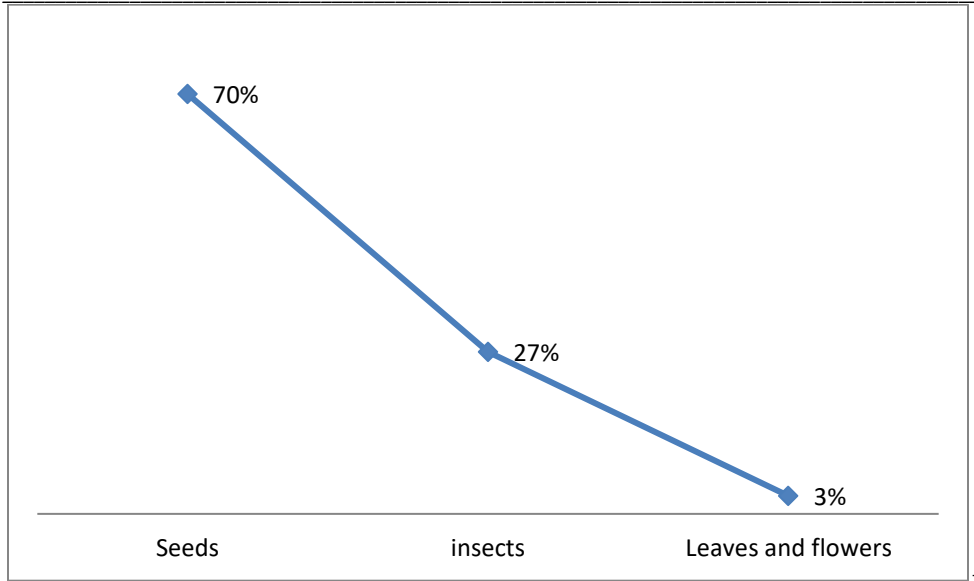
Figure 2, Depicts the rate of diet consumption by the bird species within the study area.
Table 1, Checklist of plantspeciesutilized in the study area

Name if plant species	Family	Parts used	Observations%
Amaranthus retroflexus	Amaranthaceae	Seeds	1.1
Andropogon gayanus	Poaceae	Seeds	0.06
Andropogon tectorum	Poaceae	Seeds	0.07
Aspiliaafricana	Asteraceae	Seeds	3.1
Bambusa vulgaris	Poaceae	Seeds	2.2
Boerhaviadiffusa	Nyctaginaceae	Seeds	4.3
Carica papaya	Caricaceae	Fruit and seeds	6.8
Chromolaena odorata	Asteraceae	flowers and seeds	2.2
Cymbopogon citratus	Poaceae	Seeds	5.1
Cynodonplectostachyus	Poaceae	Seeds	2.8
Cyperus rotundus	Poaceae	Seeds	1.4
Diallumguineense	Fabaceae	Fruits	1.1
Duranta repens	Verbenaceae	Fruits	6.7
Ficus Thonningii	Moraceae	Seeds	8.6
Hyparrheniarufa	Poaceae	Seeds	2.9
Hyptisspicigera	Lamiaceae	Seeds	1.1
Lawsoniainermis	Lythraceae	Fruits	10.7
Loudetiaorundinacea	Poaceae	Seeds	0.07
Moringa oleifera	Moringaceae	Flowers and leaves	1.02
Nauclea latifolia	Rubiaceae	Seeds	4.4
Olea europaea	Oleaceae	Fruits	3.3
Ocimumgratissimum	Lamiaceae	Seeds	1.4

Oryza sativa	Poaceae	Seeds	9.3
Panicum maximum	Poaceae	Seeds	14.5
Pennisetum polystachion	Poaceae	Seeds	0.04
Psidium guajava	Myrtaceae	Seeds	0.05
Rauvolfia vomitoria	Apocynaceae	Fruits	0.03
Senna alata	Fabaceae	Seeds	0.06
Setaria barbata	Poaceae	Seeds	0.02
Solanlum nigrum	Solanaceae	Seeds	0.06
Sporobolus pyramidalis	Poaceae	Seeds	0.08
Trama orientalis	Cannabaceae	seeds	0.03
Tridax procumbens	Asteraceae	Flowers	2.1
Zea mays	Poaceae	Seeds	3.4

Table 1, Checklist of insectspeciesconsumed in the study area

Name of insect species	Family	Observation%
Parasysciasudanensis	Formicidae	13.7
Zasphinctusrufiventris	Formicidae	2.1
Simoponeconradti	Formicidae	7.2
Parasysciacribrinodis	Formicidae	3.7
Dorylussavage	Formicidae	9.4
Dorylus nigricans	Formicidae	3.2
Dorylusbraunsi	Formicidae	8.4
Dorylusdepili	Formicidae	1.1
Aenictusvagans	Formicidae	2.1
Dorylusaffinis	Formicidae	4.2
TechnomyrmexAndrei	Formicidae	2.2
Lebistinasubcruciata	Chrysomelidae	7.8
Diphasiastrum alpinum	Chrysomelidae	2.9
Macrotermesbellicosus	Termitidae	16.2
M. subhyalinus	Termitidae	4.7
Odontotermessudanensis	Termitidae	11.1
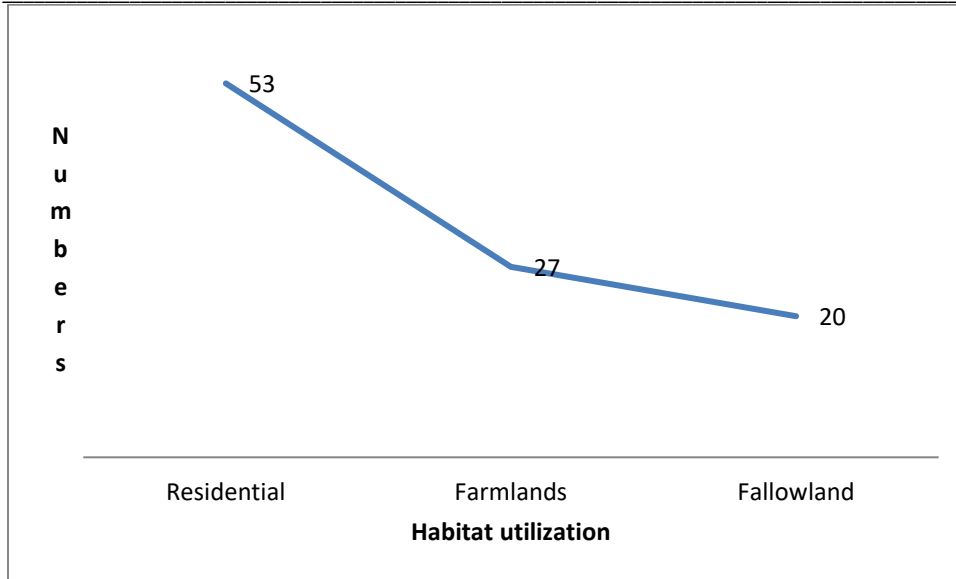
Figure 3, Illustrates the utilization of habitats by Spermestes bicolor within the study area.
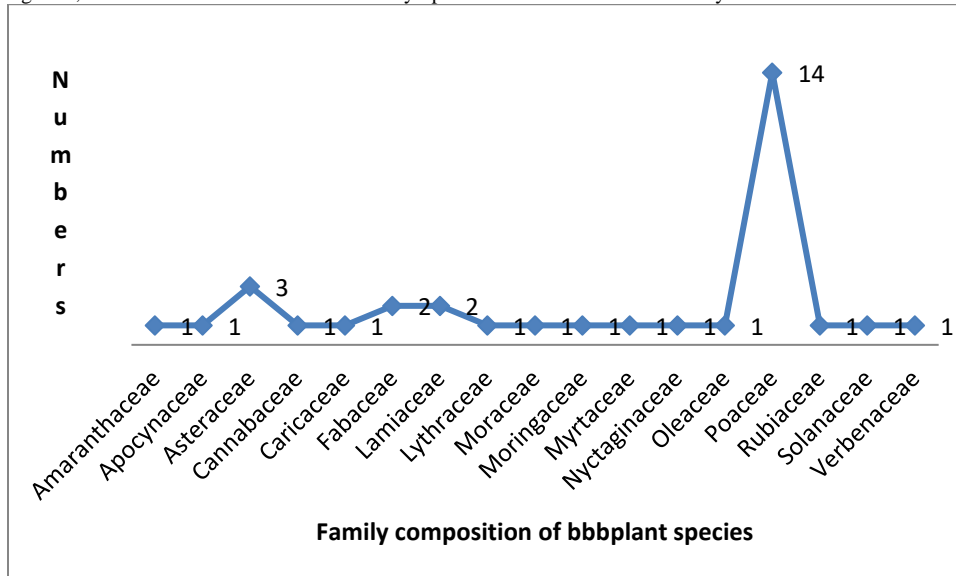
Figure 4, Family composition of tree species fed upon in the study area
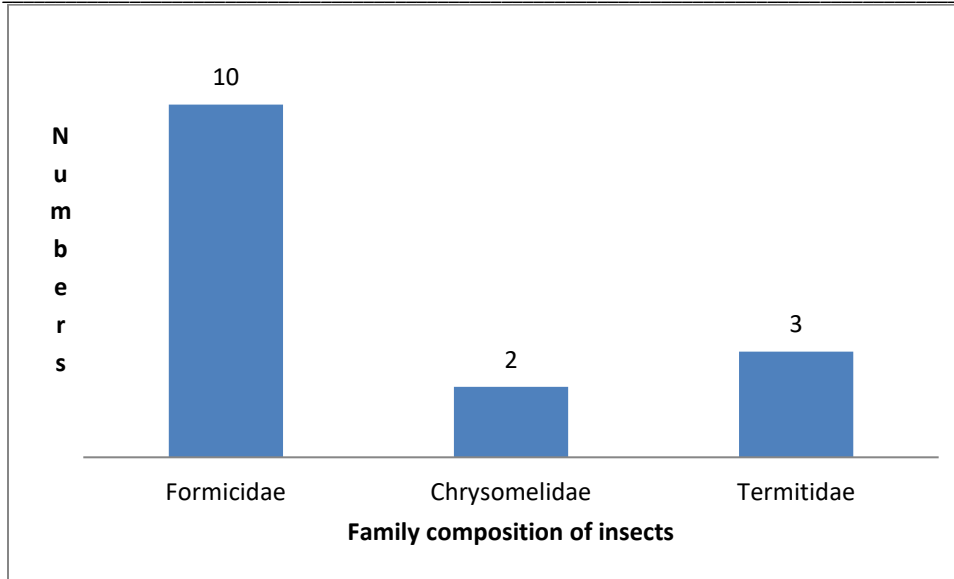
Figure 5, Family composition of insect utilised by the bird species in the study area

DISCUSSION

The Black and White Mannikin (Spermestescucullatus) primarily subsists on seeds, indicating a granivorous diet. However, they are also known to partake in insects, fruits, leaves, and flowers. Their foraging behaviour spans ground, shrub, and tree habitats, and they are even observed frequenting bird feeders for seeds and suet. During the breeding season, they supplement their offspring's diet with insects, including leaf beetles and termites. This dietary pattern is supported by various researchers. (Marques, Oiero, Canario & Luis, 2003) documented *Turdus pelios,* a related species, consuming insects, blank ants, and fruits of Azadirachta indica in South Africa. Similarly, (Sagrario, Ronald, Gurr, Kinross, Anantanarayanan & Helen,2007) found that insects constituted the primary portion of *Turdus pelios'* diet, with Orthoptera, Coleoptera, and Isoptera being the most numerically significant, comprising almost two-thirds of the insects consumed. They are known for consuming a diverse assortment of seeds sourced from grasses, weeds, and various plants. Additionally, they may occasionally consume insects, particularly during the breeding season when their dietary needs shift to accommodate more protein for egg production and nurturing their offspring. In this research, it was observed that these species primarily feed on the ground within residential areas and within the middle layer of trees in forest and farmland blocks. This observation aligns with the findings of (Yusufu, Yakubu and Madziga,2004),who noted that during the breeding season, the northern green-headed sparrow can often be observed foraging on the ground or in low vegetation. They employ a "hop and scratch" technique to uncover seeds and insects from the leaf litter or grass. In the non-breeding season, they may form mixed-species flocks and search trees and shrubs for seeds. The feeding behavior of the northern grey-headed sparrow, like many bird species, can vary depending on several factors, including the season, weather conditions, and food availability. Nonetheless, typically, sparrows exhibit peak activity and feed most actively during the morning and late afternoon or early evening hours.During the breeding season, Spermestescucullatus often commence foraging shortly after sunrise to gather sufficient food for themselves and their offspring throughout the day. They may take breaks from feeding during the hottest part of the day and resume activity in the late afternoon. Northern grey-headed sparrows are predominantly granivorous, indicating that seeds constitute the majority of their diet. However, similar to numerous bird species, they may occasionally consume other plant materials such as flowers and leaves. There are several reasons why a *Spermestes bicolor* might opt to consume flowers and

leaves. One potential explanation is their search for additional nutrients or minerals that may be lacking in their predominant seed-based diet. Certain flowers and leaves contain a rich array of vitamins, minerals, and other micronutrients essential for avian health. Another rationale is that Black and White Mannikin could be turning to flowers and leaves to supplement their diet during periods of seed scarcity, such as the winter months when food sources may be more limited. This dietary supplementation could aid in their survival during lean times. Moreover, some manikins might simply derive pleasure from the taste of flowers and leaves and consume them solely for that reason. Nonetheless, it's crucial to recognize that while flowers and leaves offer some nutritional advantages, they shouldn't constitute a substantial portion of a northern grey-headed sparrow's diet, as highlighted by (Marshall, Kanczler & Oreffo, 2020) and (McWilliams &Karasov, 2014). In a study of house sparrows in Italy, (McKilligan, 2005) observed mannikins consuming a diverse range of plant material, including flowers and leaves, across different seasons. This behavior appears to be influenced by the availability of seeds and other primary food sources in the surrounding environment.

CONCLUSION

The research clearly demonstrates that Spermestes bicolor feeds on a variety of food sources including grain seeds, fruits, leaves, flowers, and insects within the study area. Regarding habitat usage, the bird species predominantly utilizes residential blocks over other areas. It was also noted that they forage on the ground as well as on the upper shrub and middle layer trees. Despite being categorized as least concern in terms of conservation status, the fact that they utilize degraded forest ecosystems and urbanized residential areas underscores their importance for sustainable development. Preserving habitats and ecosystems that sustain diverse bird populations is crucial for biodiversity conservation.Sustainable tourism plays a significant role in this conservation effort by encouraging the preservation of habitats. Tourists participating in birdwatching or bird-focused activities often contribute to habitat conservation by supporting eco-tourism initiatives that prioritize conservation efforts. Avitourism and bird-related tourism can provide economic incentives for local communities to conserve natural habitats. This can include revenue generated from birdwatching tours, sales of birding equipment, and services such as accommodation and dining for birdwatchers. By promoting activities that attract birdwatchers, sustainable tourism

simultaneously supports local economies and conserves bird habitats.

REFERENCES

Aerts, R., Lerouge, F. & November, E. (2019). Birds of forests and open woodlands in the highlands of Dogu'aTembien. In: Nyssen J., Jacob, M., Frankl, A. (Eds.). *Geo-trekking in Ethiopia's Tropical Mountains* - The Dogu'aTembien District. SpringerNature.ISBN 978-3-030-04954-6. International Union for Conservation of Nature Red List of Threatened Species

BirdLife International (2016). "Spermestescucullata" IUCN. *International Union for Conservation of Nature Red List of Threatened Species*. 2016:e.T22719782A94643856. doi:10.2305/IUCN.UK.2013.RLTS.T22719782A94643856.en. Retrieved 12 May 2021.

Chen, C. & Hsieh, F. (2019). Composition and foraging behaviour of mixed-species flocks led by the Grey-cheeked Fulvetta in Fushan Experimental Forest, Taiwan. *IBIS International Journal of Avian Science, 144,* 317-330

Clement, P., Harris, A. & Davis, J. (1993). Finches and sparrows: an identification guide ISBN 10: 0713680172ISBN 13: 9780713680171

Gill, F., Donsker, D., & Rasmussen, P. (Eds.). (2021). Waxbills, parrotfinches, munias, whydahs, Olive Warbler, accentors, pipits. IOC World Bird List Version 11.2. *International Ornithologists' Union.* Retrieved 12 May 2024.

Isichei, A. (1995). Omo Biosphere Reserve, Current Status, Utilization of Biological Resources and Sustainable Management (Nigeria). Working Papers of the South-South Cooperation Programme on Environmentally Sound Socio-Economic Development in the Humid Tropics. Paris: *UNESCO*, 1995.

Manu, S. (2005). Effects of Habitat Fragmentation on the Distribution of Forest Birds in South Western Nigeria with Particular Reference to the Ibadan Malimbes and other Malimbes, Ph.D. Thesis. University of Oxford.

Marques, P., Oiero, M., Canario, M., & Luis, V. (2003). Variation of nestling diet across the breeding season in Spanish Sparrow Passer hispaniolensis in southern Portugal. *ARDEOLA International Journal of Ornithology, 50,* 71–75.

Marshall, K., Kanczler, J., & Oreffo, R. (2020). Evolving applications of the egg: chorioallantoic membrane assay and ex vivo organotypic culture of materials for bone tissue engineering. *Journal of Tissue Engineering*, *11*, 2041731420942734.

McKilligan, N. (2005). Herons, egrets and bitterns: Their biology and conservation in Australia. *Commonwealth Scientific and Industrial Research Organisation* publishing.

McWilliams, S. & Karasov, W. (2014). Spare capacity and phenotypic flexibility in the digestive system of a migratory bird: defining the limits of animal design. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1783), 20140308.

Megistu, A. & Salami, A (2007). Application of remote sensing and GIS in land use/land cover mapping and change detection in a part of southwestern Nigeria.

Okosodo, E., Orimaye, J. & Odewumi, O. (2016). Diet and Foraging Ecology of Fork Tailed Drongo (Dicrurusadsimilis) in Leventis Foundation Nigeria, Agricultural School South West Nigeria. *International Journal of Environment, Agriculture and Biotechnology*, *1*(2), 238527.

Sagrario, G., Ronald, S., Gurr, G., Kinross, C., Anantanarayanan, R. & Helen, L. (2007) Arthropod prey of shelterbelt-associated birds: linking faecal samples with biological control of agricultural pests. *Australian Journal of Entomology, 46,* 325–331.

Yusufu, S., Yakubu, Y. & Madziga, B. (2004). The food of Quelea birds(Queleaquelea) during dry season in Borno State, Nigeria. *Pakistan Journal of Biological Science, 7,* 620–622.

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NUTRITIONAL STATUS AND FUNCTIONAL CAPACITY OF ELDERLY IN SELECTED COMMUNITIES IN YEWA SOUTH, OGUN STATE

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ABSTRACT

This study assessed the nutritional status and functional capacity of Elderly in selected communities in Yewa south, Ogun state. By using a multi-stage sampling process, 320 respondents in total were selected. Data was collected from the respondents using a semi-structured questionnaire. The questionnaire was in sections, and it contained questions on the socio demographic and socio-economic characteristics of the respondents, and functional capacity of the respondents. Anthropometric measurements were taken and the BMI was determined and compared to WHO reference standard. Descriptive and inferential statistics were used to analyse the study data utilizing statistical product and service solutions (SPSS v. 20.0). The result shows that majority of the respondents were between the ages of 60-64 years (45.3%) and belong to Yoruba ethnic group (89.4%). Also, 30.3% of respondents had secondary school certificate, 32.2% were petty traders and 79.4% of the respondents earned above ₦20,000 monthly. Close to half of the respondents (45.9%) had normal weight, while 38.8% of the respondents were overweight. In addition, 3.1% and 12.2% were underweight and obese respectively. The result for functional capacity shows that 96.9% had a normal self-care activity, and for self-care activity functionality, 96.9% were independent. Furthermore, 82.5% of the respondents had a normal household care activity and 82.5% of them household care functionality are independent. For enjoyment and recreational activities, majority of the respondents (87.8%) have a normal activity; similarly, 87.8% of them can also carry out their activity independently. It was concluded that majority of the elderly can carry out their Basic Activities of Daily Living (BADL) and also Instrumental Activities of Daily Living (IADL) independently. Significance association (P<0.05) was observed between some socio-economic characteristics and nutritional status.

Keywords: Nutrition, Nutritional status, Functional capacity, Malnutrition, Elderly.

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1.0 INTRODUCTION

A person over 60 is regarded as an elder according to the World Health Organization (WHO, 2020). Although many people in several developing nations have been shown to be functionally "old" in their forties and fifties, chronological age is still the most accepted way to define aged or elderly. Nevertheless, this approach has been questioned in many regions. The retirement age is also divided into chronological age groups beginning at 60. The advent of different diseases, the development of particular ailments brought about by changes in the body and mind, and dietary modifications that impact the nutritional status of elderly are all signs of ageing (Silveira, Lopes, Oliveira, Fogaça, & Leandro-Merhi, 2007).

Ageing not only leads to the onset of various chronic conditions but also results in alterations in personal characteristics such as functional capacity and cognitive decline, crucial for maintaining the health of older individuals. As people age, their physical, mental, and behavioural capabilities decrease, along with a reduced ability to cope with stressors (Zihl & Reppermund, 2022).

The term "functional capacity" describes a person's ability to carry out regular daily tasks in their lives that are desirable or required of them to meet fundamental needs, fulfil obligations, and maintain one's health and welfare under carefully monitored circumstances (Patterson & Mausbach, 2010). First, Katz assessed functional capacity while considering the performance of Instrumental Activities of Daily Living (IADL) and Basic Activities of Living on a Day-to-Day Basis (BADL), which refers to all daily activities that are performed regularly, such as eating, dressing, and taking a bath (Adepoju & Coker, 2018). The Instrumental Activities of Daily Living (IADL), on the other hand, are those that call for organization and planning. These include things like grocery shopping, using transportation, preparing food, managing money, taking care of the house, and using the phone (Tracey, 2008).

Experts and family members have determined that individuals living independently need professional attention in the area of their functional capacity and the fact that they do not have enough time to prepare and eat, which can lead to malnutrition (Oliveira, Fogaça, & Leandro-Merhi, 2009). A decrease in functional capacity measurement may indicate a risk for malnutrition, which is particularly linked to a decrease in food intake. Additionally, nutrition has a big impact on how quickly people age. A healthy diet can help prevent or treat a lot of physical issues that affect the elderly. Numerous illnesses, particularly in the elderly, are influenced by nutritional status. The nutritional status of elderly individuals is a critical factor that can help us better understand how nutrition supports and maintains their independence and autonomy. Economic, social, and lifestyle factors that contribute to a sufficient and healthful diet can be valuable instruments for evaluating the nutritional risk.

Anthropometry is the most commonly used method in clinical practice and epidemiological studies; as such, it is essential to understand the health of the elderly population through nutritional assessment. In this study, the nutritional status and functional capacity of the elderly in selected Yewa South communities were assessed.

2.0 MATERIALS AND METHODS

The research was conducted in Yewa South (formerly Egbado South)**.** Yewa South is a local government area that borders the Republic of Benin and is located in the western part of Ogun State, Nigeria. Its headquarters are located in the northern town of Ilaro. As of the 2006 census, its population was 168,850; and its area measured 629 km². The region is composed of the following ten wards: Oke-Odan, Ajilete, Owode I, Owode II, Iwoye, Idogo, and Ilaro I, II, III. In addition to the Ogu language of the Gbè language family, which Yoruba language speakers refer to as "Egun," the inhabitants speak Yewa dialects of Yoruba. Their main sources of cultured food are "Fufu and Posu", farming and trading are their main occupations.

The study was cross-sectional and descriptive and it cut across the elderly in selected communities in Yewa South, Ogun state.

The sample size was determined using Cochran's (1977) formula

$$n = \frac{Z^2 pq}{e^2}$$

n = sample size

Z = 1.96 at 95% confidence level

p = proportion or prevalence of malnutrition (underweight and overweight) among the elderly 25.3% (Adepoju, Olayiwola, Onabanjo, & Lasode, 2021)).

e = margin of error (0.050

$$n = \frac{(1.96)^2 \times 0.253(1-0.253)}{0.0025}$$

$$n = \frac{3.8416 \times 0.253(0.747)}{0.0025}$$

$$= \frac{3.8416 \times 0.1889}{0.0025}$$

$$= \frac{0.7257}{0.0025}$$

$$= \frac{0.7257}{0.0025}$$

n = 290.28

The value of n obtained was adjusted to 320 by adding 10% (10%) to allow for non-responses. This resulted in a number of 319.

The sample was chosen using a multistage sampling technique. Yewa South consists of ten wards: Oke-Odan, Ajilete, Ilobi/Erinja, Iwoye, Idogo, Ilaro I, Ilaro II, and Ilaro III.

Simple random selection was used to choose two wards through balloting without replacement, and from each ward, four communities were also chosen at random. A systematic selection process was used to choose respondents from among all households with a minimum of one senior person (60 years of age or older), male or female. Simple balloting was employed to choose respondents from the homes containing multiple elderly.

A questionnaire that was semi-structured and administered by an interviewer was designed and given to the respondents. The questionnaire consists of two sections. The respondents' sociodemographic and economic details were recorded in Section A, and their functional ability was evaluated in Section B. Two primary activities were measured in order to evaluate the elderly's functional capacity: the Instrumental Activities of Daily Living Scale (IADLs) and the Basic Activities of Daily Living Scale

Table 1: Socio demographics characteristics of the respondents

(BADL). The basic activity of daily living scale was used to assess the ability of the respondents in performing day to day, routine and common activities e.g. dressing, bathing and eating, and the Instrumental Activities of Daily Living Scale (IADLs) was used to evaluate the ability of the respondents in performing more organized and planned activities like Shopping, Using transportation, meals preparation, handling finances, housekeeping and telephone usage. These were assessed by adapting the Johnson *et al.* activities of daily living questionnaire (Johnson et al., 2004).

The respondents' anthropometric parameters, including weight and height, were recorded. A portable height gauge with centimeter calibrations (cm) was used to measure the respondents' heights. For accuracy, the responders were measured on a level floor without shoes on. The measurements were made with a precision of 0.1 cm. A bathroom weighing scale was also used to acquire the weights. Prior to every measurement, the scale was reset to zero and rounded to the closest kilogram.

Statistical product and service solutions for Windows version 22.0 was used to conduct the statistical analysis. Standard deviation, mean, frequency, and percentage were among the descriptive statistics that were employed. Analysis of variance (ANOVA) was utilised to ascertain the difference between means, and chi-square (inferential statistics) was employed to ascertain the relationship between the categorical variables.

3.0 RESULTS AND DISCUSSION

Results:

Table 1 displays the sociodemographic and economic attributes of the participants. According to the results, 64.7% of them were female and 35.3% of them were male. Majority of the respondents were between the ages of 60-64 years (45.3%) and belong to the Yoruba ethnic group (89.4%). Moreover, a large proportion of the study participants belonged to the Christian faith (65. 3%) and came from monogamous homes (53.8%). Similarly, 53.8% were from a nuclear family background and 45.6% from an extended family. Also, the majority of the respondents (62.8%) were married. The educational level shows that 30.3% of respondents had secondary school certificates, 22.2% of them however had no formal education. In addition, 32.2% were petty traders and 79.4% of the respondents earned above ₦20,000 every month.

Variables	Frequency (n =320)	Percentage
Gender		
Male	113	35.3
Female	207	64.7
Age range (years)		
60-64	145	45.3
65-69	71	22.2
70-74	46	14.4
75-79	20	6.3
Above 80	38	11.9
Ethnicity		
Yoruba	286	89.4
Igbo	33	10.3
Hausa	1	0.3
Religion		
Christianity	209	65.3
Islam	95	29.7
Traditional	16	5
Family structure		
Monogamy	184	57.5

Polygamy	136	42.5
Family background		
Nuclear	172	53.8
Extended	146	45.6
Joint family	2	0.6
Marital status		
Single	11	3.4
Married	201	62.8
Widow	81	25.3
Widower	27	8.4
Level of education		
No formal schooling	71	22.2
Primary	58	18.1
Secondary	97	30.3
NCE/OND	38	11.9
HND/B.Sc	56	17.5
Present occupation		
Retired	25	7.8
Self employed	70	21.9
Farming	36	11.3
Civil service	20	6.3
Petty trading	103	32.2
An employee of private establishment	20	6.3
Personal business	29	9.1
Unable to work for pay anymore	17	5.3
Estimated income (₦)		
1, 000 - 5, 000	9	2.8
6, 000 - 10, 000	24	7.5
11, 000 - 15, 000	8	2.5
16, 000 - 20, 000	25	7.8
20, 000 and above	254	79.4

Table 2 shows the anthropometric measurements of the study participants. For male, the mean height was 1.65m, while the mean weight was 70.71 kg. For females, the mean weight was 65.29 kg while their mean height was 1.59 m. The body mass index of the male and female respondents was 26 kg/m^3 and 25.66 kg/m^3 respectively. Significance difference was observed ($p<0.05$) between the mean height and weight of the respondents. However, no significance difference was found between the BMI of the respondents.

Table 2: Anthropometric measurements

Variable	Height (m)	Weight (kg)	BMI (Kg/m^3)
Sex			
Male	1.65 ± 0.74	70.71 ± 11.25	26.00±3.49
Female	1.59 ± 0.70	65.29 ± 14.01	25.66 ± 4.75
F	54.48	12.44	0.46
P-value	0.00*	0.00*	0.49

Significant at $p < 0.05$

Additionally, the nutritional status of the responder is displayed in figure 1 below. Close to half of the population (45.9%) of the respondents had a normal nutritional status. While 38.8% of the respondents were overweight. Also, 12% of the respondents were obese, while only few (3%) were underweight.
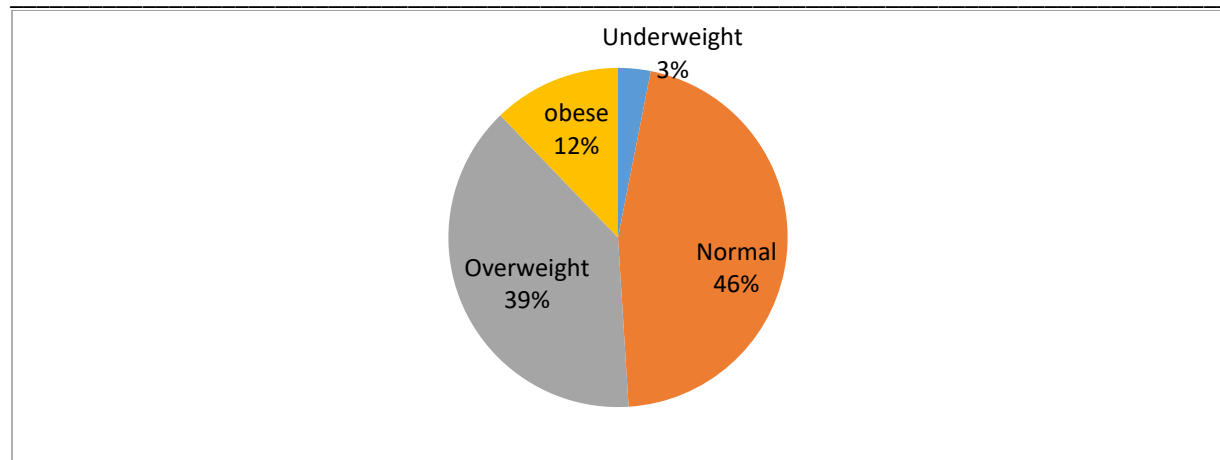
Figure 1: Nutritional Status of the respondents

Table 3 below shows the functioning capacity of the elderly. Majority of the respondents (96.9%) had a normal self-care activity, for self-care activity functionality, 96.9% are independent. Also, 82.5% of the respondents had a normal household care activity and for 82.8% of them, household care functionality are independent. For enjoyment and recreational activities, majority of the respondents 87.8% had a normal activity; similarly, 87.8% of them can also carry out the activity independently.

For shopping and money activities, close to the whole respondents (93.8%) had a normal activity and carried out the activity independently. For traveling activities, 89.4% of the respondents carried out a normal activity, and also carried out the function without depending on anybody. For communication, 93.4% communicate normally and do not need to depend on anyone to communicate.

Table 3: Functioning Capacity of Elderly

Variables	Frequency (n=320)	Percentage (100)
Self-care activities		
Normal	310	96.9
Moderate impairment	1	0.3
Severe impairment	9	2.8
Self-care activity functionality		
Functionality independent	310	96.9
Functional dependent	10	3.1
Household care		
Normal	264	82.5
Moderate impairment	32	10
Severe impairment	24	7.5
Household care functionality		
Functionality independent	264	82.5
Functional dependent	56	17.5
Employment and Recreation		
Normal	281	87.8
Moderate impairment	23	7.2
Severe impairment	16	5
Employment and Recreation functionality		
Functionality independent	281	87.8
Functional dependent	39	12.2
Shopping and money		
Normal	300	93.8
Moderate impairment	15	4.7
Severe impairment	5	1.6
Shopping and money functionality		
Functionality independent	300	93.8
Functional dependent	20	6.3
Travel		
Normal	286	89.4

Moderate impairment	28	8.8
Severe impairment	6	1.9
Travel functionality		
Functionality independent	286	89.4
Functional dependent	34	10.6
Communication		
Normal	299	93.4
Moderate impairment	19	5.9
Severe impairment	2	0.6
Communication functionality		
Functionality independent	299	93.4
Functional dependent	21	6.6

Table 4 below shows the association between socioeconomic characteristics and nutritional status. Significance association (p-value<0.05) was observed among educational level, present occupation and estimated monthly income of the respondents and their nutritional status.

Table 4: Association between socioeconomic characteristics and nutritional status

Variables	Nutritional status		
	χ2	Df	p-value
Educational level	23.37	12	0.02*
Present occupation	33.80	21	0.01*
Estimated income	34.82	12	0.00*

Significant at p-value<0.05

DISCUSSION

This study was aimed at assessing the nutritional status and functional capacity of the elderly in Ilaro, Ogun State. Age plays a significant role in determining an aged person's functional ability and nutritional state. This study found that 45.3% of the elderly were between the ages of 60 and 64 years. A similar result was also reported in the study conducted by Adepoju *et al.* (2021) where the majority of the respondents were in this age range. The results further corroborated the finding of Adepoju *et al.* (2021), which stated that a small percentage of the respondents were over 80 years of age. This may be partially due to the population's low survival skills, which are ingrained in the level of poverty and the nation's economic circumstances. Women made up 64.7% of the responders - the majority in this study. A similar finding was made in the study by Cacador *et al.* (2021), where the bulk of the participants were women. This could be the outcome of studies showing that women often live longer than men do (Mota-Pinto, 2011). However, similar results were also discovered in a Portuguese study conducted by Baixinho et al. (2019) and Figueiredo-Duarte et al. (2019), where the majority of respondents were female. Regarding education, thirty-three percent of the participants had finished secondary school. This result was in line with the findings of the Cacador et al. (2021) study, which indicated that the majority of participants had just finished their eleventh year of school. Furthermore, a significant number of the respondents in this study—22.2%—had no formal education, which is similar to the majority of respondents in a study conducted by Adepoju et al. (2021) in Ibadan. In contrast to Adepoju et al.'s (2021) estimated income, which showed that most respondents made less than ₦6,000, 79.4% of respondents reported earning ₦20,000 or more. Based on their estimated income, level of education, and present employment, the majority of study participants belong to the medium-class socioeconomic background. However, Nambooze, Fujimura, and Inaoka's (2014) findings—which indicated that the majority of respondents were from low socioeconomic backgrounds—contradict the statistics presented in this study.. Anthropometry is a vital tool for evaluating an individual's overall health, growth, and nutritional status. Anthropometric measurements illustrate the differences in a person's body composition by gender and life stage. In the current study, male respondents had a higher BMI than female respondents and were both heavier and taller than female respondents. However, these findings differ from those of Adepoju et al. (2021), who found that respondents who were male were taller, heavier, and had a higher BMI than respondents who were female. Specifically, the difference in respondents' weight and height between the male and female genders could be attributed to aging. Growing older has been associated with several structural changes to the skeletal system, including demineralization, which alters the bone's composition in a variety of ways, including long bone deformities (Padilla-Colón *et al.*, 2018). Additionally, ageing is linked to several physiological and nutritional changes, which are typically expressed as a decrease in height, weight, an increase in fat mass, less muscle mass, and a redistribution of adipose tissue Wang, Xu, & Li (2022).

The nutritional status shows that 38.8% of the respondents had an overweight status and 12% had an obese status; these results were less than those of the study by Cacador *et al.* (2021), in which 59.3% of the respondents had an overweight status. Based on height and weight, it has been determined that BMI is an objective indicator of body fat. Elevated body mass index (BMI) is deemed a risk factor for the health of the elderly population due to its correlation with declining life expectancy and elevated rates of illness and mortality (Al-Snih, *et al.*, 2007). Even though being overweight is linked to a decline in physical well-being, most of the study participants did not exhibit a reduction in their capacity to carry out everyday tasks. The use of BMI as a proxy for adiposity in older adults is controversial because, according to Sorkin, Muller, & Andres (1999), people lose height as they age, which causes BMI values to be overestimated. Additionally, BMI

is not able to distinguish between visceral and peripheral obesity in older adults. Accordingly, unfavourable cardiovascular illnesses may also be a danger for older persons with central obesity who present with a normal BMI (Batsis, Mackenzie, Bartels, Sahakyan, Somers, & Lopez-Jimenez, 2016; Sahakyan, Somers, Rodriguezescudero, Hodge, Carter, Sochor, Coutinho, *et al.,* 2015). Furthermore, the persistent loss of muscle mass that occurs with ageing and is linked to obesity (sarcopenic obesity) may go unrecognized, indicating that it is conceivable to have a high BMI yet receive inadequate nutrition (Wang *et al.,* 2022).

To provide the elderly with better care, functional capacity is essential. According to Ajayi, Adebusoye, Ogunbode, Akinyemi, & Adebayo (2015), one of the most reliable measures of an older person's health is their capacity. Different definition criteria, evaluation instruments, and techniques of functional capacity assessment may contribute to the global variation in the degree of functional incapacity. The Instrumental Activities of Daily Living (IADL) and Basic Activities of Daily Living (BADL) comprise this fundamental functionality. The result in supports those of Adepoju *et al.* (2021), who found that only 9% of respondents had functional impairments related to BADL and that roughly 29.5% had impairments related to IADL activities. Adepoju & Coker's (2018) study also revealed comparable results. Because activities involving IADL require more physical, mental, educational, and cognitive integrity than BADL, it is possible to attribute the high percentage of respondents who can perform IADL activities to the majority of respondents having completed secondary school. While there are a small percentage of people who are functionally impaired when performing IADLs, cultural practices in African nations where asking for help and support when performing a task or activity is customary may have contributed to the barrier preventing them from performing these different IADLs (Ajayi, *et al*., 2015).

A significant correlation (P-value<0.05) was found between the respondents' nutritional state, estimated monthly income, current occupation, and educational level. It is believed that an individual socio-economic status affects their nutritional status as well as functional capacity.

4.0 CONCLUSION
A high prevalence of overweight (39%) was observed among the respondents. Also, the majority of the elderly could carry out their Basic Activities of Daily Living (BADL) and Instrumental Activities of Daily Living (IADL) independently. A significant relationship (P-value <0.05) was observed between socio-economic characteristics (educational level, present occupation and income) and nutritional status.

REFERENCES

Adepoju, A. B., Olayiwola, I. O., Onabanjo, O. O., & Lasode, O. A. (2021). Nutritional status and functional capacity of elderly in selected communities in Ibadan, Oyo State. *Nigerian Journal of Nutritional Sciences*, 42(2), 41-52.

Adepoju, A. B., Coker, O. J. (2018) Nutritional status, household food security and dietary diversity of the elderly residing in Ilaro, Ogun state, Nigeria. *International Journal of Food Science and Nutrition,* 3(6), 125-135.

Ajayi, S., Adebusoye, L., Ogunbode, Akinyemi, J. O., Adebayo, A. (2015). Profile and correlates of functional status in elderly patients presenting at a primary care clinic in Nigeria. *African Journal of Primary Health Care & Family Medicine*, 7(1), 1-7. DOI:10.4102/phcfm.v7i1.810

Al-Snih, S., Ottenbacher, K.J., Markides, K.S., Kuo, Y. F., Eschbach, K., & Goodwin, J.S. (2007). The Effect of Obesity on Disability vs Mortality in Older Americans. *Arch. Intern. Med,* 167, 774–780.

Baixinho, C.L., Dixe, M.D.A., Madeira, C., Alves, S., & Enriques, M.A. (2019). Falls in institutionalized elderly with and without cognitive decline A study of some factors. *Dement. Neuropsychol,* 13, 116–121.

Bassem, E., & Kim, E. H. (2011). The geriatric Assessment. American Family Physician, 83(1): 48-56.

Batsis, J.A., Mackenzie, T.A., Bartels, S.J., Sahakyan, K.R., Somers, V.K., &Lopez-Jimenez, F. (2016). Diagnostic accuracy of body mass index to identify obesity in older adults. *Int. J. Obes,* 40, 761–767.

Caçador, C., Teixeira-Lemos, E., Oliveira, J., Pinheiro, J., & Mascarenhas-Melo, F. (2021). The relationship between nutritional status and functional capacity: A Contribution study in Institutionalised Portuguese Older Adults. *International Journal of Environmental Research and Public Health,* 18, 37 - 89. file:///C:/Users/Toluthalk/Downloads/ijerph-18-03789.pdf

Figueiredo-Duarte, C., Espirito-Santo, H., Sério, C., Lemos, L., Marques, M., Daniel, F. (2019). Validity and reliability of a shorter version of the Geriatric Depression Scale in institutionalized older Portuguese adults. *Aging Ment Health*, 3, 1–7.

Johnson, N., Barion, A., Rademaker, A., Rahkemper, G. and Weintraus, S. (2004). The activities of daily living questionnaire. *A validation study in patients with Dementia, Alzheimer Disease and Associated Disorders*, 18(4):223-230.

Mota-Pinto, A., Rodrigues, V., &Botelho, A. (2011). Veríssimo, M.T.; Morais, A.; Alves, C.; Rosa, M.S.; De Oliveira, C.R. A sociodemographic study of aging in the Portuguese population: The EPEPP study. Arch. Gerontol. *Geriatr,* 52, 304–308.

Nambooze, J., Fujimura, M. & Inaoka, T. (2014). Nutritional status and functional capacity of community-dwelling elderly in southern Laos. *Environ Health Prev Med* 19, 143–150 https://doi.org/10.1007/s12199-013-0367-1

Padilla-Colón, C. J., Molina-Vicenty, I. L., Frontera-Rodríguez, M., García-Ferré, A., Rivera, B. P., Cintrón-Vélez, G., & Frontera-Rodríguez, S. (2018). Muscle and bone mass loss in the elderly population: advances in diagnosis and treatment. *J Biomed (Syd)*., 3, 40-49. doi: 10.7150/jbm.23390.

Patterson, T. L., & Mausbach, B. T. (2010). Measurement of functional capacity: a new approach to understanding functional differences and real-world behavioral adaptation in those with mental illness. *Annu Rev Clin Psycho*, 6, 139-54.

Sahakyan, K.R., Somers, V.K., Rodriguezescudero, J.P., Hodge, D.O., Carter, R.E., Sochor, O., Coutinho, T., Jensen, M.D., Roger, V.L., & Singh, P. (2013). Normal-Weight Central Obesity: Implications for Total and Cardiovascular Mortality. Ann. *Intern. Med.* 163, 827–835.

Sampaio, L.R. (2004) Nutirional Evaluation and Aging. *Brazilian Journal of Nutrition,* 17, 507-514.

Santos, J.L., Albala, C., Lera, L., Garcia, C., Arroyo, P., Pérez-Bravo, F., Angel, B. and Peláez, M. (2004). Anthropometric measurements in the elderly population of Santiago,Chile.*Nutrition,* 20, 452-457.

Silveira, E.A., Lopes, A.C Oliveira, M.R., Fogaça, K.C. & Leandro-Merhi, V.A. (2009). Nutritional status and

functional capacity of hospitalized elderly. *Nutr J* 8, 54 https://doi.org/10.1186/1475-2891-8-54

Sorkin, J.D., Muller, D.C., & Andres, R. (1999). Longitudinal change in height of men and women: Implications for interpretation of the body mass index: The Baltimore Longitudinal Study of Aging. *Am. J. Epidemiol,* 150, 969–977.

Tracey, Fisher. (2008). Assessing Function in the Elderly: Katz Activities of Daily Living (ADL) and Lawton Instrumental Activities of Daily Living (IADL) For: Dr. Susan Doble OCCU 6504

Wang, X., Xu, M., & Li, Y. (2022). Adipose Tissue Aging and Metabolic Disorder, and the Impact of Nutritional Interventions. *Nutrients,*14(15):3134. doi: 10.3390/nu14153134.

Zihl, J., & Reppermund, S. (2022). The aging mind: A complex challenge for research and practice. *Aging Brain*, 19;3:100060.

EFFECT OF SEX AND ENVIRONMENTAL PARAMETERS ON PERFORMANCE AND PHYSIOLOGY OF RABBIT

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ABSTRACT
The cramped conditions in which rabbits are housed in intensive breeding units have drawn criticism because it prevents them from exhibiting behaviours unique to their species. A research was done using a total of 40 weaner rabbits comprising of 20 of males (M) and 20 females (F) housed based on sex in galvanized battery cage hutches equipped with concrete feeders and drinkers and kept either indoor (I) or outdoor (O) for 56 days. The rabbit were grouped based on sex and housing system in a 2×2 factorial arrangement given rise to four treatments as follows: Treatment (T) 1: 10 MI, T 2: 10 F I, T 3: 10 M O, T 4: 10 F O. Growth performance, blood, body physiology and stress marker data was collected using standard procedures and subjected to analysis of variance in a completely randomized design using the SAS (2010) software package. Rabbits reared under the outdoor system had significantly (P<0.05) higher feed intake (4521.6g) than rabbits reared indoor (4184.9g). Rectal temperature, body temperature, haematological parameters were not significantly (P>0.05) influenced by sex and housing systems. Rabbits reared outdoor had significant (P<0.05) higher creatinine level (0.99 mgdl^{-1}) than those reared indoor (0.62 mgdl^{-1}). FO rabbits had a significantly (P<0.05) higher cortisol level (6.59 and 6.94) when compared with the cortisol level of their male counterpart (4.44 and 4.93). It was concluded that growth performance was not different between male and female rabbits while cortisol level of female rabbits reared outdoor are higher than male rabbits. It was recommended that rearing rabbit indoor housing reduces stressors.

Keyword: Housing, Rabbit, Sex, Stressor

1.0   INTRODUCTION

Global production of rabbit meat is expanding in order to meet the growing demand for a variety of meat products that will meet the dietary needs of the world's growing population. China is the world's greatest producer of rabbit meat, followed by Europe, with an annual production of roughly 1.4 million tons (FAOSTAT, 2020). According to Zotte (2002), rabbit meat has good sensory qualities; it is flavourful, lean, and soft with less fat than other meats like chicken and pork. It is also high in protein, unsaturated fatty acids, conjugated linoleic acid, and minerals, all easily digested by humans. According to Zotte and Szendroe (2011), meats are also high in polyamine, antioxidant vitamins, and selenium.

Due to their higher metabolic rates and production capabilities, rabbits are more vulnerable to environmental stressors such as intense farming, high temperatures, transportation, and changes in feed composition (Marai et al., 2011). Due to their thick villi and lack of sweat glands, rabbits are particularly vulnerable to the negative effects of high temperatures on their health and performance. In response to high temperatures outside, rabbits will extend their bodies to increase their body temperature through convection and radiation and by stretching their ear pinnae and spreading them apart to expose their surface to the environment (Nielsen *et al.,* 2020).

The confinement of animals in intensive breeding units has been challenged since the animals are housed in a constrained setting where they cannot conduct their species-specific behavioural features, such as locomotor movements (Sabry, 2021). Thus, comparing the performance of sexed rabbits raised in various housing systems was the goal of this study.

2.0   MATERIALS AND METHODS

Experimental location
The study was done at the Rabbit Unit of Federal Polytechnic IlaroTeaching and Research Farm, Ogun State, Nigeria. It has an altitude of 141m above sea level and coordinates latitude 6.895550ºN and longitude 2.977167ºE (GPS display, 2021).

Experimental Animals and Management

A total of 40 weaner rabbits comprising 20 males and 20 females were purchased from a reputable farm and used for this study. The animals were housed based on sex in galvanized battery cage hutches equipped with concrete feeders and drinkers and kept either indoors or outdoors. The indoor house was a standard rabbitry while the outdoor house roof was covered by polythene and palm frond, other locally available materials such as bamboo, rope, and nylon were also used. The experiment lasted for 56 days. Baseline blood samples were collected at the commencement of the experiment for haematological, serum and stress markers. Commercial feed and water were given *ad libitum*.

Experimental Design
The animals were housed either indoors or outdoors and were grouped based on sex in a 2×2 factorial arrangement giving rise to four treatments as follows:
Treatment 1: Male 10 rabbits reared indoor
Treatment 2: Female10 rabbits reared indoor
Treatment 3: Male10 rabbits reared outdoor
Treatment 4: Female10 rabbits reared outdoor
Each animal was housed in each cell in the hutch and house, serving as replicates.

Data collection
Each replicate of the rabbit was weighed at the start of the experiment and every week thereafter. The difference between the two weight readings represents the rabbits' weekly body weight gain. Each rabbit received a predetermined amount of feed, and the amount of feed left over was weighed to calculate the daily and, subsequently, weekly feed intake. By dividing the entire amount of feed consumed by the total amount of weight gained, the feed conversation ratio for each replicate was calculated.
Blood sample (5 ml) was collected from five rabbits per treatment at the beginning (1day) and toward end of the experiment (50th day) using syringes and needle into the tubes containing ethylene diamine tetra acetate (EDTA) as anticoagulant and sample bottles without anticoagulant for heamatological parameters (packed cell volume, red blood cell, heamoglobin and white blood cell as well as haematological indices mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) according to Davice and Lewis (1991) and serum biochemistry (total protein (TP), globulin,

albumin, urea, aspartate amino transferase, alanine amino transferase, and cholesterol) analysis.

Determination of Rabbit Body Physiology

Daily micro-environment data i.e. daily ambient temperature and relative humidity was taken at 6 hours, 14 hours and 20 hours using thermo hygrometer. The rectal and body temperature of all the animals was also taken at 6am (06hours) and 2pm (14hours) using the Kris Alloy digital thermometer. The thermometer was inserted into the rectum of each rabbit at approximately 4 cm for 1 minute after which the reading was taken. The body temperature was determined by inserting a digital thermometer into the armpit of the rabbit.

Determination of Stress Marker Profile of Rabbits

On the 1st day and 50th day of the experiment, blood samples were collected from the ear pinner of three rabbits per treatment. The blood sample in the tube of each rabbit was 20ul of cortisol standards, control and serum was added into the Streptavidin-coated micro-wells. 50ul of biotin reagent and 100ul of cortisol enzyme conjugate were also added to the wells thoroughly mixed for 10 seconds and incubated for 60 minutes. The liquid was removed from the resultant mixture and incubated again for 10 minutes at 25°C. Cortisol levels were recorded and cortisol standard value was checked on each vial.

Statistical analysis

The SAS (2010) software package was utilized to arrange all the data in a 2 × 2 factorial configuration and then subject it to Analysis of Variance in a Completely Randomized Design. Significant variations among treatment means were isolated using the Duncan multiple range test as supplied in the software. The estimations of the Pearson correlation between the physiological parameters and body weight of male and female rabbits housed in indoor and outdoor environments were obtained using the same software program.

Statistical Model

$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \Sigma_{ijk}$

Where:

Y_{ijk}= Individual kth observation on ith effect of sex and jth of housing systems

μ = Overall Mean

A_i= fixed effect of ith sex (male and female)

B_j = fixed effect of jthHousing system (indoor and outdoor)

$(AB)_{ij}$ =fixed effect of interaction between sex and housing system

Σ_{ijk} = random residual error

3.0 RESULTS AND DISCUSSION

Growth performance of rabbits reared in indoor and outdoor

housing systems

Table 1 shows the growth performance of rabbits reared under indoor and outdoor housing systems. Rabbits reared under the outdoor system had significantly (P<0.05) higher feed intake (4521.6g) and significantly (P<0.05) higher water intake (11798.5ml) than rabbits reared indoor (4184.9g) and (9511.7ml). All other growth performance parameters considered (final weight, weight gain and feed conversion ratio) were not significantly (P>0.05) influenced by different housing systems. Results presented in Table 2 showed that sex had no significant (P>0.05) influence on all growth parameters of rabbits considered. The effect of the interaction of sex and housing systems on the growth performance of rabbits is presented in Table 3, it showed that the interaction of sex and housing systems had no significant (p> 0.005) influence on the growth performance of rabbits.

Table 1: Effect of housing systems on growth performance of rabbits

Parameters	Indoor	Outdoor	P- value
Initial weight (g)	1131.60±160.90	1173.70±423.40	0.71
Final weight (g)	1917.80±203.92	2050.00±352.97	0.17
Total Feed intake (g)	4184.90±374.47[b]	4521.60±567.41[a]	0.04
Total Weight gain (g)	786.30±220.11	876.30±470.13	0.41
FCR	5.64±1.34	7.91±8.44	0.26

FCR: Feed conversion ratio

[a b]: Means in the same row with different superscripts differ significantly (P<0.05)

Table 2: Growth performance of different sex of rabbits

Parameters	Female	Male	P- value
Initial weight (g)	1118.40±301.94	1186.84±335.34	0.53
Final weight (g)	2024.74±278.57	1943.16±307.03	0.36

Feed intake (g)	4325.30±472.51	4381.20±545.07	0.81
Weight gain (g)	906.30±387.53	756.30±334.20	0.19
FCR	6.79±8.26	6.75±2.74	0.93

FCR: Feed conversion ratio

Table 3: Effect of interaction of sex and housing systems on growth performance of rabbits

Parameters	Indoor		Outdoor		
	Female	**Male**	**Female**	**Male**	**P- value**
Initial weight(g)	1165.00±74.72	1094.44±221.42	1066.67±439.45	1270.00±406.34	0.19
Final weight(g)	1971.00±161.62	1858.89±238.19	2084.44±370.94	2019.00±353.00	0.81
Feed intake(g)	4230.90±378.77	4133.72±385.39	4430.11±563.44	4603.90±588.05	0.39
Weight gain (g)	806.00±210.45	764.44± 241.15	1017.78±511.39	749.00±414.20	0.34
FCR	5.51± 1.26	5.79±1.50	8.23±12.13	7.63±3.36	0.83

FCR: Feed conversion ratio

Effects of different housing systems on physiological response of rabbit

Table 4 presents the physiological data of rabbits reared under two distinct housing systems. Result revealed that rectal temperature and body temperature were not significantly (P>0.05) impacted by housing systems. Table 5 indicates the effect of sex on the physiological response of rabbits. Result showed that all parameters studied were not substantially (P>0.05) impacted by sex. Table 6 indicated the relationship of sex and housing systems on the physiological response of rabbits. The relationship of the housing system and sex did not significantly (P>0.05) affect any physiological parameters.

Table 4: Effects of different housing systems on physiological data of rabbits

Parameters	Indoor	Outdoor	P-value
Rectal temperature morning (°C)	37.96±0.04	37.99±0.05	0.53
Rectal temperature evening (°C)	38.31±0.05	38.28±0.05	0.63
Body temperature morning (°C)	38.88±0.04	38.76±0.06	0.07
Body temperature evening (°C)	39.18±0.03	39.11±0.03	0.13

[a b]: Means in the same row with different superscripts differ significantly (P<0.05)

Table 5: Effect of sex on the physiological response of rabbits

Parameters	Female	Male	P-value
Rectal temperature morning (^{0}C)	37.94±0.05	38.02 ±0.05	0.27
Rectal temperature evening (^{0}C)	38.26±0.05	38.33±0.05	0.38
Body temperature morning (^{0}C)	38.76±0.05	38.89±0.04	0.05
Body temperature evening (^{0}C)	39.14±0.03	39.15±0.04	0.90

Table 6: Interactive effect of sex and housing system on the physiological response of rabbits

Parameters	Indoor		Outdoor		P-value
	Female	Male	Female	Male	
Rectal temperature morning (^{0}C)	37.94±0.06	37.98±0.06	37.95±0.07	38.05±0.07	0.65
Rectal temperature evening (^{0}C)	38.29±0.06	38.33±0.07	38.23±0.07	38.32±0.08	0.76
Body temperature morning (^{0}C)	38.85±0.05	38.92±0.06	38.67±0.08	38.85±0.07	0.38
Body temperature evening (^{0}C)	39.16±0.06	39.20±0.03	39.12±0.33	39.09±0.06	0.58

Haematological indices of sexed rabbits under different housing system

Table 7 shows the haematological indices of rabbits reared under indoor and outdoor housing systems. Results showed that housing systems had no significant (P>0.05) effect on the haematological

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parameters of the rabbits. The effect of the sex of rabbits on the haematological indices of rabbits is shown in Table 8. Results revealed that sex had no significant (P>0.05) effect on the rabbits' haematological parameters considered at the initial and final stages of the experiment. The impact of the interaction of sex and housing

systems (indoor and outdoor) on the haematological indices of rabbits is as shown in Table 9. Haematological parameters of rabbits considered were not significantly (P>0.05) influenced by the interaction of sex and housing system at both the initial and final stages.

Table 7: Effects of housing system on the haematological indices of rabbits

Parameters	Indoor	Outdoor	P-value
Packed cell volume (%)	37.00±3.71	39.40±4.43	0.12
Hemoglobin (g/dl)	12.37±1.24	14.62±5.54	0.19
White blood cell (x10^9/L)	8564.00±1878.08	18050.00±26006.46	0.26
Red blood cell (x10^{12}/L)	4.94±0.51	5.28±0.51	0.10
Means corpuscular volume (fl)	61.03±3.66	60.19±1.94	0.51
Mean cell haemoglobin concentration (g/dl)	25.56±0.92	25.75±0.92	0.64
Mean cell haemoglobin (pg)	40.89±1.32	40.97±5.52	0.96

Table 8: Effect of sex on the haematological indices of rabbits

Parameters	Female	Male	P-value
Packed cell volume (%)	37.70± 5.19	38.70± 3.020	0.50
Hemoglobin (g/dl)	14.22± 5.74	12.77± 1.00	0.39
White blood cell (x10^9/L)	17107± 26367.42	9507± 1589.00	0.36
Red blood cell (x10^{12}/L)	5.07± 0.60	5.15± 0.46	0.68
Means corpuscular volume (fl)	60.99± 2.4946	60.23 ±3.32	0.55
Mean cell haemoglobin concentration (g/dl)	25.47± 0.94	25.84± 0.87	0.37
Mean cell haemoglobin (pg)	41.44± 1.35	40.42± 5.46	0.58

Table 9: Effect of sex and housing system on the haematological indices of rabbits

| Parammeters | Indoor | | Outdoor | | P-value |
	Female	Male	Female	Male	
Packed cell volume (%)	34 00± 2.55	40.00± 1.41	41.40 ±4.44	37.40±3.78	0.00
Hemoglobin (g/dl)	11.40± 0.83	13.34± 0.63	17.04± 7.31	12.20± 1.02	0.06
White blood cell (x10^9/L)	7454 ±936.79	9674 ±1994.58	26760 ±36475.51	9340± 1277.88	0.24
Red blood cell (x10^{12}/L)	4.62 ±0.38	5.26± 0.43	5.52 ±0.41	5.04 ±0.52	0.11
Means corpuscular volume (fl)	62.46± 1.43	59.60± 4.80	59.52± 2.56	60.86± 0.88	0.12
Mean cell haemoglobin concentration (g/dl)	25.64± 0.87	25.48± 1.10	25.30± 1.1	26.20±0.5	0.21
Mean cell haemoglobin (pg)	40.40± 0.89	41.38 ±1.60	42.48± 0.80	39.46± 7.89	0.29

Serum biochemistry of sexed rabbit under different housing system

Table 10 shows the serum biochemical parameters of rabbits reared indoor and outdoor housing systems. Result showed that at the initial stage rearing rabbits on two different housing systems (indoor and outdoor) had significant (P<0.05) effect on creatinine parameters of rabbits, with rabbits reared outdoor had significant (P<0.05) higher creatinine level (0.99 mgdl^{-1}) than those reared

indoor (0.62 mgdl^{-1}). Other serum parameters considered were not significantly (P>0.05) affected by different housing systems. Table 11 shows the effect of sex on the serum biochemical parameters of rabbits. All serum biochemical parameters considered were not significantly (P>0.05) influenced by the sex of rabbits. The interactive effect of sex and housing systems on serum biochemical parameters of rabbits presented in Table 12 of this experiment revealed that interaction of sex and housing systems had no

significant (P>0.05) effect on the serum biochemical indices of rabbits.

Table 10: Effect of housing system on serum biochemical parameters of rabbits

Parameters	Indoor	Outdoor	P-value
Total protein g/dl	6.77± 0.28	6.82± 0.46	0.80
Albumin g/dl	3.82±0.16	3.87±025.	0.62
Globulin g/dl	2.96±0.37	2.91±0.54	0.82
Aspartate amino transferase (U/L)	65.70±8.00	65.30±6.63	0.90
Alanine amino transferase (U/L)	56.50±6.93	56.90±8.69	0.92
Glucose (mg/dl)	115.78±16.98	116.48± 29.00	0.95
UREA	16.16±7.33	16.06±5.33	0.97
Creatinine (mgdl^{-1})	1.79± 0.66	1.87± 0.68	0.79

[a b]: Means in the same row with different superscripts differ significantly (P<0.05)

Table 11: Effect of sex on serum biochemical parameters of rabbits

Parameters	Female	Male	P-value
Total protein g/dl	6.87±0.47	6.72±0.23	0.38
Albumin g/dl	3.84±0.26	3.85±0.15	0.92
Globulin g/dl	3.01±0.55	2.86±0.33	0.49
Aspartate amino transferase	63.90±5.30	67.10±8.62	0.34
Alanine aminotransferase	56.10±4.91	57.30±9.93	0.75
Glucose	113.37±17.14	118.89±28.62	0.63
UREA	13.63±6.29	18.60±5.37	0.29
Creatinine	1.89±0.80	1.77±0.21	0.69

Table 12: Effect of sex and housing systems on serum biochemical parameters of rabbits

	Indoor		Outdoor		
Parameters	Female	Male	Female	Male	P-value
Total	6.74± 0.30	6.80± 0.27	7.00± 0.60	6.64 0.18	0.23
Albumin	3.80± 0.17	3.84± 0.17	3.88± 0.34	3.86± 0.15	0.77
Globulin	2.92± 0.36	2.98± 0.41	3.08± 0.73	2.74± 0.18	0.37
Aspartate amino transferase	62.00± 4.18	69.4± 9.61	65.8± 6.06	64.8 ±7.85	0.21
Alanine amino transferase	55.60±5.18	57.4±8.91	56.6 ±5.18	57.2 ±11.95	0.87
Glucose	115.44± 10.18	116.12± 23.35	111.30± 23.38	121.66±35.76	0.66
Urea	14.10± 7.64	18.22± 7.19	13.16± 5.49	18.96 ±3.57	0.76
Creatinine	2.08± 0.71	1.50± 0.37	1.70± 0.83	2.04± 0.52	0.14

Effect of sex and housing systems on stress markers of rabbits

Table 13 shows the effect of housing systems (indoor and outdoor) on the cortisol levels of rabbits. Significantly (P<0.05) higher cortisol levels were observed in rabbits reared outdoors (6.655) compared (p> 0.05) to those reared indoors (5.218). Table 14 revealed the effect of sex on the level of rabbits. Results showed that female rabbits had significantly (P<0.05) higher cortisol levels (6.59 and 6.94) when compared with the cortisol levels of their male counterpart (4.44 and 4.93). The effect of the interaction of sex and the housing system on the stress level of rabbits is shown in Table 15. Results showed that the interaction of sex and housing systems had no significant (P>0.05) influence on the stress level of rabbits.

Table 13: Effect of housing systems on cortisol level of rabbits

Parameters	Indoor	Outdoor	P-value
Cortisol (mcg/dL)	5.218±0.56[b]	6.655±0.52[a]	0.02
Superoxidase dismutase	0.00± 0.00	0.00± 0.00	0.00
Glutathione peroxidase	24.9±6 8.01	25.60± 6.09	0.82

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Table 14: **Effect of sex on cortisol level of rabbits**

Parameters	Female	Male	P-value
Cortisol (mcg/dL)	6.94±0.43[a]	4.93±0.45[b]	0.01
Superoxide dismutase	0.00± 0.00	0.00 ±0.00	0.25
Glutathione peroxidase	23.73 8.04	26.83 5.74	0.33

[a b]: Means in the same row with different superscripts differ significantly (P<0.05)

Table 15: Interaction of sex and housing system on the cortisol level of rabbit

Parameters	Indoor		Outdoor		
	Female	Male	Female	Male	P-value
Cortisol	6.20±0.50	4.24±0.59	7.68±0.34	5.63±0.44	0.92
Superoxide dismutase	0.00± 0.00	0.00 ±0.00	0.00± 0.00	0.00± 0.00	0.58
Glutathione peroxidase	20.26± 9.22	29.66± 2.72	27.20± 5.52	24.00± 6.84	0.35

Discussion

The result obtained on the growth performance of rabbits in this study revealed that feed intake and water intake were only significant when rabbits were reared under two different housing systems, with rabbits reared outdoors consuming more water and feed. Increased water intake in rabbits reared outdoors can result from the higher environmental temperature the rabbits were subjected to, thus rabbits need to consume more water to reduce heat stress caused by higher temperatures. Increased water intake can lead to an increase in the feed intake of rabbits (Tschudin et al*.,* 2011). The result was in line with the study of Krohn et al*.,* (1999) and Rizzi et al*.,* (2008) who reported that rabbits consumed more water when reared outdoors than when kept indoors. The current study's findings also show that while housing systems boosted feed and water intake, they had no discernible effect on other growth performance metrics, such as weight gain, ultimate weight, and feed conversion ratio. This conclusion was consistent with a study by Rizzi et al. (2008) that found that while rabbits housed outside consumed more food, their body weight did not increase noticeably above those kept indoors. However, the D'Agata et al. (2009) study, which found that raising rabbits outside significantly improved their growth performance, conflicted with this conclusion. Results obtained from this study revealed no visible difference in all growth performance parameters (Feed intake, weight gain, final weight, water intake and feed conversion ratio) as a result of sex difference. This result contradicted the study of Salisu and Erakpotobor, (2014) who recorded higher feed intake and body weight in female rabbits than in male rabbits.

The result of the physiological data obtained in this study collaborated with the report of Lambertini et al*.,* (2001) and Machado et al*.,* (2019) who reported higher environmental temperatures in the outdoor housing system of rabbits than indoor housing system. It was noticed that while environmental temperature was affected by housing systems, rectal temperature and body temperature were influenced by housing systems. This result further explained the reason for the increase in water intake as an increase in water intake is a coping mechanism for rabbits subjected to higher environmental temperatures (Ramnaraine, 2017). Result in this study showed that body temperatures were similar in both sexes, and this in line with the study of Akinsola

(2012) who reported no significant difference in the body temperature of both male and female rabbits. Jimoh and Ewuola (2018) reported the rectal temperature of male rabbits averaged 37.60°C in the morning and 38.4°C in the evening, while female rectal averaged 37.41°C in the morning and 37.92°C in the evening. Although the rectal temperature values in the above study and those in this study differ slightly. However, the current study is similar to that reported by Jimoh and Ewuola (2018), who also reported no significant difference in the rectal temperature of male and female rabbits. The difference in the rectal temperature values can be as a result of environmental differences as Jimoh and Ewuola (2018) study was carried out in Oyo state, while this study was carried out in Ogun state. The interaction of sex and housing had no visible effect on the physiological state of rabbits, this result supported the findings of Massaro *et al.,* (2006) who reported no significant difference in the physiological data (body temperature, rectal temperature and respiratory rate) of both male and female rabbits reared under different housing systems.

Haematological indices are an index and a reflection of the status of the blood available for an animal to meet its physiological, biochemical and metabolic necessities (Ewuola et al., 2004). Results on the haematological indices showed that all haematological indices considered were within the normal blood haematology range of rabbit reported by Ewuola et al. (2004) and Etim et al. (2014). This result contradicted the study of Aderemi (2004) who stated that the haematological parameters of animals can be affected by the environment. The haematological indices on sex results also contradicted the study of Chineke et al*.* (2006) who stated that sex can influence the haematological parameters of rabbits, with male rabbits having higher values than females Hb, PCV, and RBC. Also, Animashahun et al*.* (2006) reported that haematological values may be influenced by sex, age and nutrition among others.

The result of this present study on the serum biochemical indices showed that although there was a slight difference in the creatinine level of rabbits as a result of different housing systems at day 1 of the experiment, the serum biochemical indices were still within the normal range reported by El-Banna et al. (2005). The increased level of creatinine in rabbits reared outdoors can be as a result of a change in environmental temperature subjected to on the first day. The result was in contrast with the study of Mutwedu et al*.,* (2021) who

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reported no significant difference when rabbits were reared in different housing systems. Differences in the result of this present study and Mutwedu et al.*,* (2021) can be as a result of the different region where the experiment was carried out (Temperate and Tropical region). Furthermore, the serum levels in both male and female rabbits were not significantly different. This report supported the findings of Ayo-Ajasa et al.*,* (2015) who reported no significant difference in serum parameters of both male and female rabbits.

One hormone that shows a body's reaction to stress is cortisol. According to Perez-Fuentes *et al*. (2020), rabbits housed in outdoor housing types may have been subjected to higher levels of chronic stress, which could indicate that their welfare conditions were not optimal. In this study, cortisol concentration was greater in rabbits reared outdoors than those reared indoors and this can be associated with the higher environmental temperature in outdoor housing. This result was in line with the report of Pérez-Fuentes et al.*,* (2020) who reported a significant increase in the cortisol level of rabbits as environmental temperature increased. This conclusion is in line with recent research that found that rabbits raised outdoors had faecal corticosterone concentrations three times higher than those raised indoors (Szendrő et al.*,* 2012). Similar findings were made by Mugnai *et al*. (2011) and Rommers et al. (2006) about elevated corticosterone concentrations in communally raised rabbits. The result in this present study was in line with the report of Bayazit and Khan (2005) who stated that cortisol levels were significantly higher in female rabbits than in male rabbits. Increased level in cortisol in female rabbits is an indication that male rabbits can withstand stressors better than female rabbits.

4.0 CONCLUSION

From this study, it could be concluded that:

- Rearing rabbits in outdoor housing increased feed intake and water intake, without enhancing body growth,
- Growth performance was also not different between male and female rabbits.
- Body temperature and rectal temperature were not significantly affected by sex and housing systems.
- Haematological parameters of rabbits were not affected by either sex or housing system (indoor and outdoor).
- Creatinine level was higher in rabbits kept outdoor than those kept indoor but did not vary with sex.
- Cortisol level was higher in rabbits reared outdoor than those reared indoor, and female rabbits indicated higher cortisol level than male rabbits under outdoor system

Recommendation

The following recommendations were made from results of this study:

- To reduce feed intake while still maintaining optimal growth performance, rearing rabbits indoor is recommended.
- To reduce stressors in rabbits, rearing rabbit's indoor housing is recommended.
- Only male rabbits may be considered for production rearing where outdoor housing is paramount.

References

Aderemi, F. A. (2004). Effects of replacement of wheat bran with cassava root sieviate supplemented or unsupplemented with enzyme on the haematology and serum biochemistry of pullet chicks. *Tropical Journal of Animal Science*, 7,147-153.

Akinsola, O. M. (2012). Genetic and physiological evaluation of Hyla rabbits in guinea savannah zone of Nigeria, Zaria: *M.Sc. Dissertation submitted to the Department of Animal Science, Ahmadu Bello University.*66–70.

Animashahun, R. A., Omoikhoje, S. O. & Bamgbose, A. M. (2006). Haematological and biochemical indices of weaner rabbits fed concentrates and *Syndrella nodiflora* forage supplement. *Proceedings of 11th Annual Conference of Animal Science Association of Nigeria. Institute of Agricultural Research and Training, Ibadan, Nigeria, 29-32.*

Ayo-Ajasa, O. Y., Aina A. B. J., Sowande, O. S., Egbeyale, L.T., Ozoje, M. O., Agaviezor, B. O. & Abel, F. A. S. (2015). Haematology and serum profile of rabbits due to generation interval, housing systems and sex. *Nigerian Journal of Animal Production*, 15, 61-70.

Bayazit, .V. & Khan, L. M. (2005). Effects of different physiological and environmental conditions on plasma cortisol level in rabbits. *Journal-chemical society of Pakistan* 27(4), 409-412.

Chiericato, G. M., Bailoni, L., & Rizzi, C. (1992). The effect of environmental temperature on the performance of growing rabbits. *Journal of Applied Rabbit Research,* 15, 723–31.

Chineke, C. A., Ologun, A. G. & Ikeobi, C.O.N. (2006). Haematological Parameters in Rabbit Breeds and Crosses in Humid Tropics. *Pakistan Journal of Biological Sciences*. 9(11), 2102-2106.

D'Agata, M, G., Preziuso, C., Russo, A., DalleZotte, E., Mourvaki, C., & Paci, G. (2009). Effect of an outdoor rearing system on the welfare, growth performance, carcass and meat quality of a slow-growing rabbit population. *Journal of Meat Science,* 83, 691 – 696.

Davice, J. U., & Lewis, S.M. (1991). Practical haematology 8th Edition. *Longman Ltd., London, UK, 22-68.*

El-Banna, A., Badr El Dine, F., Abd-el-Moneim, R., & Dwedar, F. (2014). A toxicological, histological, and biochemical study of the effect of Aroclor 1254 on thyroid follicular cells and the possible protective role of zinc sulphate in adult male Albino rats. Ain Shams. *Journal of Forensic Medicine and Clinical Toxicology*, 22(1), 56-73.

El-Banna, S.G., Hassan, A.A., Okab, A.B., Koriem, A.A., & Ayoub, M. A. (2005). Effect of feeding diets supplemented with seaweed on growth performance and some blood hematological and biochemical characteristics of male Baladi Rabbits. *4th International Conference on Rabbit Production in Hot Climates, Sharm Elsheikh, Egypt, 373–382*

Etim, N., Mary E. Williams, Uduak, A., & Edem E. A. (2014). Haematological parameters and factors affecting their values. *Journal of Agricultural Science, 2*(1), 37-47.

Ewuola, E. O., Folayan, O. A., Gbore, F. A., Adebunmi, A. I., Akanji, R. A., Ogunlade, J. T. & Adeneye, J. A. (2004). Physiological response of growing West African Dwarf goats fed groundnut shell-based diets as the concentrate supplements. *BOWEN Journal of Agriculture* 1(1), 61-69.

FAOSTAT (2020).The Statistics Division of the FAO. (2020). http://www.fao.org/faostat/en/#data (accessed February 17, 2022)

Jimoh, O. A., & Ewuola., E. O. (2018).Thermophysiological traits in four exotic breeds of rabbit at least temperature-humidity index in humid tropics. *The Journal of Basic and Applied Zoology,* 79, 18-24.

Krohn, T. C., Ritskes-Hoitinga, J., & Svendsen, P. (1999). The effects of feeding and housing on the behaviour of the laboratory rabbit. *Laboratory Animals* 33, 101-107.

Lambertini, L., Vignola G., & Zaghini G., (2001) – Alternative pen housing system for fattening rabbits: Effect of density and litter. *World Rabbit Science 9,* 141-147.

Machado, L. C., Santos, A. M., Zeferino, C. P., Bittencourt, M. T., Geraldo A., Camargos R. S., Faria C. G., & Garcia, V. C. (2019). Influence of pen housing with litter on sanitary status, performance and carcass traits of growing rabbits. *Ars Veterinaria.\,* 35, 33-37.

Marai, I. F. M., Haeeb, A. A. M. & Gad, A. E. (2007). Biological functions in young pregnant rabbit does as affected by heat stress and lighting regime under subtropical conditions of Egypt. *Tropial and Subtropical Agroecosystem.* 7:165–76

Massaro, M., Habib, A., Lubrano, L., Turco, S. D., Lazzerini, G., Bourcier, T., & De Caterina, R. (2006). The omega-3 fatty acid docosahexaenoate attenuates endothelial cyclooxygenase-2 induction through both NADP (H) oxidase and PKCε inhibition. *Proceedings of the National Academy of Sciences*, 103(41), 15184-15189.

Mugnai, C. A., Dal Bosco, C., & Castellini, A. (2009). Effect of different rearing systems and pre-kindling handling on behaviour and performance of rabbit does. *Applied Animal Behaviour Science*, 118, 91-100.

Mugnai, C., Alessandro, D. B., Moscati, L., Battistacci, L., & Castellini, C. (2011). Effect of genotype and husbandry system on blood parameters, oxidative and native immune status: welfare and implications on performance of organic laying hens. *The Open Veterinary Science Journal*, 5, 12-18.

Mutwedu, V. B., Nyongesa, A. W., Oduma, J. A., Kitaa, J. M., & Mbaria, J. M. (2021). Thermal stress causes oxidative stress and physiological changes in female rabbits. *Journal of Thermal Biology*, 95, 102780.

Nielsen, S. S., Alvarez, J., Bicout, D. J., Calistri, P., Depner, K., & Drewe, J. A. (2020). Stunning methods and slaughter of rabbits for human consumption. *EFSA Journal* 18, 5927. doi: 10.2903/j.efsa.2020.5927

Pérez-Fuentes, S., Muñoz-Silvestre, A., Moreno-Grua, E., Martínez-Paredes, E., Viana, D., Selva, L., ... & Corpa, J. M. (2020). Effect of different housing systems (single and group penning) on the health and welfare of commercial female rabbits. *Animal*, 14(6), 1270-1277.

Ramnaraine, A. (2017). Keeping your rabbit cool in the summer. *MH Magazine Word Press.* https://rabbit.org/faq-warm-weather-concerns/.

Rizzi, C., Chiericato, G. M., Xicato, G., Trocino, A., & Lukefahr, S. D. (2008). Effect of environmental conditions on productive and physiological responses in growing rabbits. *World Rabbit Science Association, Proceedings of the 9th World Rabbit Congress, Verona*, 1233-1238.

Rommers, J. M. & de Greef, K. H. (2018). Are combi parks just as useful as regular parks for fatteners for part-time group housing of rabbits does? *World Rabbit Science, 26: 299-305.*

Sabry, M. I. E., Zaki, M. M., Elgohary, F. A., & Helal, M. M. (2021). Sustainable rabbit production under the global warming conditions in the Southern Mediterranean region. *World's Veterinary Journal, 11(4), 543-548.*

Salisu, I. B. & Grace, T. I. (2014). Effect of age and sex of rabbits on nutrient intake and digestibility. *Journal of Global Biosciences. 3(2), 569-575.*

Szendrő, Z., Szendrő, K., & DalleZotte, A. (2012). Management of reproduction on small, medium and large rabbit farms: A review. *Asian-Australian Journal of Animal Science, 25(5), 738–748*

Tschudin, A., Clauss, M., Codron, D., Liesegang, A., & Hatt, J. M. (2011). Water intake in domestic rabbits (Oryctolagus cuniculus) from open dishes and nipple drinkers under different water and feeding regimes. *Journal of Animal Physiology and Animal Nutrition*, 95(4), 499-511.

Tscudin, A., Clauss, M., Codron, D., Liesegang, A. & Hatt, J. (2011).Water intake in domestic rabbits from open dishes and nipple drinkers under different water and feeding regimes. *Journal of animal nutrition*, 95(4): 499-511.

Zotte, A. D. & Szendroe, Z. (2011). The role of rabbit meat as functional food. *Meat Science*. 88, 319–331.doi: 10.1016/j.meatsci.2011.02.017

Zotte, A. D. (2002). Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. *Livestock Production Science, 75, 11–32. doi: 10.1016/S0301-6226(01)00308-6*

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SAFEGUARDING DATA INTEGRITY: A COMPREHENSIVE EXPLORATION OF DATABASE BACKUP AND RECOVERY USING *TAMPER-RESISTANT PROPERTIES OF BLOCKCHAIN*

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ABSTRACT:

Data integrity is a critical concern in database management systems, particularly in ensuring the security and reliability of stored information. Traditional methods of database backup and recovery face challenges such as centralized control, vulnerability to tampering, and single points of failure. This paper presents a comprehensive exploration of leveraging blockchain technology to enhance database backup and recovery processes, thereby safeguarding data integrity. Drawing on the decentralized and tamper-resistant properties of blockchain, this study investigates how blockchain can be integrated into database backup and recovery systems to mitigate risks associated with data manipulation, unauthorized access, and data loss. The proposed approach utilizes cryptographic hashing, decentralized storage, consensus mechanisms, and smart contracts to create secure, transparent, and auditable backups of database records. Through a detailed analysis of existing literature, case studies, and technical implementations, this paper evaluates the effectiveness and feasibility of blockchain-based solutions for database backup and recovery. It discusses the benefits of blockchain technology in ensuring data immutability, integrity verification, and fault tolerance while addressing potential challenges and limitations.

Keywords: Blockchain, Consensu-mechanism. Cryptography, Decentralization, Hashing, Interoperability

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1.0   INTRODUCTION

In the ever-evolving landscape of information technology, data serves as the lifeblood of organizations, fueling critical decision-making processes and ensuring seamless operations. The integrity and availability of this data, housed within databases, are paramount to an organization's success. However, the vulnerability of digital assets to various threats necessitates a robust strategy for database backup and recovery.

Ketan & Gurpreet (2022) described a data backup as the practice of copying data from the first to the second location. A database backup is a systematic process of creating and storing duplicate copies of a database or its components. This redundancy serves as a safety measure, providing a means to recover data in the event of accidental deletion, system failures, or catastrophic events. The primary goal of database backup is to safeguard the integrity, availability, and consistency of critical data.

A database backup involves creating a copy of the entire or a subset of a database, capturing its current state, and storing it in a secure location. This process serves as a safeguard against data loss, providing a mechanism to restore the database to a previous state in case of corruption, accidental deletions, or system failures. Database recovery, on the other hand, refers to the process of restoring the database from a backup to its consistent and usable state

The importance of database backup and recovery extends beyond mere data preservation; it is a cornerstone of business continuity and disaster recovery planning. Organizations invest in backup strategies to minimize downtime, maintain data consistency, and ensure compliance with regulatory requirements. As databases grow in complexity and scale, implementing efficient and reliable backup and recovery mechanisms becomes paramount for sustaining operational resilience.

Various backup methods, such as full, incremental, and differential backups, offer flexibility in tailoring strategies to specific organizational needs. According to Lorent (2022), a type of backup defines how data is copied from source to destination and lays the grounds of a data repository model. Additionally, the choice between online and offline backups influences the impact on system performance during backup operations. Implementing a well-defined backup schedule and retention policy further enhances the overall data management strategy.

According to Brooke (2024), Blockchain is an immutable digital ledger that enables secure transactions across a peer-to-peer network. She described blockchain technology as a decentralized and distributed ledger that stores the record of ownership of digital assets.

Recovery, on the other hand, pertains to the restoration of a database to a previous state after a data loss event. Whether due to system failures or accidental deletion, the recovery process is critical for minimizing downtime and ensuring business continuity. Recovery mechanisms typically involve restoring data from the latest backup and applying transaction logs or incremental backups to bring the database up to the desired point in time.

The principles of database backup revolve around creating copies of the data within a database to ensure data integrity, availability, and recovery in the event of data loss or system failures. These principles (such as backup types, backup frequency, transaction log etc.) encompass various considerations, strategies, and practices to effectively implement and manage database backup processes.

There are four major types of backup, grouped into categories, based on certain criteria. These types are diagrammatically demonstrated below.

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┌───┐
│   **TYPES OF BACKUPS**   │
│   │
│ CATEGORY 1: Based on current data on   CATEGORY2: Based on what goes into the │
│ the system and the data on the backup   backup   │
│   │
│   Online Backups   Full backups   │
│   │
│   Near-Line Backups   Incremental   │
│   │
│   Offline Backups   Differential   │
│   │
│ CATEGORY 3: Based on storage of   CATEGORY 4: Based on the extent of the │
│ backup   automation of the backup   │
│   │
│   Highly automated   │
│   On-site Storage   │
│   Scheduled and   │
│   Off-site Storage   automated   │
│   │
│   Manual backups   │
└───┘

The modern digital landscape is characterized by an unprecedented reliance on databases, which store and manage vast volumes of critical information. Whether it be financial transactions, customer records, or intellectual property, the value of this data cannot be overstated. However, with the proliferation of cyber threats, system failures, and human errors, the need for a robust database backup and recovery mechanism becomes paramount

A comprehensive understanding of database backup and recovery involves exploring the intricacies of safeguarding data at multiple levels. This encompasses not only the technical aspects of implementing efficient backup strategies but also the strategic considerations in aligning these processes with organizational goals.

2.0 BACKGROUND AND RELATED WORK

According to Yashodha ,S. & Rajashekarappa. (2016) highlighted the importance of efficient backup mechanisms in database systems, emphasizing comprehensive coverage and minimal system performance impact to meet the dynamic demands of modern organizations. Kruti and Kavita (2012) discussed the necessity of cloud computing for database backup and recovery, identifying various contemporary strategies such as HSDRT, PCS, ERGOT, Linux Box, Cold and Hot Backup Technique, SBBR, and REN. They concluded that PCS is somewhat dependable due to its cost-efficiency and privacy maintenance but struggles with implementation complexity. Zhang, Zhou, Li, Liu, Xie, Cheng, & Xing (202) explored incremental and differential backup methods, analyzing the trade-offs between data recovery speed and storage efficiency, and provided insights on tailoring backup approaches.

Praveen, Ambika, & Mahantesh, (2017). investigated the implications of cloud-based solutions on database backup and recovery, emphasizing the need for organizations to adapt their strategies to the features and constraints of cloud environments.

Malatesh (2018) offered options for storage repository models, such as native file systems and Hadoop Distributed File System (HDFS), concluding that HDFS is cost-effective and can be built with low-cost commodity hardware. Johnson & Wang (2019) delved into the role of training and user awareness in mitigating data loss risks, emphasizing the need for a holistic approach to data protection that integrates technology and human factors. Wang & Gupta (2020) explored the integration of artificial intelligence (AI) and machine learning (ML) techniques to enhance the efficiency and reliability of backup processes. Karina, Amol, Damini, Rupali, & Pachghare (2021) analyzed Cassandra Database Recovery

Mechanisms, concluding that multiple servers yield better recovery outcomes than a single server and highlighted the benefits of trigger-based backup mechanisms for achieving lower RPO and RTO values.

Li & Patel (2021) discussed securing backup data, focusing on the vulnerabilities during storage and transmission. Khan, Laghari, Gadekallu, Shaikh, Javed, Rashid,& Mikhaylov (2022). provided insights into the role of geographic redundancy and distributed architectures in disaster recovery, emphasizing data availability during natural disasters or large-scale outages. According to Shaanxi & Xi'an (2023) introduced blockchain technology and an electronic data secure storage model using the Ethereum virtual machine and Practical Byzantine Fault Tolerance (PBFT) consensus algorithm. Their model effectively detects tampering and restores data using blockchain backups.
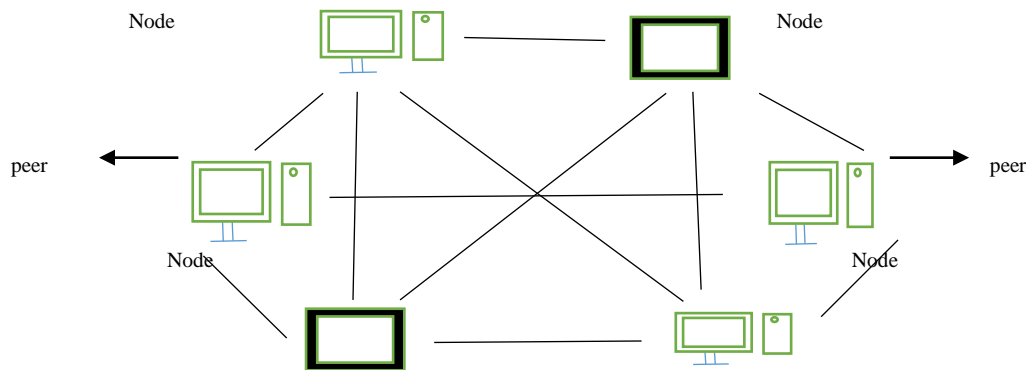
3.0 BLOCKCHAIN TECHNOLOGY

Blockchain is a decentralized and distributed digital ledger technology that records transactions across a network of computers in a secure and tamper-resistant manner. It gained prominence as the underlying technology for cryptocurrencies like Bitcoin, but its applications extend far beyond digital currencies.

Information is kept in uniform-sized blocks on a blockchain. To ensure cryptographic security, each block includes the hashed data from the one before it. The one-way hash function used for hashing is SHA256. The data and digital signature from the most recent block, as well as the hashes of earlier blocks dating all the way back to the "genesis block," the first block ever created in the blockchain, are included in this hashed data. A hash function is applied to the data, and the result is an address for the previous block. One example of a Merkle Tree, which is utilized as an effective means of data verification, is a blockchain data structure.

Fig 1: **P2P Network: Author**

Every node, or participant, in a peer-to-peer network using blockchain possesses a copy of the complete ledger. Depending on the blockchain protocol, a consensus process such as Proof of Work, Proof of Stake, or another technique is used to validate a newly created transaction when it is broadcast to the network. In the case of Proof of Work, adding a new block to the chain requires nodes to solve difficult mathematical puzzles, and in the case of Proof of Stake, staking a particular quantity of cryptocurrency. The new block is appended to the chain and all nodes update their copy of the ledger upon reaching a consensus. Immutability is one of blockchain's primary characteristics. The integrity of the whole transaction history is ensured by the fact that once a block is added to the chain, changing its contents would necessitate modifying all subsequent blocks, rendering the change computationally   impractical.
Blockchain technology is not just for currency. For instance, smart contracts are self-executing contracts containing coded terms that, when certain requirements are satisfied, automatically carry out and enforce agreements. This feature affects several industries, including supply chain management, healthcare, and finance.

Enhancing data backup and recovery through the tamper-resistant nature of blockchain.

The capacity of blockchain technology to securely preserve data in a way that makes it very difficult to change or manipulate historical transactions or records is known as its "tamper-resistant

nature."

Dispersion
In the context of blockchain, decentralization is the division of power and jurisdiction across several computers, or nodes, as opposed to depending on a single central authority. It is the cornerstone of blockchain technology and the secret to its dependability,   security,   and   reliability.

Unlike traditional centralized systems where a central authority controls and manages the entire system, blockchain operates on a decentralized network. In a blockchain network, there isn't a single point of failure, ownership, or control. To provide transparency and prevent any one party from dominating the entire system, each participant, or node, keeps a copy of the full ledger comprising all transaction   records.
Blockchain functions as a peer-to-peer network in which nodes exchange information directly to verify and spread transactions. By doing away with the need for middlemen and enabling direct communication between participants, this boosts productivity and lowers   expenses.
Consensus techniques are employed by decentralized blockchain networks to reach a consensus among nodes regarding the legitimacy of transactions and the ledger's current state. Consensus techniques improve the security and dependability of the network by   preventing   manipulation   by   a   single   actor.
Decentralization enhances the resilience and fault tolerance of

blockchain networks. Since there is no central point of failure, the network remains operational even if some nodes fail or are compromised. This makes blockchain resistant to censorship, hacking, and other forms of attacks.

Decentralization promotes trust and transparency by allowing participants to verify transactions independently without relying on a central authority. Since every transaction is recorded on the blockchain and visible to all participants, the integrity of the data can be easily verified.

Cryptographic hashing

Cryptographic hashing is a fundamental concept in cryptography, transforming input data into fixed-size hash values using mathematical algorithms. Key principles include deterministic output, fixed size, pre-image resistance, and collision resistance. Common hash functions include MD5, SHA-1, SHA-256, SHA-384, and SHA-512. Applications range from data integrity verification and password storage to digital signatures and blockchain technology. Security considerations involve algorithm selection, salt and pepper techniques, and key stretching. Despite

its benefits, cryptographic hashing has limitations and vulnerabilities, especially in weaker hash functions like MD5 and SHA-1. Overall, cryptographic hashing is crucial for ensuring security and integrity in various cryptographic operations and information systems.

Cryptographic hash functions are mathematical procedures that take an input (or message) and output a fixed-length string of characters. These algorithms are what create hash values. These routines compress the input data into an output of a constant length by processing it using particular algorithms. They guarantee predictable output, which means that the same input consistently yields the same result. Since cryptographic hash functions are one-way, deriving the original input from the hash value cannot be done computationally. Good hash functions produce uniformly distributed hash values, preventing collisions and ensuring security. Examples include SHA-256, SHA-1, and MD5, used in various cryptographic applications like data integrity verification and password storage.

Let us consider the strings 'my data' and 'my data' using the SHA-256 cryptographic hash function.

'my data'	'mydata'
f5d2e22521a862dc579a8555db3b1c3e29b83d77726c6edc0d98cf5 9cd05cf30	59f34e7b19dc295ed39e0f94a1cfab60ff7aa3abcc826e0bfa5459af 1086ae16

Table 1:SHA-256 hash value

From the hash function table above, "my data" and "mydata" shows different hash functions. Although "mydata" and "my data" looks very the same, the space in between "my" and "data" makes the algorithm to generate a different hash value. This is the bases on which data integrity is achieved using hash function.

Consensus mechanisms

Blockchain technology relies heavily on consensus mechanisms, which allow decentralized networks to reach consensus over the legitimacy of transactions and preserve the distributed ledger's integrity. These procedures ensure that no single entity controls the network by distributing decision-making authority among network nodes. Decentralization, security, scalability, and fault tolerance are important features. Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS), Proof of Authority (PoA), and Proof of Burn (PoB) are examples of common consensus procedures. Each mechanism has its own approach to transaction validation and block creation, balancing factors like energy consumption, decentralization, and security.

Emerging consensus mechanisms like Proof of Space (PoSpace), Proof of History (PoH), and Proof of Replication (PoRep) offer innovative solutions to scalability and performance challenges. However, considerations such as energy consumption, centralization risks, and scalability remain important factors in selecting the appropriate consensus mechanism for a blockchain network.

For safeguarding data integrity in a public blockchain context where decentralization and security are paramount, Proof of Work (PoW) or Proof of Stake (PoS) might be preferred due to their established security models. However, for private or enterprise-

focused applications where trust and identity are established, Proof of Authority (PoA) could be a suitable choice. However, the selection of the best consensus mechanism depends on the specific requirements, trade-offs, and priorities of the blockchain application. It's essential to carefully evaluate each option and consider factors such as security, decentralization, energy efficiency, scalability, and governance considerations before making a decision.

Immutability

In the context of blockchain technology, immutability refers to the feature wherein data entered into the ledger is virtually impossible to change or remove once verified. Immutability, which is attained through decentralization, consensus processes, and cryptographic hashing, guarantees the security and integrity of blockchain data. Because every block in the chain includes a hash of the data from the previous block, manipulation is very difficult. Immutability reduces the danger of fraud and promotes transparent record-keeping, which finds widespread uses across industries. On the other hand, inaccurate data correction presents difficulties. Overall, immutability is a foundational feature of blockchain technology, offering robustness and trustworthiness in data management and transactions.

Interoperability

Interoperability between blockchain and databases represents a pivotal advancement in data management, enabling organizations to leverage the strengths of both technologies in tandem. By seamlessly integrating blockchain with traditional databases, interoperability bridges the gap between decentralized, tamper-resistant ledger systems and established centralized data storage solutions. One of the key facets of interoperability lies in its ability

to facilitate data exchange and synchronization. Through standardized protocols and interfaces, blockchain platforms can communicate with existing databases, enabling the seamless transfer of data between disparate systems. This integration allows organizations to capitalize on the security and transparency of blockchain while maintaining compatibility with their existing data infrastructure.

Moreover, interoperability opens the door to a wide array of use cases across industries. In supply chain management, for instance, blockchain can be utilized to track and trace products throughout the supply chain, while traditional databases store detailed product information and transaction records. Interoperability enables real-time data sharing between blockchain-based supply chain networks and legacy database systems, enhancing transparency, traceability, and efficiency throughout the supply chain ecosystem. Additionally, interoperability fosters innovation by enabling the integration of blockchain capabilities, such as smart contracts and decentralized applications (DApps), with traditional database-driven applications. This convergence enables the development of hybrid solutions that harness the security and immutability of blockchain alongside the scalability and flexibility of traditional databases, paving the way for transformative applications across industries such as finance, healthcare, logistics, and beyond.

Furthermore, interoperability holds the promise of simplifying cross-chain communication, allowing assets and data to seamlessly traverse multiple blockchain networks. This interoperability not only enhances liquidity and accessibility within blockchain ecosystems but also fosters collaboration and synergy between diverse blockchain platforms, driving greater innovation and value creation in the decentralized landscape.

4.0 CONCLUSION

In conclusion, the tamper-resistant nature of blockchain serves as a formidable safeguard for data integrity in various applications. By leveraging cryptographic hashing, decentralization, consensus mechanisms, immutable data structures, and digital signatures,

The cryptographic hashing algorithms used in blockchain create unique digital fingerprints for each block of data, ensuring that any attempt to tamper with the data would result in detectable change to the hash values. Decentralization ensures that no single entity controls the network, making it challenging for attackers to compromise the integrity of the data without consensus from the majority of the network.

Consensus mechanisms play a crucial role in maintaining data integrity by ensuring that all participants in the network agree on the validity of transactions and the state of the ledger. Immutable data structures ensure that once data is recorded and confirmed on the blockchain, it becomes practically impossible to alter or delete.

Furthermore, digital signatures provide an additional layer of security by verifying the authenticity and integrity of transactions, ensuring that they cannot be tampered with during transmission.

In essence, the tamper-resistant nature of blockchain technology establishes trust and transparency in data management by providing a secure, decentralized, and immutable ledger. This makes blockchain an invaluable tool for safeguarding data integrity in a wide range of applications, including financial transactions, supply chain management, healthcare records, and more. As blockchain continues to evolve, its role in ensuring data integrity and trust in digital ecosystems is expected to grow even further.

References

Brooke, B. (2024). Understanding blockchain technology. Builtin. Retrieved March 25, 2023, from https://builtin.com/blockchain

Cheng, B., Zhang, J., Zhou, K., Li, G., Liu, Y., Xie, M., & Xing, J. (2021). CDBTune+: An efficient deep reinforcement learning-based automatic cloud database tuning system. The VLDB Journal, 30(6), 959-987.

Johnson, K., & Wang, Y. (2019). Human factors in database backup and recovery: The role of training and awareness. Human-Computer Interaction Journal, 25(3), 167-184.

Karina, B., Amol, B., Damini, S., Rupali, C., & Pachghare, V. K. (2021). Backup and recovery mechanisms of Cassandra database: A review. Journal of Digital Forensics, Security and Law, 15, Article 5.

Ketan, S., & Gurpree, K. (2022). Data backup and recovery. International Journal For Technological Research In Engineering, 9(10). ISSN (Online): 2347 – 4718.

Khan, A. A., Laghari, A. A., Gadekallu, T. R., Shaikh, Z. A., Javed, A. R., Rashid, M., ... & Mikhaylov, A. (2022). A drone-based data management and optimization using metaheuristic algorithms and blockchain smart contracts in a secure fog environment. Computers and Electrical Engineering, 102, 108234.

Kruti, S., & Kavita, R. S. (2012). Online data back-up and disaster recovery techniques in cloud computing: A review. International Journal of Engineering and Innovative Technology (IJEIT), 2(5).

Li, H., & Patel, R. (2021). Security considerations in database backup: A comprehensive review. Cybersecurity Insights, 18(4), 201-218.

Lorent. (2022). Types of backup. Backup4all. Retrieved March 25, 2023, from https://www.backup4all.com/backup-types-kb.html

Malatesh, K., & Meenakshi, S. (2018). Backup and recovery for file system and databases. Asian Journal of Engineering and Technology Innovation (AJETI), ISSN: 2347-7385.

Praveen, S. C., Ambika, S. D., & Mahantesh, N. B. (2017). Efficient and reliable data recovery technique in cloud computing. Internet of Things and Cloud Computing, 5(5-1), 13-18.

Shaanxi, P. C., & Xi'an, S. (2023). Research on secure storage of electronic data through blockchain technology. International Journal of Network Security, 25(3), 449-455.

Wang, X., & Gupta, S. (2020). Integrating AI and ML techniques in database backup processes. Journal of Advanced Technology Applications, 15(2), 88-105.

Yashodha, S., & Rajashekarappa. (2016). Efficient data backup mechanism for cloud computing. International Journal of Advanced Research in Computer and Communication Engineering, 5(7), 92-96

MATERIAL MATTERS: THE ACOUSTIC PROPERTIES OF NON-TRADITIONAL AGIDIGBO CONSTRUCTION

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ABSTRACT
This research explores the acoustic characteristics of non-traditional Agidigbo musical instruments. The construction of the Agidigbo, a traditional musical instrument from Nigeria, has changed over time, with its construction usually consisting of local materials, precisely wood. This research explores the acoustic effects of using unconventional materials and methods to fabricate Agidigbo. The study presents an analysis of conventional and non-traditional construction methods with an emphasis on acoustic properties such as frequency/pitch, resonance and tonal quality. Using standardized acoustic and musical techniques, Agidigbo prototypes are tested as part of the research methodology. The results show that traditional and non-traditional Agidigbo construction have significantly different acoustic properties, demonstrating the impact of materials on sound quality and output. The results further our knowledge of the connection between material selection and acoustic performance in the building of musical instruments. This research offers insights into optimizing Agidigbo construction for improved acoustic performance, while maintaining traditional workmanship, which has significance for musicians, instrument makers, and cultural preservationists.

Keywords: Agidigbo, Musical instrument, Acoustic Properties, Non-Traditional.

1.0 INTRODUCTION

Within many Nigerian communities, the Agidigbo, a traditional musical instrument, has great cultural value. The Agidigbo is crafted by expert artisans utilizing native materials and customary methods, is more than just an instrument; it represents the cultural legacy, narrative, and communal identity (Euba, 1985). Fabricating the Agidigbo has historically relied on locally produced materials including omo wood, malina wood, metal plates, and bolts and nuts to fasten the metal keys to a bridge on top of the musical instrument. These components are carefully chosen for the instrument's acoustic qualities, which add to its distinct sound qualities. The Agidigbo's rich tones are mostly produced by the resonance properties of its wooden main body and the flexibility of its metal plates (Agawu, 2003). Nevertheless, modern issues, like shifting resource availability and cultural dynamics, have forced Agidigbo builders to experiment with non-traditional building materials (Falola & Genova, 2018). This change begs interesting concerns regarding how such modifications impact the acoustic characteristics and overall sound quality of the instrument. Thus, the main inquiry guiding this investigation is what impact do unconventional materials have on the Agidigbo's acoustic characteristics? Our goal in answering this question is to investigate how modernity and material innovation have affected this culturally significant instrument's sound and its identity.

This research aims to advance knowledge of the connection between material selection and acoustic performance in the construction of musical instruments by first examining the acoustic effects of using non-traditional materials in Agidigbo construction. Through an analysis of conventional and unconventional building techniques, we aim to clarify the intricate relationship among cultural customs, material science, and musical acoustics. This research will offer insightful information to musicians, instrument makers, and cultural preservationists who are trying to build the Agidigbo while balancing tradition and modernity.

Various factors influence the sound production of the Agidigbo including its shape, size, and choice of materials. This was corroborated by Akere, (2023), who describes the Agidigbo as a traditional musical instrument with four equal-length and-width sides shaped like a rectangular box. It has a base and a soundboard with a perforated sound-hole. Akere opines that the construction of Agidigbo is influenced by several crucial elements, including the resonance cavity, wall thickness, material length, and material qualities. Moreover, Agidigbo's ability to produce sound is greatly influenced by the dimensions, form, and material qualities of the resonator wall. These emphasize how crucial it is to give these variables serious thought during the design and building of Agidigbo instruments to obtain the best possible structure and sound quality. The use of composite materials, 3D-printed materials, and metamaterials as substitutes for conventional wood in the production of musical instruments was also examined by Brezas et al. The researchers investigate manufacturing processes, vibrational and acoustical evaluations, and experimental and numerical simulation approaches in addition to discussing the benefits of these materials, which include durability, weight reduction, and adjustable acoustics. Brevas et al (2024). In line with this approach of substituting traditional materials with modern ones, this research explores the acoustic implications of the use of Medium-density Fiberboard and High-density fiberboard for the construction of the acoustic body of the Agidigbo.

Bucur (2016) explored the development of composite materials to replace wood in musical instruments, with a focus on the characteristics of nano-composites and composites reinforced with natural and synthetic fibers, as well as the advantages and disadvantages of fiber-reinforced composites. Along with offering instances of effective uses of composite materials in the production of musical instruments, looking at the standards for matching the qualities of composite materials to those of conventional wood. There has been researches that identified substitute materials for the construction of musical instruments, with a focus on the acoustic characteristics of modified wood materials under various humid circumstances. That is, wood that has been heat-modified and acetylated with melamine among other materials that have been examined by Ahmed and Adamopoulos (2018). The findings indicate that a few of these materials have acoustically promising qualities that could make them viable substitutes for conventional tropical wood species. Akere, (2023) investigates the technological innovation of the traditional Agidigbo musical instrument from a conceptual and theoretical standpoint. The researcher talks about the various varieties of Agidigbo, its construction, and design, and how crucial it is to take the acoustic qualities of the materials into account. The study suggests evaluating the impact of conservation materials on the sound and identity of Agidigbo musical instruments. In the case of this research, there is the exploration of the implication of unconventional materials on the sound of the Agidigbo.

2.0 METHOD

The method adopted for this research is experimental design approach. Many Agidigbo prototypes were built for the experimental design, each with a different non-traditional material, but all with the same basic size and design. The process started with the selection of suitable non-traditional materials and continued with the normal metalworking and woodworking procedures to fabricate the Agidigbo. Throughout the building process, great care was taken to maintain the instrument's structural form and functional features. The techniques used for assessing the acoustic properties of the non-traditional materials are:

Resonance Frequency/Pitch Response: The basic resonant frequencies of the traditional and non-traditional Agidigbo prototype were tuned and measured using an electronic tuner app. The primary resonant frequencies and harmonic content of the musical instruments were ascertained by analyzing the frequency response that was produced when played.

Wood Grain Analysis: To evaluate the structural strength and acoustic qualities of the non-traditional materials used in Agidigbo construction, a visual examination was carried out, and a pressure test was carried out on the materials. To determine how grain density, orientation, and uniformity affected resonance properties and sound transmission, these factors were assessed.

This research aims to thoroughly assess the acoustic characteristics of non-traditional Agidigbo structures and contrast them with their traditional counterparts by using these measuring methodologies. The comprehensive investigation of material influences on resonance, sound quality, and overall instrument performance was made possible by this methodology.

NON-TRADITIONAL MATERIALS USED

There are three major unconventional materials used for the construction of the Agidigbo in the course of this research, and they are the Medium-density fiberboard (MDF) plywood, high-density fiberboard (HDF) plywood, and the galvanized metal plate for the keys of the Agidigbo. Medium-density fiberboard (MDF) Plywood was used as the first sample for the construction of the Agidigbo body. Medium-density fiberboard (MDF) plywood was used due to its consistent density and stability, while the High Density Fiberboard (HDF) Plywood, offers greater durability and resonance due to its denser composition compared to conventional wood products. Galvanized Metal was however used for making the Keys galvanized metal keys were used in place of conventional iron metals.

ALTERNATIVE MATERIALS USED FOR CONSTRUCTION

Medium-density fiberboard, or MDF, and high-density fiberboard, or HDF, are two terms that have become widely used in modern woodworking. Crafted by fused wood fiber and adhesive at high pressure and temperature, they present a strong alternative to real wood. Because they are made of recycled materials and are durable due to high compression, they are an eco-friendly and sustainable option for modern construction methods. Although HDF is structurally stronger than MDF and serves the purpose of making bigger musical instruments. Even while MDF might not be as strong as HDF, it is still rather resilient and does not expand or contract as a result of changes in humidity and temperature. Different MDF types serve particular purposes and increase adaptability. Notable benefits of fiberboard are its ease of manipulation and pest resistance. However, it's important to take a few factors into account when deciding between MDF and HDF for the construction of the Agidigbo. The downside of MDF and HDF compared to natural wood is that both have worse holding strengths. This is especially significant when used to construct musical instruments that need to be assembled frequently. Although, Agidigbo as discussed in this research is a box-shaped musical instrument with fixed structures. They should therefore not be used outside because of their susceptibility to moisture or water exposure, which can cause fiber swelling and permanent damage.

Key informant trimming the wood to shape.

MDF and HDF wood in sizes to be trimmed for Agidigbo making.

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ACOUSTIC IMPLICATIONS OF USING MDF/HDF FOR MUSICAL INSTRUMENTS CONSTRUCTION

When building musical instruments, real wood versus MDF/HDF presents important acoustic considerations. Because of its special acoustic qualities, real wood, prized for its inherent resonance and tone richness has long been the preferred material for instrument fabrication. On the other hand, MDF and HDF performed differently in terms of acoustics and they provide consistency and durability in structure. Compared to instruments made of actual wood, their solid and homogeneous composition tends to absorb vibrations the right way and prevent the passage of sound waves that could have resulted in unnecessary echo and elongation of tones during performance of the instrument. Furthermore, MDF/HDF's absence of inherent grain patterns and variety might result in a more uniform sound that lacks the character and depth that players look for in their instruments when used for constructing instruments such as guitars, violins, or pianos, but for the Agidigbo, the box-shaped structure exhibits a better sound production compared to the wooden Agidigbo.

However, certain artists are now able to investigate the use of engineered materials, such as MDF/HDF, in combination with other materials to produce particular tonal characteristics, sustainability, technological breakthroughs and improvements in instrument manufacturing procedures. However, the community that creates musical instruments continues to discuss and experiment with the acoustic effects of these decisions. In the end, the acoustic trade-offs must be carefully considered against the desired sonic attributes and creative vision of the instrument manufacturer and musician, even though MDF/HDF may give practical advantages in terms of consistency, durability and affordability.

FINDINGS

The evaluation of acoustic characteristics' results offers fascinating new information about how differently built Agidigbo instruments function to their wooden equivalents. Surprisingly, the non-traditional Agidigbo prototypes demonstrated a clearer, more consistent sound profile with improved projection and clarity. The non-traditional prototypes showed better longevity and tolerance to environmental conditions than the traditional timber Agidigbo instruments, which are prone to insect infestation and deterioration if not properly managed. The instruments' structural integrity and endurance were enhanced by the principal construction materials of MDF and HDF plywood, which reduced the possibility of damage and deterioration over time. Moreover, the substitution of conventional metal keys with galvanized metal keys was beneficial in reducing corrosion and rust-related problems. The metal keys demonstrated resistance to moisture and temperature changes in the surroundings, guaranteeing dependable operation and an extended lifespan of the instrument's key mechanism. Sound quality and resonance characteristics of traditional and non-traditional Agidigbo buildings were found to differ significantly. The higher acoustic performance of non-traditional prototypes was regularly demonstrated by their stronger tonal definition and sustained resonance throughout a wider frequency range.

Overall, the findings demonstrate the potential advantages of using unconventional materials and techniques to improve Agidigbo instruments' longevity and acoustic qualities. Instrument builders can overcome historical constraints while maintaining the people's cultural integrity and distinctive musical identity by utilizing contemporary and easily accessible materials and techniques.

Source: Field work

Source: Field work

Source: Field work

DISCUSSION

Examining the findings in light of the research topic highlights how important material selection is in determining the acoustic characteristics of Agidigbo instruments. The results show that non-traditional building techniques, which make use of materials like MDF and HDF plywood, have clear benefits about sound quality, longevity, and resistance to environmental influences. This is consistent with the main goal of the research, which is to determine how unconventional materials impact the Agidigbo's acoustic characteristics. These findings have a wide range of consequences for Agidigbo construction and music-making. First off, using non-traditional materials offers a chance to solve problems that come with using traditional wooden construction, like its vulnerability to decay and insect infestation. Instrument manufacturers are now able to create Agidigbo instruments that not only survive environmental challenges over time, but also retain consistent performance by integrating materials with increased durability and stability. Moreover, the use of unconventional materials creates opportunities for Agidigbo design innovation and personalization. The capacity to explore diverse material compositions and manufacturing methods empowers craftspeople to customize instrument attributes to particular musical inclinations and performing scenarios. This adaptability enables musicians to experiment with new tonal possibilities and expressiveness in their compositions.

However, it's critical to recognize the study's shortcomings and provide possible directions for further investigation. The emphasis on a small number of unconventional materials, which might not cover all the options for the Agidigbo building, is one drawback. Subsequent research endeavors may investigate an expanded array of materials to enhance comprehension of their acoustic characteristics and appropriateness for use in the creation of musical instruments. Although the study offers insightful information about the acoustic performance of non-traditional Agidigbo constructions, more investigation is required to evaluate other factors including playability, ergonomics, and cultural significance. We could gain a deeper knowledge of the intricate interaction between material culture, tradition, and musical expression in the context of Agidigbo fabrication by incorporating multidisciplinary viewpoints from the fields of anthropology, material science, and musicology.

CONCLUSION

Conclusively, this research highlights the significance of material selection in determining the acoustic qualities and functional traits of Agidigbo as a unique African musical instrument. Music technologists and Instrument manufacturers can develop while maintaining the acoustic character and cultural legacy of this beloved musical instrument by utilizing contemporary materials and construction methods, thereby easily navigating the stress of sourcing for traditional materials that are not easily accessible due to scarcity of specific wood types resulting from urbanization and development.

REFERENCES

Adeyeye, A. & Faniyi K. (2014). Cultural and Creative Arts Music, Drama, and Dance, Nigeria: Rocket and Rocker Publishing Company.

Ahmed, S. A., & Adamopoulos, S. (2018). Acoustic properties of modified wood under different humid conditions and their relevance for musical instruments. Applied Acoustics, 140, 92-99. doi: 10.1016/j.apacoust.2018.07.014

Agawu, K. (2003). Representing African music: Postcolonial notes, queries, positions. Routledge.

Akere, A. O. (2023). Innovative construction of wireless Agidigbo traditional musical instrument: Using experimental design. Central Asian Journal of Literature, Philosophy and Culture, 4(9), 13-36.

Akere, A. O. (2023). Technological Innovation of Agidigbo Traditional Musical Instrument: Conceptual and Theoretical Perspectives. International Journal of Operational Research in Management, Social Sciences & Education (IJORMSSE), 9(2), 280-296. DOI: 10.48028/iiprds/ijormsse.v9.i2.23

Ashby, M.F. Materials Selection in Mechanical Design; Butterworth-Heinemann: Oxford, UK, 2011.

Backus, J. (1969). The Acoustical Foundation of Music. California: University of Southern, W.W.Norton & company Inc.

Brace, G. and Burton, I. (1979). Sounds, Signs and Language. Listen! Music and Nature. Cambridge: Cambridge University Press.

Besnainou, C. (1998). Composite materials for musical instruments: The maturity. The Journal of the Acoustical Society of America, 103 (5_Supplement), 2872-2873. [2]

Bucur, V. (2016). Composite Materials for Musical Instruments. In Handbook of Materials for String Musical Instruments (pp. 845–875); Springer: Cham, Switzerland, 2016; doi: 10.1007/978-3-319-27632-9_25

Brezas, S., Katsipis, M., Kaleris, K., Papadaki, H., Katerelos, D.T.G., Papadogiannis, N.A., Bakarezos, M., Dimitriou, V., & Kaselouris, E. (2024). Review of Manufacturing Processes and Vibro-Acoustic Assessments of Composite and Alternative Materials for Musical Instruments. Applied Sciences, 14, 2293; doi: 10.3390/app14062293

Duerinck, T., Verberkmoes, G., Fritz, C., Leman, M., Nijs, L., Kersemans, M., & Van Paepegem, W. Listener evaluations of violins made from composites. J. Acoust. Soc. Am. 2020, 147, 2647–2655.

Damodaran, A., Lessard, L., & Suresh Babu, A. (2015). An overview of fiber-reinforced composites for musical instrument soundboards. Acoustics Australia, 43(1), 117-122.

Euba, A. (1985). Yoruba drumming: The Dundun tradition. Olatunji, T. A. (Ed.). Bayreuth African Studies, 14.

Falola, T., & Genova, A. P. (Eds.). (2018). Music and Cultural Identity in Nigeria. University Rochester Press.

Nketia, J.H.K. (1974). The music of Africa. W.W. Norton and company, New York, London.

Terry E. Miller & Andrew Shahriari. (2012). World Music A Global Journey. Routledge Taylor and Francis group, New York and London.

Vijay, N.; Rajkumara, V.; Bhattacharjee, P. (2016). Assessment of Composite Waste Disposal in Aerospace Industries. Procedia Environ. Sci. 35, 563–570.

THE EFFECT OF FACILITATING CONDITIONS AND SELF-EFFICACY ON BEHAVIORAL INTENTION OF SURVEYORS' TOWARD PRACTICE: MODEL EVALUATION

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ABSTRACT
This research study tends to survey the direct effect of moderating variables on behavioural intention to surveying practice. It further purposes to assess the moderating role of self-efficacy on facilitating conditions to behavioural intention to practice. A total number of 84 questionnaires were processed for the analysis with responses coded for the SmartPLS software format. As a rule of thumb, item reliability, construct reliability and validity have a peak range of 0.7 and above. The generally accepted value for average variance extracted (AVE) is 0.5 or greater. The model fit result shows that model was within the Hu & Bentler adopted value less than 0.08 with a SRMR value of 0.073 was reported. This result from the reliability and validity test shows that tests are adequate with the structural analysis showing the self-efficacy is a very important variable, which explains over 70% of intention to practice and 48% of perceived behavioural control. Consequently, the study reveals that behavioural intention to practice surveying depends on the self-efficacy of the practitioner.

Keywords: Intention, latent variables, reliability, self-efficacy, SmartPLS.

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1.0 Introduction
The main purpose of information systems as an integrated set of components is to maximize productivity and job performance. Although this scientific area is faced with low acceptance, Due to this, many organizations still struggle with job performance after rejecting technological innovations.

Some of the factors perceived to be difficult in usage are those not experienced by intending users. Users become increasingly eager to incorporate information systems into their everyday job activities when they use them more frequently since they have demonstrated their value.
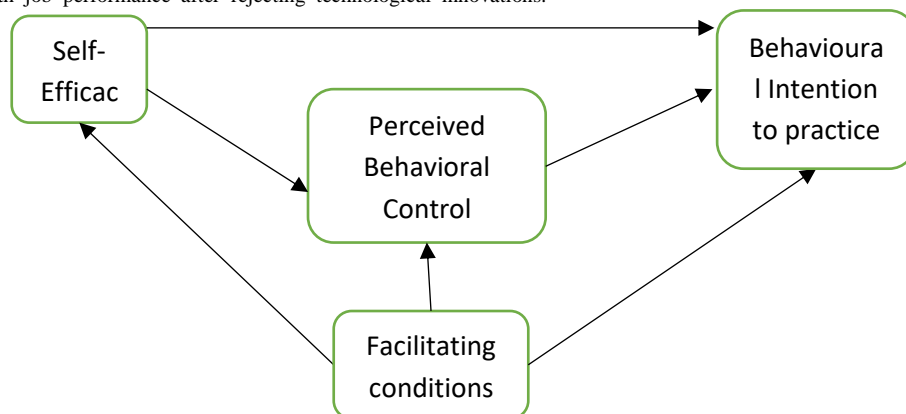
Figure 1: Research Model

Research Problem
There is a need to examine behavioural intention of surveying practitioners to understand the level of technological acceptance through evaluating the factors affecting such intentions. There exist many models that measured the factors influencing behavioural intentions but we need to model the effect of self-efficacy and facilitating conditions on the intentions.

Research Objectives
This study focused on evaluating the factors (facilitating conditions and self-efficacy) that affect behavioural intention to accept technology. For this reason, we tested the selected factors on how they influence behavioural intention and their correlation.
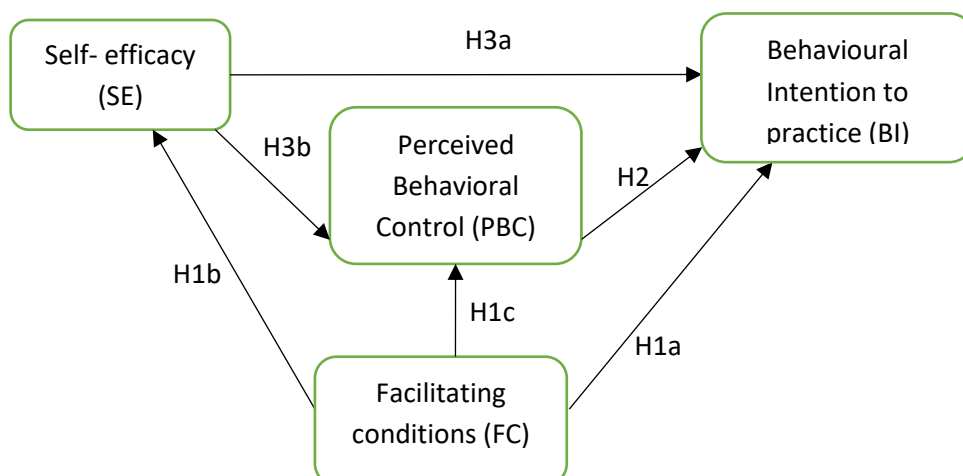
Figure 2. Hypothesis framework

As mentioned above, both facilitating conditions and self-efficacy affect people's perceived behavioral control and behavioral intention towards using technology. In light of the fact that perceived behavioral control directly influences behavioral intention, we were able to create the fundamental model for this research in the framework by combining TAM and TPB.

H1a FC has a positive impact on BI.
H1b: FC has a positive effect on SE.
H1c: FC has a positive impact on PBC.
H2: PBC has a positive impact on BI.
H3a: SE has a positive impact on BI.
H3b: SE has a positive impact on PBC.

Significance of the study
In recent studies, many variables have been identified in the theory of user acceptance of information technology for studying intentions and perceptions (Oduwole, 2021). Different theories have been postulated with varying factors. However, some major variables and their corresponding effects on intention to engage in surveying practice have low research coverage therefore this study significantly highlights two basic variables in determining behavioral intentions.

LITERATURE REVIEW
Technology Acceptance Model (TAM)
In this model we identified two main constructs; perceived usefulness and perceived ease of use determine the adoptability of a computer system by a user. In this study we will corroborate the discovery on the connections between user's belief, their attitude and usage. Factor studies further indicate that perceived usefulness and perceived ease of use are statistically different dimensions (Swanson, 1987).

Structural equation modelling (SEM)
Structural equation modelling is a statistical tool for modelling and simultaneously analysing the correlation between exogenous and endogenous variables. This modelling tool performs multivariate functions and allows many aspects of statistical and equation analysis such as simple linear regression, multiple regression and confirmatory factor analysis to mention a few. SEM is unique in that it includes both structural and measurement models. The inner model connects the latent variables, while the measurement model links the observed to latent variables.

Self-efficacy (SE)
An individual's unique belief is termed self-efficacy and determines how well he or she can execute an action plan in hypothetical situations (Bandura, 1977). Self-efficacy is the belief that one can do something or achieve a goal. It includes confidence in one's ability to manage conduct, control one's environment, and maintain motivation in the pursuit of goals Self-efficacy is a quality that people can develop in situations and areas, including relationships, careers, and other important areas

Facilitating Condition (FC)
Facilitating condition refers to the availability and accessibility of the resources and support that are needed to use technology effectively. For example, facilitating condition can include the quality and reliability of a wireless network, or availability of technical support, and the compatibility of the technology with the systems in place as well as the laws and rules that control how technology is used. In several of these research, it was discovered that where both the performance expectancy (PE) and effort expectancy (EE) constructs were present in the model. Therefore, it is important to consider facilitating conditions as a dynamic and contextual factor that can affect the acceptance and use of technology in different situations.

Perceived Behavioral Control
Perceived behavioural control (PBC) can be defined as an individual's assessment of the degree of difficulty associated with doing a specific action. It is simply assessing how one easily conducts a task. It is considered that the whole set of accessible control beliefs—beliefs regarding the existence of elements that might help or hinder the completion of the behaviour—determines perceived behavioural control.

RESEARCH METHODS
Research Methodology
The SmartPLS 3 software of Structural Equation Modelling was adopted for the statistical analysis. SEM is a simultaneous multiple-equation technique that can be used to estimate models with single or multiple items on both sides of the equations. SEM has grown very wide to become the most popular statistical estimation technique in the social sciences and many other sciences.

Research Instrument
Eighty-four (84) usable samples structured with the five-point Likert scale were collected from practitioners in three states Oyo, Ogun and Lagos, the indicators built with indicator questions that can suitably measure the constructs intended for and conform to the theoretical model. Self-efficacy and Facilitating conditions are independent variables for perceived behavioural control and behavioural intention to practice. Behavioural intention to practice is the main latent construct by the other variables. Out of the 84 questionnaires distributed with questions attached to each indicator.

Findings

4.3 Measurement Model
This part of the framework is the measurement model that examines the correlation between the latent variables. The factors (exogenous and endogenous variables) are the predictors in the measurement model (Hoyle 1995, 2011; Kline 2010).

Reliability and validity
The composite reliability (CR), average variance extracted (AVE), and factor loadings of the outer model were used to test the convergent validity first. A composite dependability of at least 0.7 is required. 0.6 or greater is appropriate for exploratory study (Bagozzi and Yi, 1988). According to Table 1, every loading for this investigation was greater than 0.7. The AVE shows the overall amount of variance explained by the latent construct with values greater than the advised average of 0.5 (Hair et al., 2014). The loadings reveal that the items reflect the constructs at levels far above 70%.
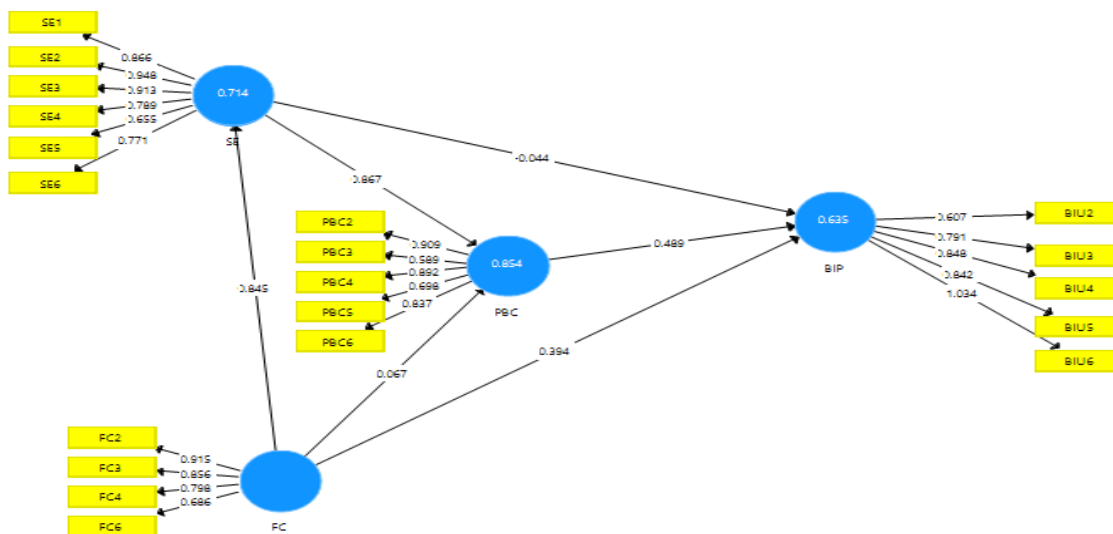
Figure 1: Results of PLS-SEM Analysis (inner and outer models)

Outer Loadings

	BIP	FC	PBC	SE
BIU2	0.714			
BIU3	0.858			
BIU4	0.882			
BIU5	0.912			
BIU6	0.945			
FC2		0.915		
FC3		0.916		
FC4		0.859		
FC6		0.755		
PBC2			0.908	
PBC3			0.745	
PBC4			0.887	
PBC5			0.797	
PBC6			0.834	
SE1				0.829
SE2				0.920
SE3				0.914
SE4				0.870
SE5				0.753
SE6				0.855

Construct Reliability and Validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
BIP	0.915	0.938	0.937	0.750
FC	0.885	0.898	0.921	0.746
PBC	0.892	0.909	0.920	0.699
SE	0.928	0.937	0.944	0.737

The discriminant validity, which follows the aforementioned analysis, shows that each construct is measured separately and not as a reflection of other variables. Low correlations between the assessed construct and other constructs show this. The recommendation made by Fornell and Larcker in 1981—according to which the square root of the AVE in each latent variable should be greater than other correlation coefficients among the latent variables—was implemented. So, the square root of AVE was calculated and bold diagonals were used to construct Table 2.

Discriminant Validity

Fornell-Larcker Criterion

	BIP	FC	PBC	SE
BIP	0.866			
FC	0.686	0.864		
PBC	0.705	0.723	0.836	
SE	0.694	0.775	0.853	0.859

The validity was further tested using heterotrait-monotrait (HTMT) (Henseler, Ringle, & Sarstedt, 2015), and all the values were below 0.85 except Self-Efficacy and Perceived Behavioural Control with value 0.917.

These variables lack discriminant validity according to Hemseler et al, but it is sufficient following the rule of 0.90.

Heterotrait-Monotrait Ratio (HTMT)

	BIP	FC	PBC	SE
BIP				
FC	0.751			
PBC	0.761	0.795		
SE	0.737	0.843	0.917	

This further suggests that some items in self-efficacy are measuring the same thing in perceived behavioural control. In other words, items of the former construct contains overlapping items from the respondents' view in these affected constructs (Hamid et al 2017).

4.4 Structural Model
Structural Model (Inner model and Fit Analysis)
Model Fit

Fit Summary

	Saturated Model	Estimated Model
SRMR	0.073	0.073
d_ULS	1.133	1.133
d_G	0.986	0.986
Chi-Square	396.816	396.816
NFI	0.775	0.775

Focus is placed on discovering the structural model's prediction abilities, as shown by the coefficient of determination (R^2), cross-validated redundancy (Q^2), also known as predictive relevance, path coefficients, and effect sizes (f). This was achieved through a bootstrapping procedure with resample of 5000.
Examining the inner model show that PBC has the highest impact on Behavioral Intention (0.342) followed by Facilitation Conditions (0.318) and

Self-Efficacy (0.156). This suggests that PBC has a more significant effect on Behavioral Intention to Practice than Facilitating Conditions and Self-Efficacy. Although, PBC strongly depends on Self-Efficacy as Facilitating Conditions sufficiently reflects Self-Efficacy at over 77%. This implies that Self-Efficacy is a strong mediating variable between FC and PBC as it explains the dependent and independent variables sufficiently but a weak mediator for Behavioral Intention to Practice.

R-Square

	R-Square	R-Square Adjusted
BIP	0.568	0.551
PBC	0.737	0.730
SE	0.601	0.596

The value here in BIP is 0.568 (57%) and SE is 0.601 (60%) which are considered moderate and a PBC of 0.737 (74%) is rated high impact relationship.
Effect sizes (F^2)

According to Samar et al 2018, the effect size F^2 have values ranging from 0.02 as small, 0.15 as medium and 0.35 as large. Path SE-BIP and FC-PBC are low, while FC-BIP is mid-range with others like PBC-BIP, SE-PBC and FC-SE on the over-effect regions.

F Square

	BIP	FC	PBC	SE
`BIP				
FC	0.090		0.036	1.505
PBC	0.071			
SE	0.012		0.815	

Accordingly, the hypotheses were tested with the path analysis to determine the significance between variables. A 5000 bootstrapping resample was run as suggested and the table below demonstrates the PLS estimation results.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
H1a = FC -> BIP	0.318	0.309	0.177	1.794	**0.073**
H1b = FC -> PBC	0.154	0.155	0.092	1.686	**0.092**
H1c = FC -> SE	0.775	0.773	0.065	11.933	**0.000**
H2 = PBC -> BIP	0.342	0.348	0.126	2.712	**0.007**
H3a = SE -> BIP	0.156	0.160	0.167	0.934	**0.350**
H3b = SE -> PBC	0.733	0.730	0.087	8.414	**0.000**

Construct Crossvalidated Redundancy

	SSO	SSE	Q² (=1-SSE/SSO)
BIP	420.000	252.389	0.399
FC	336.000	336.000	
PBC	420.000	212.818	0.493
SE	504.000	286.708	0.431

CONCLUSION
From the results obtained in the measurement and structural model analysis, it is suggested that facilitating conditions and self-efficacy are very important predictors to behavioural intentions. This was further explained by the weights of the latent variables. It is obvious that perceived behavioural control significantly influence and predicts behavioural intention more than facilitating conditions and self-efficacy. Although, the impact of perceived behavioural control on behavioural intention is increased by self-efficacy. Also, facilitating conditions influences self-efficacy. Therefore, self-efficacy can be termed the mediating factor between facilitating conditions and perceived behavioural control.
This study hereby suggest that before a conclusion is made on the behavioural intention of individuals their self-efficacy should be measured as it tends to explain if a person has high intentions towards a particular behaviour.

RECOMMENDATIONS
The study has demonstrated the importance of variables, indicators, and the influence of the chosen constructs and manifest on survey methodology. The practice and intentions of professional surveyors toward a particular behaviour can be tested using the model along with their influencing factors. These data help us comprehend the surveyors' decision-support mechanism. However, the following is what I recommend:
i. Additional statistical analysis techniques should be used to verify the statements made in this study.
ii. Using the factors recognized in the models as dependable may help us understand the intention and perspective of other professionals under investigation.
iii. The PLS_SEM SmartPLS is suggested and recommended for assessing model fit.

Policy Implications
There are few but important implications from this study for surveying practitioners. In this study, we highlighted that predictors influencing the intention to use a particular technology. The main factors influencing this are facilitating conditions and self-efficacy. We hereby suggest that further valid inferences can be made from the results in this study.

REFERENCES
Bagozzi, R. P. & Yi, Y. (1988). On the Evaluation of Structural Equation Models. Journal of the Academy of Marketing Science, 16(1), 74-94. doi:10.1007/BF02723327

Gold, A., Malhotra, A. & Segars, A. (2001). Knowledge Management: An Organizational Capabilities Perspective. J. of Management Information Systems, 18, 185-214.

Hair, J. F., Hult, G. T., Ringle, C. & Sarstedt, M. (2013). A primer on partial least squares structural equation modeling (PLS-SEM). Sage, Thousand Oak

Hauser, J. R. and Shugan, S. M. (1980). Intensity Measures of Consumer Preference. Operation Research, 28(2), 278-320.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A New Criterion for Assessing Discriminant Validity in Variance-based Structural Equation Modeling. Journal of the Academy of Marketing Science, 43, 115-135. doi:10.1007/s11747-014-0403-8

Hoyle, R. H. (1995). Structural equation modeling: concepts, issues, and applications. Sage, Thousand Oak.

Hoyle, R. H. (2011). Structural equation modeling for social and personality psychology. Sage, London.

Hu, L. T. & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Modeling 6(1):1–55.

Jeon, J. (2015). The Strengths and Limitations of the Statistical Modelling of Complex Social Phenomenon: Focusing on SEM, Path Analysis, or Multiple Regression Models. World Academy of Science,Engineering and Technology. International Journal of Social, Behavioural, Educational, Economic,Business and Industrial Engineering, 9, 1634-1642.

Kline, R. B. (2006). Reverse arrow dynamics. Formative measurement and feedback loops. In: Hancock GR, Mueller RO (eds) Structural equation modelling: A second course. Information Age Publishing, Greenwich.

Kline, R. B. (2010). Principles and practice of structural equation modelling. Guilford Press, New York.

Kline, R. B. (2011). Principles and practice of structural equation modelling. New York: Guilford Press.

Larcker, D. F. & Lessig, V. P. (1980). Perceived Usefulness of Information: A Psychometric Examination, Decision Sciences, 11(1), 121–134.

Oduwole, A. (2021). The relationship of attitude and perceived behavioural control on behavioural intention to practice surveying. Proceedings of the West Africa Built Environment Research (WABER) Conference 2021. West Africa Built Environment Research (WABER) Conference, pp1059. ISBN 9780620953672 Available at https://centaur.reading.ac.uk/103974.

Swanson, E. B. (1987). 'Information channel disposition and use', Journal of Decision Science, Vol. 18, No. 1, pp.131–145.

Tarka, P. (2018). An Overview of Structural Equation Modeling: Its Beginnings, Historical Development, Usefulness and Controversies in the Social Sciences. Quality and quantity, 52(1), 313-354.

SEMEN CHARACTERISTICS, HAEMATOLOGICAL AND SERUM- BIOCHEMICAL INDICES OF COCKS DRENCHED VARYING LEVELS OF CLOVE POWDER (*SYZYGIUM AROMATICUM*)

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ABSTRACT

The use of botanicals has been proposed as a potential alternative to conventional therapeutic options. This study aimed to evaluate the effect of clove powder (*Syzygium aromaticum*) on semen characteristics, haematological and serum-biochemical indices of cocks. Clove powder was drenched in 60 sexually matured (52 weeks old) and healthy, light ecotype Nigerian local cocks (weighing between 1.5 and 1.8 kg) cocks at 0.0, 0.05, 1.00 and 1.5 g. Semen volume, spermatozoa progressive motility, liveability, acrosome integrity, spermatozoa concentration and normal spermatozoa were evaluated for semen characteristics. Haematological parameters measured were: packed cell volume (PCV), red blood cell (RBC), white blood cell (WBC), haemoglobin (Hb), mean corpuscular volume (MCV), Mean corpuscular haemoglobin (MCH) and Mean corpuscular haemoglobin concentration (MCHC). In contrast, serum biochemical parameters evaluated were total protein, albumin, globulin, uric acid, creatinine, cholesterol and glucose. Data obtained were subjected to a one-way analysis of variance. Semen volume (0.44 – 0.47ml), sperm cell progressive motility (80.00 – 93.33%) and acrosome integrity (83.33 – 90.00%) showed significant differences ($p<0.05$), in favour of birds drenched 1.50g CP. The RBC values showed a significant ($p<0.05$) difference (3.64 – 3.76 x 10^6/mL), as the level of CP increases, the value of RBC decreases. There exists a significant difference ($p<0.05$) in Hb (3.64 – 12.86 g/dL) with the highest value in 0.00g CP, MCH (32.79 – 36.86 fl) and MCHC (31.62 – 32.85%) showed significant difference ($p<0.05$) in favour of 1.50g CP. Total protein showed significant difference ($p<0.05$) with values ranging between 4.46 and 5.40 g/dL. There exists a significant difference ($p<0.05$) in the mean value of albumin, with the highest value in 1.50g CP (5.40) in favour of 1.50 g CP. Drenching cocks with clove powder up to 1.5g was discovered posing no harmful effect on cocks.

Keywords: biochemical indices, clove, haematological indices, semen characteristics

1.0 INTRODUCTION

The increasing cost of antibiotics and their residual effects has necessitated the need to research natural plant-based products that could serve as a cheap and effective alternative to commercial (synthetic) antibiotics. Using plants with phytogenic properties as additives in livestock nutrition is becoming popular due to its resultant effect on animals such as improved productivity, reproduction, and quality of animal products through improved health (Olayemi *et al*., 2016).

Cloves are the sweet-smelling dried buds of a tree named botanically as *Eugenia caryophyllata* similarly called Syzgium. This plant is among the richest sources of phenolic compounds such as eugenol, acetate, and gallic acid. It has great potential for pharmaceuticals, cosmetics, food, agriculture, and many other applications. *Syzygium aromaticum* (clove) is a well-known medicinal herb having various proven therapeutic properties according to Shifali *et al*., (2021). Eugenol is the clove's principal constituent responsible for the clove's therapeutic property. It is traditional Ayurvedic's most commonly used spice and food preservative (Shifali *et al*., 2021). Clove has been reported to enhance semen qualities in cocks (Olarotimi and Adu, 2020)

Poultry production has a very crucial role in the economic development of many countries (Kafi *et al*., 2017). Agriculture accounts for about 35.2% of Nigeria's GDP; therefore, it plays a relevant role in reducing poverty and enhancing food security (Heise *et al*., 2015). With the gradual rise in human population, increasing demand for poultry meat as a source of protein is expected soon; as such, poultry health is a significant issue. Due to extremely crowded poultry pens, poor hygiene, and other management problems, antibiotics and other therapeutic chemical agents are used extensively to maintain health and improve poultry growth (Guil-Guerrero, 2017). These chemical agents help to overcome the issues of morbidity and mortality with poultry production; however, they can cause adverse public health issues by developing drug-resistant microflora (Mahesh & Prabhakar, 2018). In addition, the reduction of natural gut microorganisms predisposes the birds to opportunistic infections.

In 2006, the European Union banned antibiotics as feed additives due to their residual effects in animal tissues, subsequently leading to antimicrobial resistance in humans (Gobiraju *et al*., 2017). To avoid the extreme use of antibiotics and other medication, it is essential to find alternative feed supplements, to improve and decrease the cost of production through efficient feed utilisation. Alternatives include phytogenic feed additives, prebiotics, probiotics, enzymes, organic acids, and essential oils. Phytogenic feed additives are obtained from plants with antimicrobial properties (Gobiraju *et al*., 2017). This study is to evaluate the semen quality, blood parameters and serum biochemistry of cocks drenched with varying levels of clove powder.

2.0 MATERIALS AND METHODS

2.1 Procurement and Preparation of Test Ingredient

Clove (*Syzygium aromaticum*) was obtained from Sango market in Saki in Oyo State, Nigeria, in March 2023. Dried clove buds were cleaned and air-dried at room temperature for 24 hours before milling. Thereafter, they were milled using a blender to fine particle sizes and stored in air-tight bags until the period of usage.

2.2 Management of Experimental Animals

A total of 48 sexually matured and healthy light ecotype genotypes of Nigerian local cocks (normal feathered), a sample population of similar age, size, and body weight ranges (between 1.5 and 1.8 kg) used for the study were obtained from the Department of Animal Production Technology Teaching and Research Farm, The Oke - Ogun Polytechnic, Saki. Saki is located in Oyo State, Nigeria, on latitude 8^0 40' 3.43''N and longitude 3^0 23' 38.15'' E. The birds (52 weeks old) were randomly allotted into 4 treatment (T) groups: birds in T1 were drenched 0.00g CP and this served as a control group, birds in T2, T3, and T4 were drenched 0.50, 1.00 and 1.50g CP respectively. Each treatment had 12 cocks and was replicated 3 times with 4 birds per replicate. The birds were reared and managed intensively in a cage housing system and were observed and acclimatized for 2 weeks before the commencement of the study. Drenching of experimental material which lasted 8 weeks, commenced at the end of the acclimation period. Feed and water were given to the birds *ad libitum*.

2.3 Data Collection

Semen Collection and Evaluation

Semen collection and evaluation were carried out for 8 weeks. Semen was collected by abdominal massage techniques (Hafez, 1978). Semen collection was done twice a week on Mondays and Thursdays between 07:03 and 10:00 am. The birds responded to massage by partially averting their cloaca, and semen was collected from the ventral lip of the vents in calibrated tubes maintained at 35°C using insulated jackets. Individual ejaculates were collected into a 4 mL graduated collection tube, and ejaculate volumes were read to the nearest 0.1 mL. Following semen collection, the semen was maintained in a 35°C water bath for sperm motility assessment. The physical semen characteristics were analysed as described previously by Peters et al., (2008). For sperm motility, a drop of semen was placed on a microscope slide using a rubber micropipette and then covered with a glass coverslip to spread the semen uniformly on the slide. The slides were placed under a microscope for observation ($\times$ 400 magnification). Several microscopic fields were examined for each sample. Motility was expressed as a percentage of the cells that are motile within the observed area. The sperm concentration was measured with an improved Neubauer haemocytometer using a direct cell count method. The haemocytometer consists of specially designed slides that contain 2 counting chambers. The counting chambers are 0.1 mm in depth and have an area of 1.0 mm^2. The squares are further subdivided into 25 smaller squares. One millilitre of the semen was diluted with 0.9 normal saline at the rate of 1:250. The cover slip was moistened with water and affixed to the haemocytometer to enable adhesion. A drop of the diluted semen was placed at both ends of the haemocytometer and allowed to settle. The loaded haemocytometer was then placed under the microscope for observation ($\times$400 magnification). Cells which have their heads within the subdivided smaller squares at the 4 edges and the centre of the haemocytometer were counted and the average was taken for a bird. The sperm concentration was calculated using the formula: C = 50, 000 $\times$ N $\times$ D where C = concentration of semen per volume (ml), N = Number of spermatozoa counted, and D = dilution rate (Uzochukwu *et al.*, 2019). Total spermatozoa were calculated as the concentration of sperm cells in the total volume of ejaculate collected from a cock. The sperm vitality was determined by placing a drop of semen on a microscope slide with a micropipette, and a drop of eosin-nigrosine stain was added, smeared, immediately air-dried, and viewed under a microscope ($\times$400 magnification). The proportions of live (eosin-impermeable) and dead (eosin-permeable) spermatozoa in a sample were assessed based on 200 counted cells. The percentage of normal cells was determined as the percentage of cells with intact and normal morphological features.

Blood Collection

At 42 days of drenching the birds with the test ingredient, blood samples (2.0 ml) were collected with needle and syringe through the brachial wing vein of three cocks per replicate into EDTA bottles and plain bottles (2mls per cock) directly for the determination of haematological and serum biochemical indices using standard procedures, as described by Weiss and Wardrop,

(2010). Haematological indices such as red blood cell count (RBC), packed cell volume (PCV), white blood cell count (WBC) and Haemoglobin concentration were evaluated. Haemoglobin concentration was determined photo-metrically using the cyano-haemoglobin method (Elarabany, 2018), and PCV using the Hacksley hematocrit centrifuge (UK) according to the procedure by (Morris *et al.*, 2001), PCV results were determined using a micro hematocrit reader. The WBC count was determined using the Neubaer count chamber following the procedure described in previous studies (Fudge, 2000; Cray and Zaias, 2004). Serum total protein was determined using the Biuret method. Albumin was determined using the Bromoscresol Green (BCG) method as described by Peter *et al* (1982). The globulin concentration was obtained by subtracting albumin from total protein.

2.4 Statistical Analysis

At the end of the field trial, data were analysed following a one-way analysis of variance (ANOVA) in completely randomized design (CRD), using the SAS computer analytical package and means were separated with Duncan multiple range test of the same software (SAS, 2003).

3.0 RESULTS AND DISCUSSION

Table 1 shows results of semen characteristics of cock drenched with varying levels of clove powder (CP). There exists a significant difference, (P<0.05) across the treatment with semen volume ranging from 0.44 ml in the control to 0.47 ml on 1.5 g CP. The result shows a progressive increase in the semen volume with the increased level of clove powder. The result deviates from the report of Uzochukwu *et al.*, (2019) who report a decrease in semen volume of cocks with increased levels of Ethiopian pepper fruit meal, though the value obtained (0.44 - 0.47ml) in this work is greater than the value (0.18 - 0.34ml) reported by Uzochukwu *et al.*, (2019). Sperm cell progressive motility shows a significant difference (P<0.05) with 0.0g CP having the lowest value of 80.00%, followed by 1.0g CP (80%) while 0.5g CP and 1.5g CP had similar sperm progressive motility value of 90.00% and 93.33% respectively. This result corroborates with previous studies that showed an increase in progressive motility of cocks with increased levels of onions and garlic mixture (Victor *et al.*, 2016). Sperm cell liveability showed no significant difference across the treatment (P>0.05) with values ranging from 76.66 – 91.66%. Sperm cell liveability showed similar values across the treatments. Acrosome integrity showed a significant difference (P<0.05) across the treatment, 0.0g CP had the least value (83.33%) while 0.5g, 1.0g and 1.5g CP had the same value (90.00%). The result showed that the acrosome in 0.5, 1.0 and 1.5 g CP were well protected compared with the control. There exists no significant difference in sperm cell concentration (P>0.05) with values ranging from 30.00 - 40.00 (x 10^9/ml) since the result is statistically similar clove powder had no detrimental effect on sperm cell concentration. This result agrees not, with the report of Victor *et al.*, (2016) who affirmed a significant difference in sperm cell concentration of cocks fed a mixture of onion and garlic. Normal sperm cells showed the highest value in 1.0 g CP (90.00%) followed by 1.5 g CP (86.66%) and 83.33% in 0.0 and 0.5 g CP.

Table 1: Semen characteristics of Cocks drenched with varying levels of Clove Powder

Parameters	0.00g CP	0.50g CP	1.00g CP	1.50g CP	SEM
Semen volume (ml)	0.44[b]	0.46[a]	0.47[a]	0.47[a]	0.00
Sperm progressive motility (%)	80.00[c]	90.00[ab]	83.33[bc]	93.33[a]	2.35
Sperm livability (%)	90.00	76.66	90.00	91.66	6.71
Acrosome integrity (%)	83.33[b]	90.00[a]	90.00[a]	90.00[a]	1.66
Sperm concentration (x 10^{8}ml^{-1})	40.00	30.33	33.33	36. 66	3.99
Normal sperm cell (%)	83.33	83.33	90.00	86.66	2.03

[a, b, c] means with different superscripts within a row are significantly different

Table 2 shows the haematological result of cocks drenched with varying levels of clove powder (CP). Packed cell volume (PCV) values showed no significant difference (P>0.05) across the treatment. Its value ranged from 39.00 - 41.00%, which falls

within the normal value of 26.00 - 41.20% (Mitruka and Rawnsley, 1977). This could be interpreted that cloves could be drenched in cocks up to 1.5g without any harmful effect on their packed cell volume. This finding is in agreement with the report

of Ayodele et al., (2021), who reported the harmless effect of phytogenic substances (turmeric and clove) on broiler bird feed at the rate of 0.00, 1.00 and 2.00% for eight (8) week, they also stated that addition of clove did not affect PCV level of broiler birds measured at day-21 and day-42. Clove powder had a significant effect across the treatment on RBC (P>0.05) with a value ranging from 3.64 x 10^6/mL (1.00g CP) to 3.74 x 10^6/mL (0.00 CP), this value falls within the recommended range of (2.90 - 4.10 x 10^6/mL) according to Mitruka and Rawnsley, (1977). Haemoglobin values ranged between 3.64 and 12.86 g/dL. There was no significant difference (p> 0.05) in 0.0 CP and 0.5 CP (12.86 and 12.33, respectively). The haemoglobin values for 1.00 and 1.50 g CP were lowered (3.64 and 3.65, respectively) than the established normal range of 7.50 – 13.10 g/dL (Mitruka and Rawnsley, 1977). This study reveals that the administration of

higher levels of clove in cocks can affect the oxygen transport of the birds. WBC showed no significant (P>0.05) with a value ranging from 18.66 - 19.10 x 10^9/L which is within the range of 9.76 – 31.00 x 10^9/L (Mitruka & Rawnsley, 1977). This finding negates the report of Ayodele *et al.*, (2021), who reported a WBC value of 6.10 to 6.65 x 10^9/L for broilers administered 0.00%, 1.00% and 2.00% CP. MCV showed no significant difference (P>0.05) with values ranging from 103.74 (0.00g CP) -112.23 (1.50g CP) which is within the normal range of (100.00 – 128.00 fl) reported by (Mitruka & Rawnsley, 1977). MCH showed a significant difference (P<0.05) with values ranging from 32.80 pg (0.50g CP) - 36.86 pg (1.50g CP) which is higher than the value reported (27.2 - 28.9 pg) by Mitruka and Rawnsley, (1977). There exists a significant difference (P<0.05) in the value of MCHC ranging from 32.16% (0.50 g CP) - 32.85 % (1.5 g CP).

Table 2: Haematological indices of Cocks drenched with varying levels of Clove Powder

Parameters	0.00g CP	0.50g CP	1.00g CP	1.50g CP	SEM
PCV (%)	40.00	39.00	39.00	41.00	1.22
RBC (X10^6/ml)	3.74[a]	3.76[a]	3.64[b]	3.65[b]	0.07
Hb (g/dl)	12.86[a]	12.33[a]	3.64[b]	3.65[b]	0.53
WBC (X10^9/ml)	19.10	19.00	18.66	19.01	2.85
MCV (fl)	106.95	103.74	107.13	112.23	2.88
MCH (pg)	34.40[ab]	32.80[b]	34.79[ab]	36.86[a]	0.92
MCHC (%)	32.16	32.00	32.24	32.37	0.05

[a, b, c] means with different superscript within a row are significantly different

Key: PVC – Packed Cell Volume, RBC – Red Blood Cell, WBC – White Blood Cell, Hb – Haemoglobin, MCV –Mean corpuscular volume, MCH - Mean corpuscular haemoglobin, MCHC- Mean corpuscular haemoglobin concentration

The total protein on Table 3, showed a significant difference (p<0.05) ranging from 4.46 (1.00g CP) – 5.40 g/dL (1.5g CP). The value for total protein was within the normal range reported by (Mitruka & Rawnsley, 1977). Value for total protein was elevated in 1.50 g CP while value for other treatments has similar results. This could be accredited to high protein digestibility in birds placed on 1.5 g CP since high protein in serum suggested protein sufficiency (Ahamefule *et al.*, 2006). There exists a significant difference (p<0.05) in the mean value of albumin, the value increased with the increase in clove powder level with 0.50g CP having the lowest value (0.60 g/dL) and 1.50 g CP having the highest value (5.40 g/dL). A high albumin concentration usually indicates dehydration, while a low concentration may be due to poor liver function due to malnourishment and infection (Esubonteng, 2011). The result of globulin showed a significant (p< 0.05) difference, its value ranged between 3.80 and 4.20g/dL. Globulin values in this study were above the reference range of 2.13 - 3.02 g/dL (Chernecky & Berger, 2008). These raised values could be credited to enhanced host's immune system and improved hepatic function since the liver is the location of protein synthesis. The uric acid observed in this study showed a significant difference (p< 0.05) with values ranging from 0.02 – 0.03 mg/dL. Birds on 0.00 CP, 0.50 g CP and 1.00 g CP had similar results (0.02 mg/dL) while the value for 1.5 g CP was elevated (0.03 mg/dL). Uric acid in the blood is

manufactured as a consequence of protein metabolism. Amplified protein metabolism, stress and dehydration affect the concentration of uric acid in the blood (Chernecky and Berger, 2008). High serum uric acid concentrations might be due to ineffective protein deployment (Oduguwa & Ogunmodede, 1995). However, the values were below the reference range (2.47 - 8.08mg/dL) (Mitruka & Rawnsley, 1977). The phytogenic supplement (clove powder) had a significant (p<0.05) effect on the creatinine of the cocks having values ranging from 0.50 – 0.60 mg/dL, this is below 0.90 – 1.85 mg/dL reported by Mitruka and Rawnsley, (1977). Creatinine is used to determine the condition of the kidney. The kidney functions to eliminate waste products resulting from protein metabolism and muscle contraction (Ileke *et al.*, 2014). Cholesterol showed a significant effect across the treatment with 1.50g CP having the highest value (135.33mg/dl), while birds on 0.0g CP had the least value (120.66 mg/dL) with birds on 0.50g and1.00g CP had similar value (106.33 and 109.66 mg/dL respectively). However total blood cholesterol was within the reported range (52.00 - 148.00 mg/dL) (Mitruka & Rawnsley, 1977). Glucose values across the treatments showed significant differences (p< 0.05) ranging from 205.33 mg/dL in 0.50g CP and 304.00 mg/dL in 1.5g/dL. The results obtained in this study were above the 152.00 – 182.00 reported by (Mitruka & Rawnsley, 1977).

Table 3: Serum biochemical indices of Cocks drenched with varying levels of Clove Powder (CP) in grams.

Parameters	0.00 CP	0.05 CP	1.00 CP	1.50 CP	SEM
Total protein (g/dl)	4.80[b]	4.50[b]	4.46[b]	5.40[a]	0.16
Albumin (g/dl)	0.86[c]	1.60[c]	4.46[b]	5.40[a]	0.13
Globulin (g/dl)	3.93[ab]	3.90[ab]	3.80[b]	4.20[a]	0.09
A:G	0.22[ab]	0.15[bc]	0.07[c]	0.28[a]	0.00
Glucose (mg/dl)					
Uric acid (mg/dl)	0.02[b]	0.02[b]	0.02[b]	0.03[a]	0.00
Creatinine (mg/dl)	0.53[b]	0.50[b]	0.50[b]	0.60[a]	0.00
Cholesterol (mg/ml)	120.66[b]	127.33[ab]	128.33[ab]	133.66[a]	3.04

[a, b, c] means with different superscript within a row are significantly different

4.0 CONCLUSION

It is concluded that clove could be administered to cocks up to 1.5g without any detrimental effect on their semen characteristics and health status. It is recommended that cocks can be drenched up to 1.5g of clove powder for best performance.

References

Ahamefule, F. O., Ibeawuchi, J. A. & Ibe, S. N. (2006). Nutrient intake and utilization of pigeon pea-cassava peel based peel-based diets by West African dwarf (WAD) bucks. *Pakistan Journal of Nutrition*, 5, 419-424.

Ayodele, A. D., Tayo, G. O., Olumide, M. D., Adeyemi, O. A. & Akanbi, A. S. (2021). Haematological and serum biochemical responses of pullet chicks fed diets containing single and combined levels of turmeric and clove. *Nigerian Journal of Animal Production,* 48(3), 71 - 85. doi.org/10.51791/njap.v48i3.2962

Chernecky, C. and Berger, B. (2008). Laboratory tests and diagnostic procedures. St Louis Saunder Elsevier.

Cray, C. & Zaias, J. (2004). Laboratory procedures: Veterinary clinical exotic animal practice.

Elarabany, N. (2018). A comparative study of some haematological and biochemical parameters between two species from the *Anatidae* family within migration season. *Journal of Basic and Applied Zoology*, 79, 1-9.

Fudge, A. M. (2000). Laboratory Medicine: Avian and Exotic Pets. Philadephia, W. B. Saunders Company.

Gobiraju, S., Vasan, P., Purushothaman, M., Rajendran, K., Senthilkumar, S., Sakthivel, P., Gomathi, G., & Ajantha, A., (2017). Turmeric as an antibiotic alternative in commercial broiler diets. *International Journal of Science, Environment and Technology,* 6(3), 2118– 2123.

Guil-Guerrero, J. L., Ramos, L., Zúñiga Paredes, J. C., Carlosama-Yépez, M., Moreno, C., & Ruales, P., (2017). Effects of turmeric rhizome powder and curcumin on poultry production. A review. *Journal of Animal and Feed Sciences*, 26(4), 293–302. https://doi.org/10.22358/jafs/78511/2017

Hafez, E. S. E. (1978). Reproduction in Farm Animals. 5th ed. Lea & Febiger, Philadelphia, USA, 649.

Heise, H., Crisan, A., & Theuvsen, L., (2015). The poultry market in nigeria: Market structures and potential for investment in the market. *International Food and Agribusiness Management* Review, 18, 197–222.

Ileke, K. D, Odeyemi, O. O, Ashamo, M. O. & Obo H., G. (2014). Toxicological and histopathological effects of cheese wood, *alstonia boonei de wild* stem bark powder used as cowpea protectant against cowpea bruchid, *Callosobruchus maculatu* (fab.) [*coleoptera: chrysomelidae*] on albino rats. *Ife Journal of Science*, 16(1), 23-33.

Kafi, A., Uddin, M. N., Uddin, M. J., Khan, M. M. H., & Haque, M. E., (2017). Effect of dietary supplementation of turmeric (*Curcuma Longa*), ginger (*Zingiber officinale)* and their combination as feed additives on feed intake, growth performance and economics of broiler. *International Journal of Poultry Science,* 16(7), 257–265. https://doi.org/10.3923/ijps.2017.257.265

Mahesh, M. G., & Prabhakar, B. Y., (2018). Natural antibiotic effect of turmeric in poultry management. *International Journal of Poultry and Fisheries Sciences,* 2(2), 1-2. http://dx.doi.org/10.15226/2578-1898/2/2/00109

Mitruka, B. M., & Rawnsley, H. M. (1977). Clinical biochemical and hematological reference values in normal experimental animals. Masson Publishing Inc. The USA.

Morris, M.W., Davey, F.R. & Henry, J.B. (2001). Basic examination of blood. Clinical diagnosis and management by laboratory method.

Oduguwa, O. O. & Ogunmodede, B. K., (1995). Comparative growth response of three commercial vitamins and trace minerals premixes for rearing broiler chicks at the starter and finisher phases. *Pertanika Journal of Tropical Agric*ulture, 19, 81–87.

Olarotimi, O. J & Adu, O. A. (2020). Semen characteristics, gonadal and extragonadal sperm reserves in cocks fed diets containing different inclusion levels of monosodium glutamate. *Slovak J. Animal Sci*ence, 53(1), 1–11.

Olayemi, W., Oso, A., Akapo, O., Obadire, F., & Mafimidiwo, A. (2016). Hematological indices and serum metabolites of broiler chickens fed *Zysygium aromaticum, Xylopia aethiopica* and *Morinda Lucida* as phytogenic plants. *Journal of Experimental Agriculture International*, 14(2), 1–8. https://doi.org/10.9734/jeai/2016/27745

Peters, T., Biamonte, G. T. & Doumas, B. T. (1982). Protein (total protein) in serum, urine and cerebrospinal fluid: Albumin in serum. Selected methods of clinical chemistry.

SAS (*2003*). Statistical Analysis System. SAS Release 9.1 for Windows, SAS Institute Inc.Cary, NC, USA.

Thakur, S., Choudhary, S., Kumari, I., Madhusudan, S., Walia, B., Kaurav H., & Chaudhary, G. (2021). Clove (*Syzygium aromaticum*) – A review based upon its traditional therapeutic uses. *International Journal of Current Research,* 13(02), 16368-16375.

University of Science and Technology, Kumasi. (2011). An assessment of the effect of *moringa olifera* leaf powder as a nutritional supplement in the diet: Esuboteng, P. K. A. https://ir.knust.edu.gh/handle/123456789/5869

Uzochukwu, I. E., Amaefule, B. C ., Aba, C. N., Nnajiofor, N. W., Machebe, N. S. & Foleng, H. N. (2019). Semen Characteristics and Hematology of Nigerian Local Cocks Fed Varying Dietary Levels of Ethiopian Pepper Fruit Meal. *Journal of Applied Poultry Res*ources, 28, 1106–1114.

Victor, M. O. O., Christian A. M. & Ejikeme F. M. (2016). Semen quality characteristics of Koekoek breeder cocks influenced by supplemental inclusion levels of onion and garlic mixture at 35-41 weeks of age. *Revista Brasileira de Zootecnia*, 45(8), 433-440.

Weiss, D. J. & Wardrop, K. J. (2010). Hematology of chickens and turkeys. In: Schalm's veterinary hematology, (6th ed.). USA: Wiley-Blackwell Publisher. John Wiley and Sons Ltd. Publication.

PROXIMATE, MINERALS, FUNCTIONAL AND ANTI-OXIDANT PROPERTIES OF CO-FERMENTED SORGHUM - PIGEON PEAS DRIED 'OGI' FLOUR AND GRUEL SENSORY ACCEPTABILITY

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ABSTRACT

This study aimed to reduce malnutrition in the tropics and a mixture of sorghum and pigeon peas at ratios: of 100:0, 90:10, 80:20, 70:30, and 60:40%) respectively were co-fermented to produce dried 'Ogi' flour. Proximate, minerals, functional and antioxidant properties of samples were evaluated and gruel sensory properties acceptability using a 9-point hedonic scale. Results showed moisture, protein, ash, fat, fibre and carbohydrates had varied values (13.071 -10.684%, 16.315 - 9.893, 4.039 - 2.012%, 0.874 – 1.601%, 0.533 – 1.327% and 70.551 to 68.751%) respectively. Moisture, ash; fibre and carbohydrates had the highest value at 10% level and protein and fat at 20% level. Calcium and potassium had increased values (0.015 - 0.181% and 0.026%- 0.098%), respectively but sodium decreased (0.163% - 0.021%). Water and oil absorption capacity increased (1.130 - 1.340 ml/g and 1.025 - 1.180 ml/g respectively, loosed and tapped bulk density decreased (0.581 - 0.434 g/ml and 0.778 - 0.716 g/ml), respectively, and swelling capacity increased with heating temperatures. TFC, TPC and FRAP increased, DPPH decreased and TAC had highest value at 30% level. Gruel at 30% level was rated highest. Therefore, these showed that the mixture and co-fermentation had produced a nutrient-dense 'ogi' capable of tackling malnutrition in the tropics.
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Keywords: Sorghum, Pigeon peas, Co-fermentation, 'Ogi", Quality

1.0 INTRODUCTION

"Ogi"is a popular weaning and breakfast meal in Nigeria and West Africa, and it is obtained from fermented cereals of maize (*Zea mays*) (Aremu, Osinfade, Basu & Ablaku. 2011) and Sorghum (*Sorghum bi-color vulgar*) (Afolayan, Afolayan & AbuahAn. 2010) or millet (*Eleusine coracana*) (Mal, Padulosi & Ravi. 2010). Traditional methods is often used to produce wet 'Ogi' by soaking grains in water for about 24-48 hours, wet milled, sieved and allowed to sediment and ferment for 24hrs before usage (Omemu & Faniran. 2011). However, during the 'Ogi' fermentation process microorganisms such as lactic acid bacteria and yeasts have been identified (Omemu & Faniran. 2011) which play important roles in aroma/flavor development, microbial stability reducing anti-nutritional factors, and increasing nutrient density (Makunba, Patrick, Oluwafemi, Adetola & Kayitesi. 2016). The traditional methods of processing 'Ogi' have been shown to lead to nutrient loss, 'Ogi' produced from sorghum has been shown to moderately contain high protein than maize (Ajanaku, Ajanaku, Edobor & Nwinyi. 2012). However, in the tropics sorghum is a household food commodity (processed into flour, fermented products and as animal feeds) and is highly drought and diseases resistant than maize, containing higher fibre, antioxidants, phenolic compounds, vitamins and minerals which have usefulness in humans physiology (Devi, Ujayabharathi, Santhyabama & Priyadarisimi. 2011).

However, since sorghum is deficient in lysine and tryptophan, but high in methionine and cysteine (Ajanaku et al., 2012), supplementation of sorghum 'Ogi' has been done by the addition of groundnut seed (Ajanaku et al., 2012), Soybean (Adeleke & Oyewole.2010), crayfish (Ajanaku, Ajani, Siyanbola, Akinsiku, Ajanaku & Oluwole. 2013) and pawpaw fruit (Ajanaku, Oguniran, Ajani, James & Nwinyi.2010) with improved nutritional and functional properties. Meanwhile, in the tropics, some legumes which have higher values of protein, energy, dietary fiber, minerals and healthy fats like pigeon peas and jack beans are highly underutilized and are almost going into extinction (Arawande &

Borokini. 2010). Pigeon pea (*Cajanus cajan (L.) Huth*) is cultivated for its edible seeds and it is fast-growing, hardy, widely adaptable, and drought-resistant (Arawande & Borokinii. 2010). It is high in lysine content but low in methionine, high in flavonoids, total phenolic and high anti-oxidant properties (Rani, Poswal, Yadav & Deen. 2014) and its seed, roots and leave extracts have been used to treat kidney problems, diabetes, diarrhoea, hepatitis and anaemia (Pal, Sachan, Ghosh & Mishra. 2011). Though the addition of pigeon peas to cereals to produce various products has been done (Saxena, Kumar & Sultana. 2010; Makumba et al., 2016), information is scanty on co-fermentation of sorghum with pigeon peas at varied percentages to produce dried "Ogi" powder. Therefore, this study aimed to produce dried 'Ogi' as a weaning meal for infants and as a breakfast meal for adults to reduce malnutrition by co-fermentation of sorghum and pigeon peas grains and evaluate its properties

2.0 MATERIALS AND METHODS

2.1 Source of Materials and Preparation

Pigeon pea (*Cajanus cajan*) seeds and sorghum (*Sorghum bicolor vulgar*) were obtained from Sango market in Saki, Oyo State, Nigeria. The bench work was done at the Department of Food Science and Technology, The Oke-Ogun Polytechnic, Saki, Oyo State Nigeria. While all chemicals used for analysis were of analytical grade. **S**orghum and Pigeon peas were manually sorted separately to remove all impurities like stones, sack wool, broken kernel weevil or mold growth and other foreign particles/seeds before usage.

Sample formulation for co-fermented 'Ogi'

Samples of the co-fermented 'Ogi' flour product were formulated by mixing sorghum grains with pigeon pea grains at varying ratios as presented in Table 1.

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Table 1. Sample formulation of Sorghum and Pigeon peas Mixture

Sample	Sorghum Ratio	Pigeon Peas Ratio
100:0	100	0
90:10	90	10
80:20	80	20
70:30	70	30
60:40	60	40

Production of co-fermented Sorghum - pigeon pea dried 'Ogi' flour

Sorghum and pigeon peas grains blended at ratios in Table 1 were co-fermented to produce dried 'Ogi' flour as indicated in the Figure using a modified traditional fermentation method described by (Afolayan et al., 2010) . Samples were washed thoroughly in portable water and steeped in water at a grain: water ratio (1:2 (w/v) in properly labelled plastic buckets with lids for 48 hours. Soaking water was drained, grain wet-milled and then sieved using a muslin cloth to separate the pomace from the filtrate. The filtrates were allowed to settle and sour for another 48 hr. After fermentation, the water was drained and pressed and the cake was spread on an aluminium-wrapped flat plate and was dried in an air-drying oven set at 65°C. The dried product was milled into fine powder using a laboratory Wiley disc mill and sieved using a 40 mm sieve to obtain 'Ogi' powder. The powder was packaged into plastic nylon (HDPE) and stored in the refrigerator until usage for analysis.
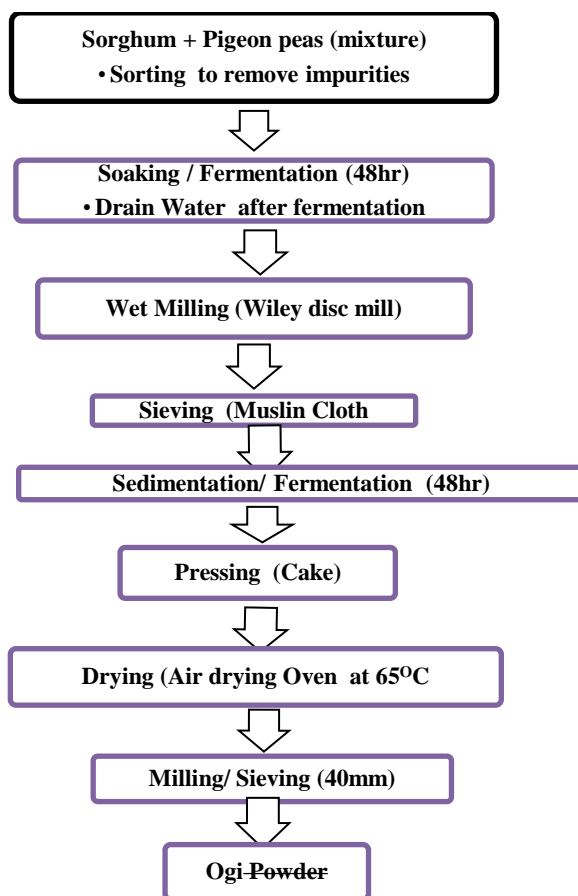
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┌─────────────────────────────────────────┐
│   Sorghum + Pigeon peas (mixture)        │
│  • Sorting  to remove impurities         │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Soaking / Fermentation (48hr)          │
│  • Drain Water  after fermentation       │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Wet Milling (Wiley disc mill)          │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Sieving  (Muslin Cloth                 │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Sedimentation/ Fermentation  (48hr)    │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Pressing  (Cake)                       │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Drying (Air drying Oven  at 65°C       │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Milling/ Sieving (40mm)                │
└─────────────────────────────────────────┘
                    ⬇
┌─────────────────────────────────────────┐
│   Ogi Powder                             │
└─────────────────────────────────────────┘
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Figure 1. Production Process for Dried "Ogi" from Co-fermented Sorghum – Pigeon peas

Sample Analysis

Determination of Proximate Composition of dried 'Ogi' Flour

Proximate composition (moisture, ash, crude protein, crude fibres and carbohydrate) was determined in triplicates by using methods described by the Association of Official Analytical Chemists (A.O.A.C., 2005). Moisture was done by oven method, ash using a muffle furnace (Carbolite AAF110, United Kingdom), crude fat by

Soxhlet apparatus, crude protein by Kjeldahl apparatus, crude fibre by digestion methods and carbohydrate content by difference.

Determination of minerals of dried 'Ogi' Flour

The method of Mbaeyi and Onweluzo, (2010) was used to determine Ca, K and Na. Nitric acid was used to digest the sample to free the minerals from the ash. Standard serial concentrations of pure forms of the minerals were prepared to standardize the Atomic Absorption Spectroscopy (AAS, model DW-AA320N) before reading the concentration of minerals. A serial dilution that was used was 0.5, 1.0, 2.0, 4.0, and 8.0 mg made from 100 mg/100 ml standard flask.

Determination of Functional Properties of Dried 'Ogi' Flour

The co-fermented 'Ogi" flour samples' functional properties (Water holding capacity (WHC), Oil holding capacity (OHC), Loosed and Tapped bulk density and swelling power/capacity (SC) at varied temperatures were determined using the method described by Adebowale and Maliki (2011)

Determination of Total Phenolic Content (TPC) of dried 'Ogi' Flour

The Folin C (Folin and Ciocalteu) colourimetric method (Pedro, Ranto & Rosso. 2016) was used to determine the total phenolic content of 'Ogi'. The assay involved the addition of Folin Ciocalteu reagent (2.5 mL) and 7% (w/v) of sodium carbonate (2 mL) to 0.5 mL of the 'Ogi'. The mixture was allowed to react for 1.5 h before reading the absorbance at 765 nm on a spectrophotometer. Gallic acid was used as standard and the TPC was estimated from the standard curve obtained.

Determination of Total Flavonoid Content (TFC) of 'Ogi' flour

The total flavonoid content of 'Ogi' flour samples was evaluated using Saikia, Dutta, Saikia & Mahanta. (2012) method. The 'Ogi (0.25 mL) was diluted with 1.25 mL distilled water followed by the addition of $NaNO_3$ solution (75 μL). The resulting mixture was incubated for 6 min before the inclusion of 10% $AlCl_3$ (150 μL) followed by 5 min of incubation. Thereafter, 1 M Sodium hydroxide (0.5 mL) was added to the mixtures and made up to 3 mL before reading at 510 nm on the spectrophotometer. Quercetin was used to construct the calibration curve which estimated the TFC concentration in mg/100g.

Determination of Total Antioxidant Content (TAC) of 'Ogi" flour

The phosphomolybdum assay was reported by Dutta, Gope, Banik, Rahman, Makhnoon, Siddiquee & Kabir. (2013) was used to determine the total antioxidant capacity of 'Ogi' samples. The mixture of sulphuric acid (3.3 mL), Sodium phosphate (335 mg) and ammonium molybdate was dissolved in 100 mL of distilled water to produce the phosphomolybdenum reagent. Boiling of the mixture 0.1 mL of 'Ogi' and the phosphomolybdenum reagent at 95 ºC for 90 minutes was done. The absorbance of the resulting mixture was read at 695 nm. A standard curve was constructed from the absorbance readings of different concentrations of gallic acid. The total antioxidant capacity was estimated in mg/g from the standard curve.

Determination of 1,1diphenyl-2-Picrylhydrazyl (DPPH) of 'Ogi' flour Samples

The radical scavenging potential of 'Ogi' flour was determined by the DPPH radical scavenging assay using the method described by Cheng, Moord & Yu (2006). About 0.004% DPPH solution was prepared. "Ogi" dilution (0.1 mL) was mixed with DPPH reagent (p.3 mL) and kept in the dark for 30 min the resulting mixture was taken at 516 nm. The DPPH reagent without the sample extract was used as a control. The percentage inhibition of the extract was calculated using Equation 1.

$Percentage\ inhibition = [\frac{(Ac-Ae)}{Ac} x\ 100)$ Where Ac= Absorbance of control; Ae= Absorbance of extract.

Determination of Ferric Reducing Antioxidant Power (FRAP)

The ferric reducing antioxidant power for "Ogi' sample was determined using modified method described by Sukrasno, Tuty & Fidrianny, (2017). The FRAP reagent was prepared by the mixture of Acetate buffer, 2, 4, 6-Tris (2-pyridyl)-s-triazine (TPTZ) and $FeCl_3.6H_2O$ in the ratio 10:1:1, respectively. Distilled water (0.7 mL) was used to dilute 0.3 mL of "Ogi" dilution, followed by the addition of FRAP reagent (2.85 mL). The reacting mixture was kept for 20 minutes at 50^OC. The equivalent concentration! (EG) as the concentration of A_O with a reducing effect equivalent to 1mmol/L Fe (II), was used to compare A_O efficiency before reading its absorbance at 700 nm. The ascorbic acid concentration in the (range 0.003 – 0.53 mg/L of Asc (R2 = 0.9882) was used to prepare the standard curve using a correlation coefficient of 0.9993 for the estimation of the antioxidant power of 'Ogi' flour samples.

FRAP value = $[\frac{AI-AO}{Ac-Ao})] x\ 2$.

Where Ac is the absorbance of the positive control; AI is the absorbance of the sample and Ao is the absorbance of the blank.

Sensory Evaluation

Panels of 20 members consisting of students in the Oke-Ogun Polytechnic, Saki who are used to consuming "ogi" porridge were selected. Samples of 'Ogi' porridge (Akamu) were prepared by mixing 100 g powder 'Ogi' into a slurry by diluting it with 50 mL water in a transparent 1000 mL plastic bowl and 400 mL of boiled water at 100 ºC was added to gelatinize the sample with continuous stirring and was further boiled for 5 min and allowed to cool to 50-60 ºC. The temperature of the gruel was maintained by pouring samples into a well-labelled vacuum flask before serving. Samples were served randomly in coded (3-digit numbers?) transparent plastic with a disposable cup, spoon and water to rinse the mouth. A 9-point hedonic scale was used for the difference test (multiple comparison tests). Where 9 rates "like extremely" and 1 rate "dislike extremely.

Statistical Analysis

All data obtained were subjected to statistical analysis using one-way analysis of variance (ANOVA). Mean separation was done by Duncan's multiple range tests to determine significant differences between the mean (p<005), i.e. at a 5% level of significance. The statistical package for the Social Sciences (SPSS) 20.0 for Windows (SPSS Inc., Chicago, IL, USA) was used

3.0 RESULTS AND DISCUSSION

Proximate composition of co-fermented dried 'Ogi' flour

Table 4 shows the proximate composition of the dried 'Ogi' flour. Moisture content had the highest value at a 10% level (13.071%). Lower moisture content of the flour could assist in maintaining stability during storage and less than 14% has been recommended (Hanee, 2013). Protein had the highest value at 20% level (16.415%). Protein varied values could be attributed to the addition of pigeon peas which has higher protein content than sorghum

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(Aminar, Vajiha & Usha. 2015). Protein plays an important role in structure, function and regulation of the body's tissues and organs and about 0.75g per kg of body weight per day for average woman and 45 or 55 g for men (Guoyao, 2016). Ash had highest value at 10% level (4.04%). Ash content has been used to determine mineral content of foods. Fat had highest value at 20% level (1.60%). Fat contribute to energy level in dieting but saturated fats from animal origin causing cholesterol has been implicated in various heart related diseases while vegetative fat from grains contains less saturated fats and are considered to be hearts friendly (Mesina,

2014). Fiber had highest value at 10% level (1.33%). Fiber from grains has been shown could assist in regular bowel movement, weight management, gut health, cholesterol reduction, reduce diabetes risk and cardiovascular diseases (Duyff, 2017) of which 25 to 30 grams per day with 6-8 grams per day coming from the soluble fiber is recommended (Fuller, Bedk, Saiman & Topsell. 2016). Carbohydrate highest value at 30% level (73.16%). Carbohydrates are needed for energy but high carbohydrates consumption have been implicated in cases of malnutrition's and diabetes and legumes (high protein and fiber) has been used as supplement.

. **Table 2. Proximate Composition of co-fermented dried 'Ogi' flour (%)**

Sample Ratio	Moisture	Protein	Ash	Fat	Fiber	Carbohydrate
100:0	11.351 ± 0.342^c	13.788 ± 0.044^c	2.780 ± 0.030^c	0.988 ± 0.012^d	0.681 ± 0.030^{bc}	70.414 ± 0.339^c
90:10	13.071 ± 0.392^a	9.893 ± 0.088^e	4.039 ± 0.017^a	1.158 ± 0.053^b	1.327 ± 0.098^a	70.515 ± 0.170^b
80:20	10.690 ± 0.297^e	16.315 ± 0.044^a	2.012 ± 0.089^e	1.601 ± 0.185^a	0.533 ± 0.012^c	68.751 ± 0.033^{cd}
70:30	10.684 ± 0.290^d	11.644 ± 0.0875^d	2.842 ± 0.083^b	1.005 ± 0.010^c	0.660 ± 0.004^{bc}	73.160 ± 0.0308^a
60:40	11.995 ± 0.379^b	15.408 ± 0.000^b	2.234 ± 0.096^d	0.874 ± 0.060^e	0.719 ± 0.004^b	68.771 ± 0.286^{cd}

The mean values on same column with different superscripts are significantly different ($p < 005$) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

Mineral composition (Ca, P and Na) of Sorghum-Pigeon peas 'Ogi' Flour

Table 3 showed composition of Ca, P and Na evaluated. Calcium values increased with increased addition of pigeon pea with highest value at 40% level (0.031%). Calcium is needed for bones developments which are required by growing children and the elderly to prevent arthritis and recommended mg/day differ with age and is between 210 to 1,300 mg (ABS, 2011). Potassium also

increased with highest value at 20% level (0.098%). Potassium has been shown could assist in lowering blood pressure, and recommended daily intake for adult is (3.7 to 5.1 mmol/L) (Ayat, Hger, Ibrahim & Omer. 2018). While sodium decreased with highest value at the control level (0.163%). High consumption of sodium salts have been implicated in increasing blood pressure and the recommended daily intake for adult is (136 to 144 mmol/L) (Ayat et al., 2018). High potassium and lower sodium content is expected to give balance electrolyte.

Table 3. Mineral Composition of Co-fermented Sorghum-Pigeon peas 'Ogi' Flour

Sample Ratio	Calcium (%)	Potassium (%)	Sodium (g/kg)
100:0	0.015 ± 0.005^c	0.040 ± 0.001^c	0.163 ± 0.003^b
90:10	0.021 ± 0.001^b	0.026 ± 0.001^d	0.149 ± 0.001^c
80:20	0.026 ± 0.001^b	0.098 ± 0.003^a	0.021 ± 0.005^{cd}
70:30	0.019 ± 0.000^c	0.037 ± 0.002^c	0.161 ± 0.001^{bc}
60:40	0.031 ± 0.001^a	0.044 ± 0.005^b	0.184 ± 0.004^a

The mean values on same column with different superscripts are significantly different ($p < 005$) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

Functional Properties of Sorghum- Pigeon peas 'Ogi' Flour

Results in Table 4 showed the functional properties of the "Ogi" samples. Water Absorption capacity (WAC) and oil absorption capacity (OAC) increased with increased pigeon peas addition with WAC had highest value at 40% level (1.340 ml/g) and OAC highest value at 40% level (1.180 ml/g). Water and oil absorption capacity measure total amount of water and oil that can be absorbed per gram of protein based on the direct interaction of protein molecule with water and other solutes and pigeon peas has been shown to have 2.60ml and 1.66ml WAC and OAC respectively (Anmar et al.,

2015). Loosed and tapped bulk densities decreased as the substitution increased and LBD had highest value at control level (0.581g/ml). While TBD had highest value at 20% level (0.778g/ml). Diets that have low bulk densities enables ease of swallowing during consumption and promotes easy digeststbility of the food (Tiencheu, Achidi, Fossi, Tenyang, Ngongang & Womeni. 2016) The density or heaviness of the processed products dictate the characteristic of its container in terms of strength of packaging materials, material handling and application in the food industry (Falade & Okafor, 2015).

Table 4. Functional Properties of Sorghum- Pigeon peas 'Ogi' Flour.

Sample Ratio	WAC (ml/g)	OAC (ml/g)	LBD (g/ml)	TBD (g/ml)
100:0	1.250 ± 0.000^b	1.025 ± 0.045^d	0.581 ± 0.001^a	0.755 ± 0.000^b
90:10	1.130 ± 0.010^b	1.154 ± 0.024^b	0.528 ± 0.002^b	0.729 ± 0.003^c
80:20	1.3370 ± 0.010^b	1.149 ± 0.045^c	0.525 ± 0.005^b	0.778 ± 0.002^a
70:30	1.297 ± 0.0130^b	1.082 ± 0.007^{cd}	0.434 ± 0.014^c	0.716 ± 0.005^{cd}

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60:40	1.340±0.0200[a]	1.180±0.010[a]	0.551±0.001[b]	0.742±0.003[bc]

The mean values on same column with different superscripts are significantly different ($p < 005$) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

WAC, Water Absorption Capacity; OAC, Oil Absorption Capacity; LBD, Loosed Bulk Density; TBD, Tapped Bulk Density

Swelling Power / capacity of Sorghum - Pigeon peas 'Ogi' Flour at Different Temperature

The swelling power of the sample flours as influenced by heating temperatures is indicated in Table 5. Swelling capacity increased with increased tiger nut addition and as the temperature of heating increased. At 50 °C the highest value was at the 40% level (1.340g/g). At 60 °C highest value was at the control level (1.253g/g), 70°C at the 30% level (1.773g/g); 80 °C at the 10% level (3.616g/g) and 90 °C at 30% level (4.760g/g). Swelling capacity

measure the ability of the flour to imbibe water when heated in aqueous suspensions and this study's results agreed with Shiqi, Mario & Benjamin. (2019) that power increases when the temperature increases. Swelling power is a measure of hydration capacity and when flour is heated to above the gelatinization range in excess water, hydrogen bonds stabilizing the structure of the double helices in crystallites are disrupted and are embraced with water, thus leading to flour swelling and increased overall volume (Shiqi et al., 2019)

Table 5. Swelling Capacity (g/g) of Sorghum- Pigeon peas 'Ogi' Flour at Different Temperatures in Degree Celsius

Sample Ratio	50	60	70	80	90
100:0	1.125±0.005[c]	1.253±0.015[b]	1.570±0.010[bc]	3.075±0.065[c]	3.490±0.040[c]
90:10	1.070±0.020[d]	1.140±0.030[d]	1.622±0.002[b]	3.616±0.026[a]	4.380±0.120[e]
80:20	1.317±0.003[a]	1.272±0.032[a]	1.552±0.023[c]	2.657±0.038[e]	4.448±0.003[d]
70:30	1.180±0.010[b]	1.270±0.010[a]	1.773±0.018[a]	3.317±0.017[b]	4.760±0.060[a]
60: 40	1.340±0.020[a]	1.230±0.010[c]	1.720±0.020[ab]	2.900±0.015[d]	4.587±0.023[b]

The mean values on same column with different superscripts are significantly different ($p < 005$) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

Anti-Oxidant Profile of Sorghum-Pigeon peas 'Ogi' Flour

Table 6 showed the anti-oxidant properties of 'Ogi' samples. Flavonoids had highest value at 10% level. (0.733mg Quercetin/g). While phenolic had highest value at 10% level (0.247 mgGAE/100g). The increased in flavonoids and phenolic substances are both contributed by sorghum (Mal et al, 2010) and pigeon peas with high potential to reduce some nutritional problem related to immunity and metabolic disorder. FRAP had highest value at 10% level (1.530mg/g) and TAC had highest value at 30% level (1.843 mg GAE/g). While, DPPH values were not significantly different

(p<0.05), but had highest value at 10% level (16.328 %). High anti-oxidant and free radical scavenging in the samples measured by FRAP, TAC and DPPH are significantly important in dieting and studies on pigeon peas (Rani et al., 2014) and sorghum (Heba, Eman, Abdul, Kaleemullah, Rafiq & Mahmoud. 2022) had shown the high anti-oxidant properties capable of assisting in the treatment of some diseases such as diabetes, fever, dysentery, hepatitis, inflammation, sickle cell anemia, etc. Therefore, results had shown an increase in anti-oxidant properties, thus making it a functional foods good for infants and adults. .

Table 6. Anti-Oxidant Profile of Sorghum-Pigeon peas 'Ogi' Flour

Sample Ratio	TFC (mg Quercetin/g)	TPC (mg GAE/100g)	FRAP (mg/g)	(TAC) (mg GAE/g)	(DPPH) (%)
100:0	0.463±0.007[d]	0.180±0.002[cd]	0.196±0.004[de]	1.161±0.005[c]	16.322±0.071[a]
90:10	0.733±0.007[a]	0.247±0.000[a]	1.530±0.009[a]	1.568±0.008[b]	16.328±0.173[a]
80:20	0.373±0.007[e]	0.194±0.004[c]	0.357±0.271[c]	0.889±0.006[e]	16.255±0.123[b]
70:30	0.663±0.013[b]	0.207±0.005[b]	0.305±0.005[d]	1.843±0.030[a]	16.119±0.071[c]
60:40	0.530±0.020[c]	0.170±0.005[d]	1.038±0.009[b]	0.961±0.15[d]	15.181±0.071[d]

The mean values on same column with different superscripts are significantly different ($p < 005$) of significance. Where samples ratios are Sorghum: Pigeon peas (co-fermented)

TFC, Total Flavonoid Content; TPC, Total Phenolic Content; FRAP, Ferric Reducing Antioxidant Power; TAC, Total Antioxidant Content; DPPH, 1,1diphenyl-2-Picrylhydrazyl

Sensory Properties of Sorghum-Pigeon peas 'Ogi' Gruel

Table 7 above shows the sensory scores by the panellist on 'Ogi'gruel samples. The highest value for gruel ranking in terms of appearance was at 40% level (7.73), mouth feels at 30% level (7.93), Color at control level (7.50), taste at 40% level (7.87) aroma at 40% level (7.53) and general acceptability at 30% level (7.97) The

increased value in mouth feel, taste, aroma and general acceptability of the rest samples might have been contributed by the addition of pigeon peas which is high in protein content and when heated impacted these acceptable characteristics and low acceptability of appearance and colour might be as a result of brown colourations of pigeon peas .

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Table 7. Sensory Properties of Co-fermented Sorghum- Pigeon peas 'Ogi' Gruel

Sample Ratio	Appearance	Mouth feel	Colour	Taste	Aroma	General Acceptability
100:0	7.36±0.233[c]	7.64±0.240[c]	7.50±0.205[c]	7.69±0.266[c]	7.00±0.228[c]	7.50±0.206[c]
90:10	7.00±0.185[c]	7.47±0.180[c]	7.033±0.189[c]	7.70±0.226[c]	7.00±0.198[c]	7.43±0.184[c]
80:20	7.53±0.190[c]	7.83±0.210[c]	7.27±0.172[c]	7.63±0.206[c]	7.20±0.188[c]	7.70±0.145[c]
70:30	7.47±0.190[c]	7.93±0.210[c]	7.43±0.202[c]	7.73±0.203[c]	7.23±0.196[c]	7.97±0.169[c]
60:40	7.73±0.200[c]	7.70±0.2042[c]	7.47±0.184[c]	7.87±0.202[c]	7.53±0.202[c]	7.67±0.194[c]

The mean values on the same column with different superscripts are significantly different ($p < 005$) of significance. Where sample ratios are Sorghum: Pigeon peas (co-fermented)

4.0 CONCLUSION

These results showed that the addition of pigeon pea to sorghum and co-fermentation had effects on proximate composition comparing the samples with the control sample with moisture, ash, fibre and carbohydrates having the highest value at 10% level and protein and fat at 20% level. Minerals of calcium and potassium increased but sodium decreased but had the highest value at 40% level Also, water, and oil absorption capacity increased, loosed and tapped bulk densities decreased and swelling capacity increased with increased heating temperature. High antioxidant activities were exhibited by the samples, showing pro-health benefits to both infants and adults while gruel samples had the highest acceptability rating at 30% level,. Therefore, the addition of pigeon peas to sorghum and co-fermentation produced a highly nutritious dense and functional food adequate to tackle malnutrition and increase the utilization of sorghum and pigeon peas in the tropics.

References

Adebowale, O. J. & Maliki K. (2011). Effect of fermentation period on the chemical composition and functional properties of pigeon pea seed flour, *International Research Journal* 18:1329-1333.

Australian Bureau of Statistics, (2011). Australian Health Survey: Usual Nutrient Intakes: In National Nutrition and Physical Activities Survey of 2011-12. Retrieved from tttp://www.abs.gov.au/statistics/health/health_Conditional.risk/Australian-health-survey-usual-nutient-intakes latest-release.

Adeleke, A. O., & Oyewole, O. B. (2010). Production of ogi from germinated sorghum supplemented with soybeans. *Africa Journal of Biotechnology*,9 (42), 7114-7121.

Afolayan M.O, Afolayan M & AbuahAn, J.N. (2010). Investigation into Sorghum-Based Ogi (Ogi-Baba) Storage Characteristics. *Advanced Journal Food Science Technology,* 2(1), 72-78.

Ajanaku, K. O., Ogunniran, K. O., Ajani, O. O., James, O. O., & Nwinyi, O. C. (2010). Improvement of nutritive value of sorghum ogi fortified with Pawpaw (Carica papaya L.). *Fruit Vegetable Cereal Science Biotechnology,* 4 (1), 98-101.

Ajanaku, K. O., Ajanaku, C. O., Edobor, O., & Nwinyi, O. C. (2012). Nutritive value of sorghum-Ogi fortified with groundnut seeds. *American Journal of Food Technology*, 7(2), 82-88

Ajanaku, K. O., Ajani, O., Siyanbola, T. O., Akinsiku, A. A, Ajanaku, C. O., & Oluwole, O. (2013). Dietary fortification of sorghum-ogi using crayfish (Paranephrops planifrons) as supplements in infancy. *Food Science and Quality Management*, 15, 1-9

Anmar, N. H., Vajiha, B. A., & Usha., A. (2015). In vitro Evaluation, Functional properties of protein from pigeon peas (Cjanus cajan) and its application in food. *Asian Journal of Microbial Biotech, Environmental Science,* Vol 17 No (1). 181-187.

Arawande, J. O., & Borokini, F. B. (2010). Comparative study on chemical composition and functional properties of three Nigerian legumes (Jack beans, pigeon pea and cowpea) *Journal of Emerging Trends in Engineering Applied Sciences*, 1 89-95

Aremu, M. O., Osinfade, B. G., Basu, S. K., & Ablaku, B. E. (2011). Development and nutritional quality evaluation of kersting's groundnut-ogi for African weaning diet. *American Journal of Food Technology* 6 (12), 1021-1033.

AOAC, (2005). Official Methods of Analysis 17th Edn Association of Official Analytical Chemists. Washington D. C., USA.

Ayat A. H., Hger, O., Ibrahim, A. A., Omer, M. (2018). Reference values for Serum Electrolytes (Na+, K+, Ca++) in Khartoum state. *Saudi Journal. of Medicine and Pharmacology Science,* 4 (7) 753-757.

Cheng, Z., Moor, J., & Yu, L. (2006). High-throughput relative DPPH radical scavenging capacity assay. *Journal of Agricultural and Food Chemistry*, 54(20), 7429-7436.

Devi, P.B., Vijayabharathi, R.S., Sathyabama, N.G., Priyadarisini, V.B. (2011). Health benefits of Sorghum and finger millet (Eleusine coracana L.) polyphenols and dietary fiber: A review. *Journal Food Science Technology,* .1 (3),4-9.

Dutta, A., Gope, P., Banik, S., Rahman, M., Makhnoon, S., Siddiquee, M. & Kabir, Y. (2013). "Physicochemical, cooking and antioxidant properties of nine aromatic rice cultivars of Bangladesh," *Acta Alimentaria,* 42, 552-564

Duyff, R.L (2017). Carbs, Sugars, Starches and Fiber In: Academy of Nutrition and Diettetics Complete food and Nutritional Guide 5th Ed New York, N.Y. Houghton Miffin Harcourt.

Falade K.O & Okafor C.A.C. (2015. Physical, Functional and Pasting properties of flour from Corms of two Cocoyam (Colocasia exculent and Xanthosoma sagittifolium) cultivars. *Journal of Food Science and Technology*, 52(6) 3440 – 3448.

Fuller, S., Bedk, E., Saiman, H., & Topsell, L. (2016). New Horizon for the Study of Dietary Fiber and Health: A review. *Plant Foods Human Nutrtioni.* 71 (1): 1-12.

Guovao, Wu. (2016). Dietary Protein Intake & Human Health. *Food Function* 7(3), 1251-65.

Heba I. Mohamed, Eman Mfawzi, Abdul Basit, Kaleemullah Raviq Losne & Mahmud R. Sofy. (2022). Sorghum Nutritional Factors, Bioactive compounds, Phamaceutical and Application in food systems: A Review. *Phyton – International Journal of Experimental Botany* 91(7) 1-23.

Khady, B., Emmanuel, T., Jacqueline, D., Ndiaga, C., & Philippe, T. (2010). Comparative study of phenolic compounds, the antioxidant power of various Senegalese sorghum

_____

varieties anda amylolytic enzymes of their malt. *Biotechnology, Agron. Soc. About*. 14(1):131-139.

Makumba, C.T., Patrick, B.N., Oluwafemi, A.A., Adetola, O.O & Kayitesi, E. (2016). The Role of Compositing Cereals with Legumes to Alleviate Protein Energy Malnutrition in Africa. *International Journal Food Science Technology,* 51(3): 543-554.

Mal, B., Padulosi, S., Ravi, S.B. (2010). Minor millets in South Asia: learning's from IFAD-NUS Project in India and Nepal. Maccarese, Rome, Italy: *Bioversity Intl and Chennai, India: M.S. Swaminathan Research Foundation.* 1–185

Mbaeyi, I. E., & Onweluzo, J. C. (2010). Effect of sprouting and pre-gelatinization on the physicochemical properties of sorghum – pigeon pea composite blend used for the production of breakfast cereal. *Journal of Tropical Agriculture, Food, Environment and Extension, 9(3): 184-192*

Messina, V. (2014). Ntritional and Health benefits of dried beans. *The American Journal of Clinical Nutrition,* 100(1), 437S -442S

Omemu, A. M., & Faniran, O. W. (2011). Assessment of the antimicrobial activity of lactic acid bacteria isolated from two fermented maize products- ogi and kunnu zaki. *Malaysian Journal of Microbiology* 7(3), 124, 124 – 128.

Pal, D., Sachan, N., Ghosh, A. & Mishra, P.. (2011). Biological activities and medicinal properties of Cajanus cajan (L) Millsp," *Journal of Advanced Pharmaceutical Technology & Research*, 2(4). 207– 214

Pedro, A.C., Granto, D., Rosso, N.D. (2016). Extraction of anthocyanins and polyphenols from black Rice Oryza sativa) by modeling and assessing their reversibility and stability. *Food Chemistry* 191, 12-20.

Rani, S, Poswal, G., Yadav, R. &. Deen, M. K. (2014). "Screening of Pigeon pea (Cajanus cajan L.) Seeds for study of their flavonoids, total phenolic content and antioxidant properties," *International Journal of Pharmaceutical Sciences Review and Research*, 28, 90–94.

Shiqi Huan, Mario M. Martinez.,& Benjamin M. Bohrer. (2019).The compositional and Functional Attributes of Commercial Flours from Tropical Fruits (Breadfruit and Banana). *Foods* 8(11), 586.

Saikia, S., Dutta, H. Saikia, D., & Mahanta, C. L. (2012). "Quality characterization and estimation of phytochemicals content and antioxidant capacity of aromatic pigmented and non-pigmented rice varieties," *Food Research International,* 46,334-340..

Saxena, K.B., Kumar, R. V., & Sultana, R. (2010). "Quality nutrition through pigeon pea-a review," *Health,* 2(11),1335–1344.

Sukrasno, S.,Tuty, S., & Fidrianny, I. (2017). Antioxidant evaluation and phytochemical content of various rice bran extracts of three varieties rice from Semarang, Central Java, Indonesia, *Asian Journal of Pharmaceutical and Clinical Research*. 10, 377-382.

Tiencheu B , Achidi, A.U, Fossi T, Tenyang N, Ngongang E F.T, & Womeni H.M. (2016). Formulation and Nutritional Evaluation of Instant Weaning Foods Processed from Maize (Zea mays), Pawpaw (Carica papaya), Red Bean (Phaseoulus vulgaris) and Mackerel fish Scomber Sconmbrus). *American Journal of Food Science and Technology,* 4 (5) 149-159.