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ASSESSMENT OF MIDWIVES' SERVICE PROVISIONS AT PRIMARY HEALTH CENTRES' (PHC) FACILITIES IN CROSS RIVER STATE

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Abstract

The importance of midwives' services to reduce maternal and newborn morbidity and mortality had long been identified by the industrialized world and that is why midwives were developed. The purpose of the study was to assess midwives' service provision at Primary Health Care level in Cross River State, Nigeria. Two research questions were raised to guide the study. The research design adopted was the cross-sectional descriptive survey method. The sample comprised of 70 mid-wives selected through the use of census sampling technique. A questionnaire developed by the researcher on the type of services provided by mid-wives was used to collect data. The data gathered were analyzed with simple percentages. Results indicated that only forty-four (44) PHCs have midwives while one hundred and fifty-eight (158) PHCs have no midwife at all. During the intra-partum care, the result revealed that 50-80% of midwives sometimes do the following services: catheterization, suturing, use of partograph, provision of emergency obstetric and immediate care of the newborn, while services such as referrals 63.4%, vaginal examination 54.3%, vital signs check 74.3% and history taking 51.3% of respondents is done most of the time. At the post-partum care, the result reveals that a good number of more than 58% of the midwives give services like family planning, general/physical examination, counseling, post-natal exercise, care of the newborn, health education of client and family are sometimes provided while 61.4% of male circumcision service is not rendered at all. Based on this finding, it was recommended that the presence of midwives in State Primary Health Care Development Agency should be strengthened. Nursing and midwifery council should review the policy to establish community midwifery in Cross River State where more midwives will be trained and automatically employed to PHC level in the State.

Keywords: Midwives, Ante-Natal, Intra-Partum Care, Post-Partum Care, Assessment

Introduction

Health systems are facing an increasing number of challenges, while governments remain dedicated to searching for cost-effective options to enhance the capacity of national health systems to perform well. Within the context of limited financial resources, rising health care costs, increasing health demands and heightened public expectations, nursing and midwifery services provide a platform from which to scale up health interventions to assist in meeting national health targets. High level skilled attendants is a pre-requisite in attaining the third Sustainable development goal of achieving health for all by 2030 (WHO, 2015). Functional health systems depend on the availability, accessibility, acceptability and quality of health workers.

Improving the global health workforce is key to achieving one of the targets under the Sustainable development goals (SDGs) agenda for health. The global maternal health workforce comprises care providers with different skillsets who practice in diverse contexts, including obstetricians, midwives,

nurses, and others. In a recent report on the “global strategy on human resources for health with regard to workforce 2030,” it is estimated that there is a global health workforce shortage of roughly 17.4 million providers as of 2013. Of this number, about nine million were nurses and midwives (WHO, 2016). The authors of the report noted that most countries are not on track to reach a threshold of 4.45 midwives per 1,000 people, which will be necessary for accomplishing the health-related SDG targets by 2030. Additionally, the health workforce tends to be concentrated in cities, leaving women in rural areas with limited access to skilled care (UNFPA, ICM and WHO, 2014). Nursing and midwifery services are a vital resource for attaining health and development targets. They form the backbone of health systems around the globe and provide a platform for efforts to tackle the diseases that cause poverty and ill-health. If we are to succeed in improving health systems performance, urgent action is needed to overcome the problems that seriously undermine the contribution these services can make to the vision of better health for all communities (World Health Organization, 2002). Researchers who modeled the projected effects of scaling-up midwifery predicted that a ten percent increase in coverage of midwifery-led care would result in a twenty-seven percent reduction in maternal mortality in low- and middle-income countries (UNFPA, ICM and WHO 2014).

The major roles of midwives include rendering care to women during pre-pregnancy, pregnancy, intra-partum and postpartum periods. Overall, this care aims towards positive outcome in the process of childbearing for both mother and baby (International Confederation of Midwives, 2005; Masterson, 2010). Furthermore, midwifery services extend to the client’s family and the larger community (ICM, 2005). The World Health Organization classifies midwives as skilled birth attendants alongside with doctors and nurses with midwifery skills (WHO, 1999). This means that midwives are very important in the reduction of maternal mortality. A strategy by WHO to reduce maternal mortality is skilled birth attendance in addition to emergency obstetric care (EmOC) and community mobilization (De Brouwere, Tonglet & Larberghe, 2002; Henry, Thea, Hamer, & Dejong, 2017).

The importance of midwives’ services to reduce maternal and newborn morbidity and mortality had long been identified by the industrialized world and that is why midwives were developed (United Nation, 2007). Consequently, the maternal mortality in such nations are relatively low, for example, the developed regions have maternal mortality ratio (MMR) of 12/100,000 live births; while it is 546/100,000 in the developing region like sub-Saharan Africa. Country estimates show that MMR of Nigeria is 814/100,000; United Kingdom is 9/100,000 and United States of America is 14/100,000 live births (WHO, 2015). A systematic review has shown that there are better maternal and newborn outcomes with midwife-led births (Hatem, et al, 2014). This implies that a high population of midwives can go a long way to improve birth outcomes thus, reducing morbidities and mortalities in mothers and their babies.

Following the Alma Ata declaration in 1979 (WHO, 2008) the health care delivery system in Nigeria has been stratified into primary, secondary and tertiary levels. The tertiary level consists of Teaching and Specialist hospitals; the secondary health facilities are the General hospitals while the Primary Health Care (PHC) level comprises the Primary Health Centres, Health Posts and Mobile Clinics. The essence of the PHC is to reach out to the people where they live and work (Alenoghena, et al, 2014). Although there are some PHC facilities in the urban areas, majority of these are located in the rural areas (Abdulraheem, et al, 2012). Studies have shown that majority of the Nigerian population reside in the rural areas and it has also been established that most maternal deaths in Nigeria occur in the rural areas (Abdulraheem, et al, 2011).

This may be associated with faulty maternal health services which may connote defective midwifery services. Additionally, it has been observed that the tertiary and secondary health facilities being more cosmopolitan have more human resources; on the contrary, due to the mostly rural location, PHCs may not have highly qualified health professionals which include midwives and this can have an implication on maternal mortality. Maternal mortality remains a major public health challenge globally, with an estimated 295,000 annual maternal deaths. This high global prevalence is attributed to mortality from low- and middle-income countries especially sub-Saharan Africa which accounts for 66.3% of all maternal deaths compared to 5% in developed countries. The high prevalence in sub-Saharan Africa is secondary to poor access to maternal and child health services. Nigeria, one of the largest countries in sub-Saharan Africa accounts for 15% of all maternal deaths globally and a maternal mortality ratio (MMR) of 917 per 100,000 live births (WHO et al, 2019). Cross River which is one of the states in South-Eastern Nigeria tops the list for high maternal mortality in the country with MMR of 2000 per 100,000 live births (NDHS, 2013).

The reason for this alarming ratio is presumed to be that antenatal, delivery and postnatal services in the state are mostly provided by traditional birth attendants (TBAs), and faith-based institutions without skilled attendants at birth accounting for only 41.3%. (NDHS, 2013). The close correlation between access to a skilled, motivated, and supported midwife and maternal and child health is well established (Roskam, et al. 2011). Worldwide however, there is an estimated shortage of 4.3 million midwives, nurses, and doctors, with the shortage most severe in low- and middle-income countries (Roskam et al 2011; WHO, 2006). Meanwhile, research indicates that teams of midwives and midwife assistants working in facilities could increase coverage of maternity care by up to an additional 40% by 2015 (Koblinsky, et al, 2006).

The availability of skilled health providers (particularly midwives) is critical in ensuring high quality ante natal, intra-partum, emergency obstetric and post-natal services. Indeed, SDGs for maternal health is unlikely to be achieved without attention to the recruitment and retention of midwives (WHO, 2017; ICN, 2017). Accelerating progress towards the SDGs and pursuing an ambitious post-2030 development agenda will require governments, civil societies and professional associations to work with educational institutions, NGOs and a range of international and bilateral organizations to ensure that midwives are more actively sought and retained, and that the value of existing staff is better recognized, to avoid the risk of a post-2030 slow-down (WHO, 2012).

According to Moses & Chugani (2014), in support of the roles stated previously, midwives have proficiency to manage normal (uncomplicated) pregnancies, childbirth, immediate postnatal period, identify, manage and refer complications as well as offer base-line emergency obstetric and new-born care when needed. They have been recognized as being pivotal in the reduction of maternal mortality. In Cross River State, for both institutional and non-institutional deliveries, maternal mortality occurs as a result of antepartum and post-partum haemorrhages, pre-eclampsia and eclampsia, obstructed labour, sepsis, unsafe abortion, thrombosis and thromboembolism, ectopic pregnancy, HIV/AIDS exacerbated during pregnancy.

These causes if properly assessed and managed by skilled birth attendants are preventable. Additionally, these complications are common in sub-Saharan Africa and it has been observed that there is inappropriate distribution of skilled birth attendants between rural and urban areas. There is a high concentration of skilled birth attendants in the urban areas, therefore, resulting in higher maternal deaths in the rural areas (Bhutta, et al, 2010). Various strategies have been put in place in Nigeria to help increase the number of midwives in rural areas and one of those strategies is the Midwives Service Scheme (MSS) designed specifically to recruit retired but still active midwives and the newly qualified ones to be employed and deployed to health facilities located in rural areas (NPHCDA, 2009). Programmes with these essential elements have been able to attract, recruit, and deploy newly qualified, unemployed, and in some cases, retired but still productive midwives to areas where their skills can make a difference in saving lives and improving the health of women and newborns (NPHCDA, 2009). Currently this strategy is no more functional in most of the states.

The major challenges being that participating state governments were not able to retain the midwives hired by the scheme as the implementation of the memorandum of understanding signed with state and

local governments was a persisting problem, these mainly involved provision of accommodation for the midwives and irregular or delayed salary payment (Abimbola, et al, 2012). Another strategy that was put in place to ensure availability of midwives in rural areas was the Subsidy Reinvestment Empowerment Programme for maternal and child health (SURE-P MCH) project. The programme three key supply measures were improving primary health care facilities' infrastructure, providing adequate midwife staff for PHC facilities, and ensuring steady supply of drugs, consumables, and other commodities for the provision of quality maternal and child health services (World Bank, 2013). However, with the change of government at the national level in 2015, the programme was stopped.

Recently, Cross River State Primary Health Care Development Agency and the World Health Organization (WHO) stated that the state needs 784 (seven hundred and eighty-four) midwives across the 18 Local Government Areas with at least four midwives per ward, this was declared during the International Day of the Midwife (IDM) 2017 celebration held in Cross River State. Also in that occasion, the State Commissioner for Health expressed regret toward the lack of adequate number of midwives in the state explaining further that in some Local Government Areas, there are no midwives and the state is commencing the recruitment of midwives that will gradually close up that gap. Therefore, this study seeks to assess midwives' service provision at primary health care level in Cross River State, Nigeria.

Statement of Problem

Maternal mortality remains a major public health challenge globally, with an estimated 295,000 annual maternal deaths. This high global prevalence is attributed to mortality from low- and middle-income countries especially sub-Saharan Africa which accounts for 66.3% of all maternal deaths compared to 5% in developed countries. The high prevalence in sub-Saharan Africa is secondary to poor access to maternal and child health services. Nigeria, one of the largest countries in sub-Saharan Africa accounts for 15% of all maternal deaths globally and a maternal mortality ratio (MMR) of 917 per 100,000 live births (WHO et al, 2019). Cross River which is one of the states in South-Eastern Nigeria tops the list for high maternal mortality in the country with MMR of 2000 per 100,000 live births (NDHS, 2013). The high prevalence of maternal mortality in sub-Saharan Africa might be secondary to poor population of midwives at primary health care level. This situation may not be different from the scenario in Nigeria where only 1 in 5 births are attended to by skilled birth attendants (Ugo, 2016; National Population Commission, 2014).

During the researcher's rural posting in this programme, it was observed that most Primary Health Care facilities within that Local Government Area lack midwives and this may be responsible for the high number of pregnant women who patronize Traditional Birth Attendants (TBAs) and faith-based facilities. Some of the women who booked in the health facilities end up delivering at TBA and Faith based homes. Studies have shown that most of these women who have their babies in these alternative birth places ended up developing serious complications that resulted in either the death of mothers or their babies (Etuk, Itam, & Asuquo, 2000; Kucho, & Mekonnen 2017).

Since 2009, several strategies towards improving maternal and child outcomes by the government have focused on programmes that strengthen the health system by improving access and utilization of health care. These led to the introduction of programmes such as Saving One Million Lives (SOML), Midwives Service Scheme (MSS), Subsidy Reinvestment and Empowerment Programme on maternal and child health (SURE-P MCH). The MSS and the SURE-P MCH in Nigeria aimed to close the gap of inadequate population of midwives. This effort is in line with the WHO recommendation for the provision of skilled birth attendants as one of the strategies to reduce maternal mortality. However, it has been observed that the MSS and the SURE-P MCH midwives are no more available in the PHC facilities in Cross River State to the extent that some of these facilities do not have any midwife.

This is in spite of the current situation of high maternal mortality in the state. In view of the globally acknowledged roles of midwives towards improvement of birth outcomes, coupled with the obvious lack of midwives in some PHC facilities in the study setting; little is known empirically about the

population and services of midwives in the study setting; therefore, it is pertinent to assess the service provision of midwives at Primary Health Care level in Cross River State, Nigeria.

Purpose of the Study

This study seeks to assess midwives' service provision at Primary Health Care level in Cross River State, Nigeria. Specific objectives for this study are to:

1. Identify the PHC facilities with midwives in Cross River State.
2. Examine the type of services provided by the midwives at PHC facilities in Cross River State.

Research Questions

1. Which of the PHC facility has midwives in Cross River State?
2. What are the types of services provided by midwives in PHC facilities in Cross River State?

Operational definitions of terms

Assessment: The act of determining the number of midwives present at a Primary Health Centre.

Midwives: These are nurses who have undergone competency-based training in midwifery and have been certified to practice midwifery in Nigeria.

Service provision: Task provided by midwives at primary health, care level.

Primary health care facilities: These are the basic health facilities in Cross River State, where midwives provide healthcare to childbearing women.

Antenatal care services: These are the services midwives provide to pregnant women at PHC facilities throughout the period of pregnancy.

Intra-partum services: These are the services midwives provide to women at PHC facilities throughout the period of delivery.

Post-partum care: These are the services midwives provide to mothers immediately after birth of the placenta to six weeks after delivery at PHC facilities.

Methodology

Research design

A Cross-sectional descriptive study design was used to determine the level of knowledge, attitude and practice of care of elderly among health workers in University of Calabar Teaching Hospital Calabar Cross River State. According to Sunday et al (2023), the descriptive study survey allows orderly collection of data. The cross-sectional approach involves the collection of data at a point in time and considered suitable for the phenomenon being studied (Sunday, 2024).

Study Setting

Cross River State is one of the thirty-six (36) States of the Federal Republic of Nigeria and is located in the South-South Geopolitical Zone and it has eighteen local government areas. The state is divided into three (3) Senatorial Districts which are Southern Senatorial District, Central Senatorial District and Northern Senatorial District. It shares common boundaries with Cameroon Republic in the East, Benue State in the North, Ebonyi and Abia States in the West and the Atlantic Ocean and Akwa Ibom State in the South. There are many languages in the State but Efik and Ejagham languages are widely spoken with English as the official language. The vegetation varies from tropical rain forest in the south and savannah in the north. The people of Cross River are predominantly farmers and fishermen with a few petty traders and civil servants.

The state has a total land mass of about 23,000 square kilometers with a population of 2,892,988, and female population of 69,086,302 (Census 2006). The state has an average annual population growth rate of 2.99% which is slightly above the population growth rate of the country (2.8%). An examination of the age distribution of the population reveals that in 2006, the proportion in the age bracket of 15-49 years (child bearing age) is 53.9% of the total female population of the State and 22% of the total population of the State (DHIS, PRS Department, SMOH Calabar, 2015). The demographics in Cross River State shows that women and children under 5 who are the most vulnerable, constitute 22% and 20% of the total population of the State respectively. Available data on disease specific morbidities shows that Cross River State has an HIV prevalence of 8% (NDHS 2008). Health indicators such as maternal mortality (2000/100,000), Under-five mortality (176/1000) and infant (120/1000) mortality rates rank Cross River State amongst the States with the highest maternal and child death in Nigeria. The state has three hundred and forty-eight (348) public primary health centres. The State has six hundred and forty-five (645) registered nurse-midwives and one hundred and forty (140) registered community health nurses (USAID, 2017).

Study Population

The target population for this study involved all midwives working at Primary Health Care facilities in Cross River State.

Sampling Procedures

The study adopted a census sampling procedure. Census is the study of every unit, every one or everything, or every element in the study area (Australian Bureau of Statistic, 2013). In this study, the total population of PHC facility with midwives and the total number of midwives in those facilities were used for quantitative aspect of the study. The researcher chose to study the entire population because the population that has the particular set of characteristics that the researcher is interested in is typically small.

Inclusion and Exclusion Criteria

Only midwives that were currently working in primary health care facilities and were willing to participate. Also, every other health worker who is not a registered midwife, midwives not working in Primary health care facilities, as well as those not willing to participate in the study.

Instrument for Data Collection

Questionnaire was used for quantitative data collection. A questionnaire is a set of systematically structured questions used by a researcher to get needed information from respondents or any written instruments that present respondents with series of questions from among existing answers. The questionnaire may be self-administered, posted or presented in an interview format. It includes: check lists, attitude scales, projective techniques, rating scales and a variety of other research methods. As an important research instrument and a tool for data collection, a questionnaire has its main function as a measurement tool. It is the main data collection method in surveys and yields to quantitative data. Also, due to provision for open-endedness, the instrument may be used to generate qualitative and exploratory data (Ong'anya & Odado, 2010). Questionnaire is the best instrument for the quantitative aspect of this study because it will allow each midwife the opportunity to provide anonymous responses; it will also help to identify patterns and trends that will merit further exploration using qualitative methods.

In this study, two self-developed questionnaires were used for the study. One generated data from the records of the Cross River State Primary Health Care Development Agency on the overall population of midwives at PHC level and also provided data on the proportion of PHC facilities that have midwives and those that do not have in the State. The second instrument was used to generate data on the type of services provided by midwives and population of midwives in each PHC facility.

Data Analysis Results

Socio-demographic characteristics

Table 1 shows that, there were no male midwives as at the time of this study in the various sample areas, while the female dominated all the PHCs with the highest number 100%. This therefore implies that among the sample respondents, none of the centres have male midwives. The age of midwives within the age of 27-35 years is higher with 42.8%, followed by those within 36-45 years of age 40.1%, 46-55 has 15.7% and then those in 56 years and above 1.4%.

The result of midwives' marital status shows that majority of the midwives 57(81.4%) are married, 9(12.9%) of them are single while 4(5.7%) are widows. The professional qualification of the midwives shows that those with RN/RM are more with the highest percentage of 81.4%, followed by those with BNSc 12.9%, while those with RM only have 5.7%. Also, the result of midwives' years of working experience reveals that those within the range of 11-20 (55.7%) indicated having more experience, followed by those within 1-10 (30.0%), those within 31-35 years have 8.6% while 21-30 years have 5.7%. However, the implication of this result could be as a result of the number of midwives present at the PHCs at the time of this study.

Further, the result of the professional rank of the midwives shows that those with NS rank 28(40.0%) are the highest in the sample area, followed by SNS & SNO 16(22.9%), PNS /PNO 10(14.3%) those with SNS professional rank 9(12.9%), ACNS/ACNO have least number 4(5.7%), while those with CNO and above are 12(17.1%). The implication of this result shows that among the professional rank, NS have the highest number while ACNS/ACNO are the least number in the professional rank, while 68(97.1%) of the midwives found at the different PHCs are government employed, 2(2.9%) were mentor midwives on contract and none of them indicated being volunteer staff.

Table 1: Socio-demographic Variable of respondent (n=70)

S/N	Variable	Frequency (F)	Percentage (%)
1	Gender		
	Male	-	-
	Female	70	100
2.	Age		
	27-35	30	42.8
	36-45	28	40.1
	46-55	11	15.7
	56 and above	1	1.4
	Total	70	100
3.	Marital Status of Midwives		
	Single	9	12.9
	Married	57	81.4
	Divorced	-	-
	Widowed	4	5.7
	Total	70	100
4.	Professional Qualification		
	RN/ RM	57	81.4
	RM only	4	5.7
	BNSc	9	12.9
	Total	70	100
5.	Years of Experience		

	1-10	21	30
	11-20	39	55.7
	21-30	4	5.7
	31-35	6	8.6
	Total	70	100
6.	Professional Rank		
	NS	28	40.0
	SNO/ SNS	16	22.9
	PNS /PNO	10	14.3
	ACNS	4	5.7
	CNO and above	12	17.1
	Total	70	100
7.	Nature of Employment		
	Government	68	97.1
	Volunteer	-	-
	Contract	2	2.9
	Total	70	100

Analysis of findings

The data collected from the questionnaire were analyzed using descriptive statistics to show the level of response on each item. Hence, percentages and frequency of the items will be shown.

Research Question One: Which PHC facility has midwives in Cross River State?

Table 2 shows that out of two hundred and two (202) Primary Health Care facilities in Cross River State, only forty-four (44) PHCs have midwives while one hundred and fifty-eight PHCs have no midwife at all. Comprehensive Health Centre Ikom is the facility in Cross River State with seven (7) midwives. PHC Mma Effa, PHC Akim, PHC Ntamkpo, PHC Ekuntack, Model PHC Utuwngwan, PHC Obudu urban, Model PHC Kassan Erowan, PHC department Calabar South, PHC department Yala LGA are the only PHC facilities that have two midwives each.

Table 2

Names of Health Centres in Cross River State that have Midwives (n=70)

S/N	LGA	NAME OF PHC	NUMBERS OF MIDWIVES
1	ABI	PHC EDIBA	1
		PHC EKUREKU	1
		PHC ANONG	1
2	AKAMKPA	PHC MMA EFFA	2
		PHC OJOR	1
		PHC MFAMOSING	1
		PHC ENGHAUGHT	1
		DEPARTMENT OF PHC IN THE LGA	1
3	AKPABUYO	IKOTNAKANDA	1
4	BAKASSI	-	-

5	BEKWARA	MODEL PHC	2
		PHC UPA	1
		PHC EYAYA	1
		PHC GAKIM	1
6	BIASE	P HC AKPET 2	1
7	BOKI	MODEL PHC KASSAN EROWAN	2
		PHC BATRICO	1
		OKUNDE PHC	1
8	CALABAR MUNICIPALITY	PHC AKIM	2
		PHC IKOT ISHE	1
		PHC EDIBA	1
		PHC IKOT OMIN	1
		PHC DEPARTMENT	2
9	CALABAR SOUTH	PHC EKPO ABASI	1
10	ETUNG	-	-
11	IKOM	COMPREHENSIVE HEALTH CENTRE	7
		PHC EKONOKOR	1
		PHC NKARANSI	1
		PHC EBE VICTORIA	1
12	OBANLIKU	PHC UTANGA	
13	OBODU	MODEL HEALTH CENTRE	2
		UTUGWANG	
	OBUDU	PHC OHONG	1
		PHC OBUDU URBAN	2
14	ODUKPANI	PHC ODUKPANI JUNCTION	1
		PHC ITO	1
		PHC DEPARTMENT	1
15	OBUBRA	PHC OCHONG	1
		PHC OFATURA	1
		DEPARTMENT OF PHC	1
16	OGOJA	PHC EKUNTACK	2
17	YAKURR	PHC EKORI	1
		PHC NTAMKPO	2
		PHC UGEP	1
18	YALA	PHC OLACHOR, OKPOMA	1
		PHC WANIHEM	1
		PHC YACHE	1
		PHC OKUKU	1
		PHC OBA, OKPOMA	1
		PHC WANIKADE	1

DEPARTMENT OF PHC	2
TOTAL	70

The majority thirty-six (36) PHC Wanikade, PHC Oba, Okpoma, PHC Okuku, PHC Yache, PHC Wanihem, PHC Olachor, PHC Okpoma, PHC Ugep, PHC Ekor, Department of PHC Obubra, PHC Ofatura, PHC Ochion, PHC department Odukpani LGA, PHC Ito, PHC Odukpani Junction, PHC Ohong, PHC Ekonokor, PHC Nkaransi, PHC Ebe Victoria, PHC Ediba, PHC Ekpo Abasi, PHC Ikot Omin, PHC Ikot Ishie, Okunde PHC, PHC Batrico, PHC Upa, PHC Gakim, PHC Eyaya, PHC Ikot Nakanda, PHC Ediba, PHC Ekureku, PHC Anong, PHC Ojor, PHC Mfamosing, PHC Enghaught, Department of PHC in Akamkpa LGA all have only one midwife each.

Research question two: What are the types of services provided by midwives in PHC facilities in Cross River State?

Table 3 showed the descriptive statistics of type of services provided by the midwives in PHCs in ante-natal care, intra-partum care and postpartum care in Cross River State. From the result presented, Table 3a reveals that for ante natal care, more than 50% of the services like vital signs check, height/weight measurement, physical examination, pelvic assessment, health education, and counseling on prevention of mother- to- child transmission of HIV are sometimes provided. The result also shows that 44.3% of respondents' carry out administration of drugs, 48.6% abdominal examination, 50.0% booking/registration and 47.1% urine testing is also provided some of the time. During the intra-partum care, the result in table 3b revealed that 50-80% of midwives sometimes do the following services: catheterization, suturing, use of partograph, provision of emergency obstetric and immediate care of the newborn, while services such as referrals 63.4%, vaginal examination 54.3%, vital signs check 74.3% and history taking 51.3% of respondents is done most of the time. At the post-partum care, the result in table 3c reveals that a good number of more than 58% of the midwives give services like family planning, general/physical examination, counseling, post-natal exercise, care of the newborn, health education of client and family are sometimes provided while 61.4% of male circumcision service is not rendered at all. The implication of this result is that most of the services are delivered some of the time as a result of inadequate number of midwives present at the PHCs.

Table 3A

Description of Type of Services (n=70)				
Ante-natal services	Always	Most times	Sometimes	Not at all
Booking/registration	9 (12.9%)	26(37.1%)	35(50. 0%)	-
Vital signs check	14 (20.0%)	16 (22.9%)	40 (57.1%)	-
Height/ weight measurement	11 (15.7%)	20 (28.6%)	38 (54.3%)	1 (1.4%)
Physical examination	11 (15.7%)	14 (20.0%)	44 (62.9%)	1 (1.4%)
Abdominal examination	14 (20.0%)	19 (27.1%)	34 (48.6%)	3 (4.3%)
Pelvic assessment	9 (12.9%)	8 (11.4%)	51 (72.9%)	2 (2.9%)
Urine testing	14 (20.0%)	23 (32.9%)	33 (47.1%)	-
Health education	12 (17.1%)	16 (22.9%)	39 (55.7%)	3 (4.3%)

Counseling	10 (14.3%)	10 (14.3%)	44 (62.9%)	(8.6%)
Administration of drugs	16 (22.9%)	23 (32.9%)	31 (44.3%)	-

Table 3B

Intra-Partum care	Description of Type of Services (n=70)			
	Always	Most times	sometimes	Not at all
History taking	16 (22.6%)	36 (51.4%)	18 (25.7%)	-
Vital signs check	11 (15.7%)	52 (74.3%)	6 (8.6%)	1 (1.4%)
Vaginal examination	12 (17.1%)	38 (54.3%)	20 (28.6%)	-
Abdominal examination	15(21.42%)	13(18.58%)	42(60%)	-
Use of partograph	5 (7.1%)	21 (30.0%)	44 (62.9%)	-
Catheterization	6 (8.6%)	8 (11.4%)	54 (77.1%)	2 (2.9%)
Giving/suturing of episiotomy	6 (8.6%)	11 (15.7%)	52 (74.3%)	1(1.4%)
Provision of Emergency- Obstetric care	13 (18.6%)	11 (15.7%)	46 (65.7%)	-
Immediate care of the new born	18(25.71%)	19(27.14%)	33(47.15%)	-
Referrals	12 (17.1%)	43 (61.4%)	15 (21.4%)	-

Table 3C

Post-Partum care	Description of Type of Services (n=70)			
	Always	Most times	sometimes	Not at all
General/Physical examination	15 (21.4%)	9 (12.9%)	46 (65.7%)	-
Vulva care	18(25.71%)	19(27.14%)	33(47.15%)	-
Care of the new born	15 (21.4%)	9 (12.9%)	44 (62.9%)	2(2.9%)
Post-natal exercise	4 (5.7%)	13 (18.6%)	45 (64.3%)	8(11.4%)
Drugs administration	14 (20.0%)	23 (32.9%)	33 (47.1%)	-
Counseling	13 (18.6%)	8 (11.4%)	46 (65.7%)	3 (4.3%)
Immunization	12 (17.1%)	12 (17.1%)	32 (45.7%)	14(20.0%)
Male circumcision	-	2 (2.9%)	25 (35.7%)	43(61.4%)
Family planning	11 (15.7%)	7 (10.0%)	51 (72.9%)	1 (1.4%)

Health education of clients and family	9 (12.9%)	8 (11.4%)	51 (72.9%)	2 (2.9%)
Follow-up care	5 (7.1%)	21 (30.0%)	44 (62.9%)	-

Conclusion

The population of midwives at PHC level in Cross River State is grossly inadequate. This deprives the women of child bearing age of their right to be attended to by competent midwives as recommended by ICM and WHO. This implies that the women particularly in rural areas where PHCs are the only source of modern health care facilities, are exposed to the risk of morbidity and mortality.

Recommendations

1. The government should employ more midwives as a way to improve midwives' population at Primary Health care level in the State.
2. The government should focus on providing basic amenities in the community for quality maternity services at Primary Health care level in the State
3. Policy makers should formulate policies that will help promote midwifery workforce at the Primary Health care level in the State.
4. Midwives should embark on advocacy to the government and non-governmental bodies on the need to improve midwives' population which will lead to improved service delivery in PHC level in the State
5. The presence of midwives in State Primary Health Care Development Agency should be strengthened.
6. Nursing and midwifery council should review the policy to establish community midwifery in Cross River State where more midwives will be trained and automatically employed to PHC level in the State.

Implications of this Study to Midwifery Practice

The findings of this study imply that there is gross shortage of midwives' population in all primary health care facilities in Cross River State. Due to inadequate number of midwives in primary health care facilities the findings revealed that, task shifting, poor quality of care was practiced, where most of the services midwives were supposed to render were being provided by other health workers who do not have midwifery training and adequate skills. This shifting of significant midwifery task is perceived to contribute significantly to maternal morbidity and mortality in Cross River State. In this study, majority of participants are of the opinion that maternal mortality rate in Cross River State can never reduce without increasing midwives' population in all the PHC facilities.

Contribution to knowledge

- i. This study has been able to identify the state of inadequate midwifery workforce at PHC level in Cross River State.
- ii. It has also identified a gap in midwifery service provision at PHC level in Cross River State.
- iii. It has identified the Impact of reduce human resources on services
- iv. This work when published, will also add to already existing literature that scholars could use as reference in Maternal and Child health Nursing.

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NUTRITIONAL CONTENT OF FORMULATED COOKIES MADE FROM COMPOSITE FLOURS OF WHEAT AND ORANGE-FLESHED SWEET POTATOES

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Abstract

This study evaluated the nutrient compositions of cookies made with composite flour of four different plants namely orange-fleshed sweet potato (O) and oyster mushroom (M). The different composite formulations were wheat + orange fleshed sweet potato + avocado seed flours (W.O.A-50:40:10 %), wheat + mushroom + wheat+ orange-fleshed sweet potato + mushroom flours (W.O.M-40:30:30 %), and wheat flour only (W-100%) to serve as control. The proximate composition of the cookies indicated a significantly higher amount ($P<0.05$) of moisture in W.O.M than others and relative to W (control), but for carbohydrate, crude fiber and energy, W (control) had a higher value than the composites. Vitamin results indicated a significantly higher ($P<0.05$) amount of vitamin A in W.O.A, but for vitamin B1 and B2, W (control) had higher amounts relative to the composites, vitamin B3 was higher in W.M.A. In conclusion, results of this study showed that cookies made from this composite flour contain nutrients, vitamins, minerals, phytochemicals, which are beneficial and are in recommendable amounts compared to the W (control) cookies used as standard in these studies. Thus, this study indicates the possible use of the studied mixture of composite flours to reduce the amount and total dependability on W (control) in making cookies that will contribute to maintaining healthy living especially in the face of world scarcity.

Keywords: Cookies, Flours, Wheat, Orange-Fleshed, Sweet Potatoes

Introduction

Nutrition is “the science of food; the nutrients and the substances therein; their action, interaction and balance in relation to health and disease; and the process by which the organism (that is body) ingests, digests, absorbs, transports, utilizes and excretes food substances (The Council on Food and Nutrition of the American Medical Association, 2023). Nutritional evaluation is the systematic process of collecting and interpreting information in order to make decisions about the nature and cause of nutrition related health issues that affect an individual (British Dietetic Association, 2012).

Wheat grain (*Triticum aestivum* L.) is a grass widely cultivated for its seed and also as a cereal grain which is a wholegrain staple food. It is grown all over the world for its highly nutritious and useful grain, as one of the top three most produced crops along with corn and rice. It is used in the production of bread, biscuits, feeds, confectionary among many utilization (Zareef, et al, 2021; Shun, Shuliang, et al, 2022). Wheat is composed of proteins, starch, lipids, sugars and enzymes (Gray, 2023), cell wall polysaccharides (dietary fibre), and a range of minor components that may confer benefits to human health (Peter, et al, 2013). In addition, wheat flour contains B vitamins, calcium, folate, iron, magnesium, phosphorus, potassium, zinc and other trace elements (Oklahoma State University, 2010).

Sweet potatoes (*Ipomoea batatas* L.) on the other hand, is a dicotyledonous angiosperm plant which belongs to the Convolvulaceae family and it is capable of producing nutritious tuberous roots eaten worldwide (Claudio *et al.*, 2020). Sweet potatoes is an important economic crop in many countries. It fulfills a number of basic roles in the global food system, all of which have fundamental implications for meeting food requirements, reducing poverty and increasing food security (El-Sheikha & Ray, 2017). Depending on the flesh colour, sweet potatoes contain high levels of β -carotene, anthocyanin, phenolics, dietary fibre, vitamins, minerals and other bioactive compounds (Throng *et al.*, 2007). *Ipomoea batatas*, the common sweet potatoes is an important food staple in many tropical and temperate countries and ranks as the fifth most important crop in developing nations in terms of economic value and seventh for energy production (Leobenstein, 2009). Sweet potatoes originated in the tropical America and was

grown extensively throughout the continent well before the arrival of the Europeans. It was then introduced to the Europe, Africa and Asia and is now one of the major root crops in the developing world where over 90% of the population is found (StockBridge School of Agriculture, 2023). In the United States, the commercially popular type is the orange-fleshed sweet potatoes with low dry matter content, high β -carotene level, sweet and moist-texture after cooking (Throng *et al.*, 2007). Studies in Africa demonstrated that increased consumption of orange-fleshed sweet potatoes improved the vitamin A status of children, pregnant women, and lactating mothers (Steed & Truong, 2008; Jan, et al, 2009). Sweet potatoes can be enjoyed with or without the skin and can be baked, boiled, roasted, fried, steamed, or pan-cooked (Erica, 2023). Sweet potatoes, in recent studies have been evaluated for its nutritional and medicinal importance and results of these studies have demonstrated that it contains Vitamin A (in form of beta-carotene), Vitamin B6, Vitamin C, Potassium, Fibre, Zinc, Magnesium. They have a large level of carbohydrate, but they generally have a low glycemic index (Yvette, 2023).

Among all varieties of potatoes, Orange-fleshed sweet potato has a good source of different vitamins, specific minerals, antioxidants and phytochemical compounds (Endrias, et al, 2016). It is considered an excellent source of dietary carotenoids and polysaccharides, whose health benefits include antioxidant, anti-inflammatory and hepato-protective activity, cardiovascular protection, anticancer properties and improvement in neurological and memory capacity, metabolic disorders, and intestinal barrier function (Martinez-Sanz, et al, 2022). Orange-fleshed sweet potatoes (OFSP) is a good source of non-digestible dietary fibre, different vitamins, specific minerals and antioxidants (Endrais *et al.*, 2016).

More so, a cookie is a baked snack or desert that is typically small, flat and sweet. It usually contains flour, sugar, egg and some type of oil, fat or butter. It may include other ingredients such as raisins, oats, chocolate chips, or nuts (Wikipedia, 2024).



FIG. 1: Wheat grains and white flour (*Triticum aestivum L.*) by iStockphoto



FIG. 2: Orange fleshed sweet potatoe (*Ipomoea batatas L.*) by Shutterstock.(n.d.).

Statement of the problem

Wheat flour is used in the production of functional foods, especially baked products like cookies. However, wheat flour does not contain all the nutrients required for adequate health and also contains gluten which causes allergies in some persons hence the need for composite flours. More so, for

economic reasons and current scarcity of world wheat supply due to the ongoing war in Ukraine, there will be need to reduce total dependence on wheat for the production of baked products.

Objective of the study

The objective of this study is to evaluate the nutritional content of formulated cookies made from composite flours of Wheat and Orange-fleshed sweet potatoes. The following parameters were determined

1. Proximate (Moisture, Fibre and Ash, Protein, Lipid, Carbohydrate) contents.
2. Glycemic Index of the cookies.
3. Vitamin composition (Vitamin A, Vitamin B-complex which include B₁, B₂, B₃, Vitamin C, Vitamin D, Vitamin E and Vitamin K).

Literature Review

Nutritional evaluation of medicinal plants

Evaluating the nutritional composition of medicinal plants reveals their potential as both therapeutic agents and nutritional supplements. The natural extracts of plants or isolated active compounds exhibit many pharmacological properties and have lesser side effects as compared to the synthetic compounds. So, the drug discovery from plants is bringing new aids to world of modern medicine (Kavita & Prakash, 2022). Studies have shown that these plants contain essential phytochemicals, vitamins and minerals that contribute to health benefits. Many medicinal plants are rich in bioactive compounds like flavonoids and saponins, which have antioxidant and anti-inflammatory properties (Arti *et al.*, 2022). The nutritive value that they pack are highly recommended for their healing powers. Known to induce no side effects, they have a unique aroma and flavor and when consumed regularly, they act as a perfect mechanism to bring about a balanced harmony between mind and body (Kavita & Prakash, 2022).

Medicinal plants play a vital role in healthcare, especially in underdeveloped nations where they are readily available and cheaper than modern medicines (Wikipedia, 2024; Brekkie and Christianity, 2024). However, caution is needed as some plants can be toxic if not used properly (Brekkie and Christianity, 2024). The incorporation of medicinal plants into composite flours enhances their nutritional profile and functional properties. Studies indicate that blending traditional flours with herbal powders can significantly improve the nutritional quality of baked products.

Composite flour

Composite flour defined as a mixture of flours obtained from tubers which are rich in starch such as cassava, yam, potato, and protein-rich flour and cereals, with or without wheat flour that are made to satisfy specific functional characteristics and nutrient composition (Noorfarahzilah, *et al.*, 2014). For example, wheat with sweet potatoes (Awuni, *et al.*, 2018; Edun, *et al.*, 2019), wheat and cassava (Lagnika, *et al.*, 2019; Tien, *et al.*, 2019), wheat and many legumes (Shrivastava & Chakraborty, 2018; Tufan, *et al.*, 2019), or without wheat flour (Awolu, 2018; Nour, *et al.*, 2018) and other composites (Adeyeye 2018; Mezgebo, *et al.*, 2018). The use of composite flour to produce baked goods, if feasible, would help to lessen total dependence on imported wheat, being that composite flour as an innovative flour has attracted much attention in research as well as in food product development (Hasmadi, *et al.*, 2014; Suresh & Samsher 2013; Gbenga-Fabusiwa, *et al.*, 2018; Hasmadi, *et al.*, 2018; Hasmadi, *et al.*, 2018; Jafari, *et al.*, 2018; Nyembwe, *et al.*, 2018; Emmanuel, *et al.*, 2019).

Composite flour has better nutritional value in terms of minerals, vitamins, fibres and proteins than flour milled from any specific cereal alone. Shanti *et al.* (2005), reported that the composite flour mixture could provide a balanced nutrient. There has been increasing interest in replacing conventional gluten-free formulations made from refined gluten-free flour, starch, and hydrocolloids with those enriched with functional gluten-free ingredients (Traynham, *et al.*, 2007; AlvarezJubete *et al.*, 2010).

Composite flours are rich in proteins, fibres, vitamins, and minerals which can help combat life-style related diseases. They often include flours from sweet potatoes, cassava, maize, and legumes like soy

and peanuts. This variety not only improves nutritional profiles but also lowers production costs by utilizing locally available crops (Chandra *et al.*, 2015). These flours are versatile and can be used in making a wide range of products including bread, pasta and snacks. Composite flours can replace a significant portion of wheat flour while maintaining quality. They are suitable for various baked goods and snacks, providing unique flavours and textures (Noorfarhzila *et al.*, 2014; Nwanekezi, 2013). Composite flours containing soy or lupine flour can increase protein content by 57-62% compared to wheat flour alone (Abdel-Gawd, Rashwan, El-Naggar and Hassan, 2016). For example, a blend of 70% wheat and 30% soy or lupine flour increased protein from around 13% in wheat to 19-20%; amaranth and lupine flours are particularly good sources of protein, with amaranth increasing protein to 21-22% and lupine reaching 23-26% in wheat composites (Hofmanova, Marie and Ivan, 2014); hemp and teff flours also boost protein, though to a lower extent, with hemp reaching 15-17% and teff 135 protein in 80-90% wheat blends (Hofmanova, Marie, and Ivan, 2014). Composite flours are able to significantly enhance the protein content compared to wheat flour alone, with increases ranging from 15-30% depending on the specific ingredients used. Legumes like soy and lupine provide the greatest protein boost.

Composite flours are mixed solely for economic and nutritional reasons, and are often used in times of scarcity of wheat, from whatever cause, climatic or economic (Chandra, Singh and Kumari, 2015). The use of composite flour is a promising approach to enhance food security, improve nutritional intake and support local agriculture, particularly in developing regions (Noorfarahzilah *et al.*, 2014; Chandra *et al.*, 2015).

Constituents of Composite Flour in the Current Studies

Nutrients derived from orange-fleshed sweet potato (OFSP), oyster mushroom, and avocado seed are crucial for several reasons which include enhanced nutritional profile, functional properties, health benefits, food security and culinary versatility.

Orange-Fleshed Sweet Potato

Orange-fleshed sweet potato (OFSP) flour is derived from the tubers of the OFSP plant, known for its colour and high nutritional value, particularly in beta-carotene, which is a precursor to vitamin A. From the dietary point of view and nutritional perspective, OFSP ranked as number one among all vegetables (Satheesh and Solomon, 2019). Due to its many positive aspects related to agriculture, nutritional security and food security there has been intensified research on OFSP to augment its production and consumption in different countries (Satheesh and Solomon, 2019). Orange fleshed sweet potato flour is produced by grinding dried orange fleshed sweet potato into flour to sustain the promising source of pro-vitamin A from the cultivars. The demand for this product is increasing thus the need to ensure the safety and quality of orange fleshed sweet potato flour produced and/or marketed for local consumption and export market (Tanzania Bureau of Standards, 2023).

Orange-fleshed sweet potato flour is notably rich in vitamins A and C, fibre, and antioxidants, making it beneficial for improving overall health and addressing vitamin A deficiency (VAD), especially in vulnerable populations such as children and pregnant women (Owade, et al, 2018; Jenfa, et al, 2024). It has also been reported that OFSP is a rich source of carotenoids, β -carotene and polyphenols and is gaining importance as the least expensive source of antioxidants which provide several essential health benefits, one of which is the prevention of vitamin A deficiency (Alam *et al.*, 2016). The flour exhibits favourable functional properties, such as good water absorption and viscosity, which enhance its usability in various food products, including baked goods and snacks. It can improve the texture and nutritional profile of these products when blended with other flours, such as wheat or sorghum (Jenfa *et al.*, 2024; Korese, Chikpa, and Hensel, 2021). OFSP can be incorporated into a variety of foods, including bread, cookies, and other baked goods, often serving as a partial substitute for wheat flour. Studies indicate that using OFSP can enhance the sensory attributes and nutritional value of these products, making them more appealing to consume (Korese *et al.*, 2021; Malavi, Mbogo, Waura, Low, and Muzhingi, 2022). Utilizing OFSP flour can reduce reliance on imported wheat flour, promoting

local agriculture and providing economic benefits to farmers and communities involved in its production (Owade *et al.*, 2018).

Cookies made from a composite of whole wheat and OFSP flour are enriched with B-carotene, a precursor to vitamin A. Studies show that cookies with 40% OFSP puree contain approximately 1.83mg of B-carotene per 100g. The total retinol activity equivalent (RAE) for these cookies can reach around 216.67ug/100g, depending on the proportion of OFSP used. The nutritional benefits highlight the potential of OFSP in alleviating vitamin A deficiency through fortified baked goods (Wafula, Drick, Daniel, Mwaura, Mukani and Tawana, 2022; Temesgen, Abebe and Tigist, 2023; Satheesh and Solomon, 2019).

In Nigeria, the seed powder is used as a supplement for cardiovascular diseases and prevention with management of hypertension (Anaka *et al.*, 2009, Ozolua *et al.*, 2009; Imafidon and Amaechina, 2010). With increasing awareness on the potential of avocado seed as an antioxidant-rich and safe to consume part of the fruit, the use of the seed as nutraceutical is gaining increasing acceptance (Arajuo *et al.*, 2018). It finds application as herbal teas, or eaten as sliced, dried snack (Olaeta *et al.*, 2007; Ogunwusi and Ibrahim, 2016) or ground to powder and mixed with fermented corn meal, ogi (Anaka *et al.*, 2009). In order to improve utilization of avocado seed as food in the Nigerian diet, moi-moi was produced by adding the 10% of the seed flour to cowpea (Emelike, Ujong and Achinewhu, 2020).

Cookies made from a composite of whole wheat and oyster mushroom flour are likely to contain various B-complex vitamins, including thiamine (B₁), riboflavin (B₂), niacin (B₃), pantothenic acid (B₅), pyridoxine (B₆). Whole wheat flour retains a significant portion of these vitamins compared to refined flour, with whole wheat providing about 80% of thiamine and riboflavin and 95% of pyridoxine (Satheesh and Solomon, 2019). Whole wheat flour and oyster mushroom flour are good sources of several B vitamins, with oyster mushroom being particularly rich in B vitamins (Ayo *et al.*, 2018; Jillian kubala, 2021). The most abundant B vitamins in these composite cookies are likely niacin (B₃), pantothenic acid (B₅), riboflavin (B₂) and pyridoxine (B₆) (Ayo, Ojo, Omelagu and Kaaer, 2018; Jillian Kubala, 2021), and the exact amounts will depend on the ratio of the flours used.

Wheat Flour

Wheat flour is an excellent source of complex carbohydrates. All types of wheat flour, except high gluten flour get at least 80% of their calories from carbohydrates. Depending on the flour type, the percent of calories from protein ranges from 91.5%, except from gluten, which has a 45% protein content. Calories from fat are usually never more than 5%. In addition, wheat flour provides from 3g (cake flour) to 15g (whole wheat flour) of dietary fiber per 100g or ~1 cup serving. Wheat flour contains B vitamins, calcium, folate, iron, magnesium, phosphorus, potassium, zinc and other trace elements (Oklahoma State University, 2024).

Materials and Methods

Equipment

Refrigerator (Haier THERMOCOOL), Gas Oven, Digital Kitchen Scale, Electric Blender, UV-Visible Spectrophotometer (SEARCH TECH), Muffle Furnace (GELLEN KAMP), Analytical Weight Balance, Water bath (GELLEN KAMP), Centrifuge (JENWAY), Soxhlex Apparatus (YORW), Electronic Oven (CARBOLITE), Hotplate (JENWAY), Kjeldahl Distillation Apparatus (KJELDAHL), Water Distiller (JENWAY), Homogenizer (ULTRA TURRAX), Calorimeter, Volumetric flask, Measuring Flask, Conical Flask, Filter papers (WHATMAN), Fluorimeter, Separating funnel, Colorimeter, Incinerator, Glass Mortar, Buchner funnel, Beaker, Pipette, Wash bottle, Desicator, Colorimeter, Photometer.

Chemicals and Reagents

EDTA/TCA solution, Rutin, Phenanthroline solution, Petroleum ether, Eriochrome Black-T-Indicator (EBT), Acetone, Gallic acid, Potassium ferrocyanide, Chloroform, Potassium hydroxide, Anti-foaming agent, Sulphoric acid, Sodium hydroxide, Hydrochloric acid, Anhydrous Sodium Sulphate (Kjeldahl catalyst), Hydrochloric acid, Celite, Acetone, Folin-ciocalteus reagent, Petroleum spirit, concentrated Ammonium hydroxide, Glacial acetic acid.

Collection of Plant Materials

Fresh tubers of Orange –fleshed sweet potatoes were purchased directly from Asa-Uwe Okorowo Ekeye farm in Port Harcourt, South Nigeria. Oyster Mushrooms were bought from an Organic farm in Akpabuyo L.G.A of Cross River State. Whole Wheat grains were purchased from organic grains shop at Watt market in Calabar South LGA, Cross River State. These collected plants were authenticated at the Department of Botany, University of Calabar, Nigeria and then taken to the Human Nutrition and Dietetics Department for preparation.

Preparation of Plant Materials

The orange-fleshed sweet potatoes were thoroughly washed, peeled, grated into small pieces and air dried at room temperature. After which they were pulverized with an electrical blender, sifted finely and stored in an airtight container for later use. The mushrooms were trimmed, cleaned carefully and thoroughly, air dried at room temperature. After which the mushrooms were pulverized using an electrical blender, sifted into fine powder and stored in an air tight container for later use as well.

The whole wheat grain was milled into flour using electrical blender, sifted into smooth powder and finally kept in an air tight container for later use. Other ingredients for baking cookies were bought from confectionary stores in Watt market, in Calabar South LGA, Cross River State. These ingredients included: Olive oil, Evaporated Milk, Fresh eggs, Table salt, baking powder, Dates (*Phoenix dactifera*) in place of sugar were dried, milled and sifted to powdered form and all kept ready for use.

Methods

Preparation of Cookies

The processed flours with the other ingredients were used to prepare cookies in different percentage combinations of:

- (A) 100% Wheat flour to serve as control.
- (B) 50% Wheat flour + 40% Orange-fleshed sweet potatoes flour + 10% Avocado seed flour.
- (C) 50% Wheat flour + 40% Mushroom flour + 10% Avocado seed flour.
- (D) 40% Wheat flour + 30% Orange-fleshed sweet potato flour + 30% Mushroom flour

Each of the four different combinations were used to prepare the cookies with the other ingredients using a recipe described by (Taylor, 2023). After baking, sensory evaluation was conducted on the cookies by humans and the cookies were further evaluated for the Proximate, Glycemic Index, Vitamins, Minerals, Phytochemicals compositions and Sensory attributes of each formulations. The experimental design is shown in Table 1.

Table 1
Experimental design and formulation of cookies

S/NO	Formulated Products	Formulated Products
1	Wheat flour only (100%) to serve as control.	Wheat flour only (100%) to serve as control.
2	Wheat flour + OFSP flour + Avocado seed flour in the ratio of 50: 40: 10	Wheat flour + OFSP flour + Avocado seed flour in the ratio of 50: 40: 10
3	Wheat flour + Mushroom flour + Avocado seed flour in the ratio of 50: 40: 10	Wheat flour + Mushroom flour + Avocado seed flour in the ratio of 50: 40: 10
4	Wheat flour + Orange fleshed sweet potato flour + Mushroom flour in the ratio of 40: 30: 30	Wheat flour + Orange fleshed sweet potato flour + Mushroom flour in the ratio of 40: 30: 30
5	Orange-fleshed sweet potato flours + Mushroom flour + Avocado seed flours in the ratio 40 : 40: 20	Orange-fleshed sweet potato flours + Mushroom flour + Avocado seed flours in the ratio 40 : 40: 20

On completion of the finished products (cookies), the following evaluation were carried out on the cookies

1. Proximate composition (Carbohydrate, Protein, Lipid, Moisture, crude Fibre, crude Ash).
2. Glycemic index levels
3. Vitamin composition of vitamins (A, B₁, B₂, B₃, C, D, E and K).
4. Sensory attributes (aroma, colour, taste, texture, and overall acceptability)

Determination of Moisture Content of the Samples

Moisture content was determined according to the standard method of Association of Official Analytical Chemists (AOAC, 2010), using Gravimetric method.

Oven dishes were cleaned and dried in the oven at 100°C for 1 hour to achieve a constant weight. They were cooled in a desiccator and then weighed. Two grams of sample was placed in each dish, weighed and dried in the oven at 105°C until constant weight was achieved. The dishes together with the samples were cooled in a desiccator and weighed.

Calculation:

$$\% \text{ Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where,

W₁ = weight of dish

W₂ = weight of dish + sample before drying

W₃ = weight of dish + sample after drying

Determination of Crude Fibre Content of the Samples

Crude fibre was determined, using Weende method of sequential acids extractions according to (AOAC, 2010). Three (3) grams of the sample was weighed into a 50ml beaker and fat was extracted with petroleum ether by stirring, settling and decanting three times. The defatted sample was air dried and transferred to a 600ml dried beaker. Then 200ml of 1.25% sulphuric acid and few drops of anti-foaming agent were added to the beaker. The beaker was placed on digestion apparatus with pre-adjusted hot plate and boiled for 30 minutes, rotating beaker periodically to keep solid from adhering on the sides of the beaker. At the end of 30 minutes, the mixture was allowed to stand for one minute and then filtered through a Buchner funnel. Without breaking suction, the insoluble matter was washed with boiling water until it was free of the acid. The residue was washed back into the original flask by means of a wash bottle containing 200ml of 1.25% sodium hydroxide solution. It was again boiled briskly for 30 minutes with similar precautions as before. After boiling for 30 minutes, it was allowed to stand for one minute and then filtered immediately under suction. The residue was washed with boiling water, followed by 1% hydrochloric acid and finally with boiling water until it was free of acid. It was washed twice with alcohol and then with ether for three times. The residue was transferred into ash dish and dried at 100°C to a constant weight. Incineration to ash was done at 600°C for 30 minutes, cooled in a desiccator and weighed. The difference in weight between oven dry weight and the weight after incineration was taken as the fibre content of the sample. This was expressed as a percentage weight of the original sample taken for analysis.

% Crude fibre =

$$\frac{\text{Weight of oven dried sample} - \text{weight of sample after incineration}}{\text{Weight of sample taken}} \times 100$$

Determination of Ash Content of the Samples

Ash determination was carried out according to AOAC (2010) procedure. Two grams of sample was placed in silica dish which had been ignited, cooled and weighed. The dish and sample were ignited first

gently and then at 550°C in a muffle furnace for 3 hours, until a white or grey ash was obtained. The dish and content were cooled in a desiccator and weighed.

$$\% \text{ Ash} = \frac{W3 - W1}{W2 - W1} \times \frac{100}{1}$$

Where,

W1 = weight of dish

W2 = weight of dish + sample before ashing

W3 = weight of dish + sample after ashing

Determination of Fat Content of the Samples

The fat content was determined using solvent extraction with Soxhlet extraction method according to AOAC (2010). A 500ml capacity round bottom flask was filled with 300ml petroleum ether and fixed to the soxhlet extractor. Two grams of sample was placed in a labelled thimble. The extractor thimble was sealed with cotton wool. Heat was applied to reflux the Soxhlet apparatus for six hours. The thimble was removed with care and the petroleum ether was recovered for reuse. When the flask was free of petroleum ether it was removed and dried at 105°C for 1 hour in an oven. The flask was removed from the oven, cooled in a desiccator and weighed. The weight of fat extract was expressed as a percentage of the weight of the analyzed sample and is given by the expression below:

$$\% \text{ Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times \frac{100}{1}$$

Determination of Carbohydrate Content of the Samples

The Carbohydrate was determined by difference according to AOAC (2010), by subtracting the sum (g/100g dry matter) of crude protein, crude fat, ash and fibre from 100g. The caloric value was determined based on Atwater factor as follows:

$$\% \text{ Carbohydrates} = 100 - (\% \text{ moisture} + \% \text{ fat} + \% \text{ ash} + \% \text{ protein} + \% \text{ crude fibre})$$

Determination of Energy Value of the Samples

The values obtained for protein, fat and carbohydrate were used to calculate the energy value of the samples using the Atwater formula as described by Onyeka (2013) and the value is expressed as kilocalories (kcal):

$$\text{Protein content (\%)} = P$$

$$\text{Fat content (\%)} = F$$

$$\text{Carbohydrate content (\%)} = C$$

$$\text{Energy value (Kcal/100g)} = P \times 4.0 + F \times 9.0 + C \times 4.0$$

Determination of Riboflavin (Vitamin B₂) Content

Riboflavin was determined according to AOAC (2010) fluorimetric methods. Two grams of sample was placed in a conical flask and 50ml of 0.2N HCl was added to the sample, boiled for 1 hour, and then cooled. The pH was adjusted to 6.0 using sodium hydroxide; 1N HCl was added to the sample solution to lower the pH to 4.5. The solution was filtered into 100ml measuring flask and made to volume with water.

In order to remove interference, two tubes were taken, labeled 1 and 2. Ten milliliters of filtrate and 1ml of riboflavin standard were added to test tube 2. About 1ml of glacial acetic acid was added to each tube and mixed, and then 0.5ml of 3% KMnO₄ solution was added to each tube. They were allowed to stand for 2 minutes, after which 0.5ml of 3% H₂SO₄ was added and mixed well. The fluorimeter was adjusted to excitation wavelength of 470nm and emission wavelength of 525nm. The fluorimeter was adjusted to zero deflection against 0.1N H₂SO₄ and 100 against tube 2 (standard). The fluorescence of tube 1 was read. Two milliliters of sodium hydrogen sulphate was added to both tubes and the fluorescence measured within 10 seconds. This was recorded as blank reading.

Calculation:

$$\text{Riboflavin mg/g} = \frac{X}{100} \times \frac{1}{1}$$

$$Y - X \quad W$$

Where

W = weight of sample

X = reading of sample – blank reading

Y = reading of sample + standard tube (2) – reading of sample + standard blank

Determination of Niacin (Vitamin B₃) Content

The spectrophotometric method described by Okwudili and Ndu (2005) was employed. A measured weight sample of 5g was mixed with 30ml of normal H₂SO₄ solution and shaken for 30min. It was filtered to obtain the extract. The extract was made alkaline by adding 3 drops of concentrated NH₄OH and aliquot of the extract (10ml) was treated with 5ml of normal potassium ferrocyanide solution followed by 5ml of 0.02N H₂SO₄ solution. It was allowed to stand for 5min at room temperature before absorbance was read at 470nm wavelength. Meanwhile, standard Niacin solution was prepared and 1ml of the solution was treated with the cyanide solution, the absorbance of the sample and that of standard were measured in a spectrophotometer at a wavelength of 470nm.

A reagent blank was used to set the instrument at zero. The formula below was used to calculate the niacin content.

$$\text{Niacin (mg/100g)} = \frac{100}{W} \times \frac{A_u}{A_s} \times C \times \frac{V_f}{V_a}$$

W = weight of the sample analyzed

A_u = Absorbance of sample

A_s = Absorbance of standard

C = Concentration (mg/ml) of standard niacin solution

V_f = total volume of filtrate (extract)

V_a = volume of extract analyzed

General Acceptability

Statistical Analysis

GraphPad prism software version 8 (GraphPad software, Inc., La Jolla, CA, USA) was used for statistical analysis. The raw data obtained were analyzed using one-way ANOVA, followed by post-hoc (Least square difference) comparison of the groups. Differences at P < 0.05 was used to consider statistically significant and values expressed as mean ± standard deviation.

Results of Proximate (Moisture, Carbohydrate, Crude Protein and Crude Fiber) Composition of Cookies Made from Composite Flours

Table 2, shows the proximate composition result of cookies made from the different flour. From the result all the cookies made from composite flours had high moisture content compared to the WF only cookies, W.O.M followed by W.M.A cookies indicated the highest amount of moisture content than O.M.A while the lowest moisture content was recorded in W.O.A cookies. But carbohydrate content recorded is higher in wheat flour cookies that served as control no significant ($P < 0.05$) difference were recorded between W.O.A and W.M.A cookies, but they indicated a higher carbohydrate content compared to W.O.M and O.M.A with the lowest carbohydrate content. The result further indicated that crude protein content is higher in W.O.A cookies compared to WF cookies with higher crude protein content compared to W.M.A, W.O.M and O.M.A respectively.

Also, crude fiber result showed that WF cookies have high amount of crude fiber followed by W.O.A and O.M.A cookies while significantly lower amount of crude fiber was obtained in W.M.A and W.O.M cookies respectively

TABLE 2: Results of proximate (moisture, carbohydrate, crude protein and crude fiber) components of cookies made from composite flours

Cookies	Moisture (%)	Carbohydrate (%)	Crude protein (%)	Crude Fibre (%)
WF	16.78±0.04 ^a	70.24±0.10 ^c	1.55±0.01 ^d	1.28±0.02 ^d
W.O.A	19.41±0.01 ^b	69.86±0.08 ^d	1.61±0.01 ^e	1.19±0.01 ^c
W.M.A	21.66±0.08 ^d	69.55±0.07 ^c	1.49±0.01 ^c	0.95±0.01 ^a
W.O.M	23.46±0.01 ^e	67.58±0.06 ^b	1.38±0.02 ^a	0.90±0.01 ^a
O.M.A	20.66±0.06 ^c	65.81±0.06 ^a	1.45±0.00 ^b	1.16±0.01 ^c

Values are reported as mean ± standard deviation. Values with different superscript letters in the same column indicate significant difference ($p < 0.05$) among means. W.M.A = Wheat flour+ Mushroom flour + Avocado seed flour, O.M.A = Orange flesh potato flour + Mushroom flour + Avocado seed, W.O.A =Wheat flour + Orange flesh potato flour + avocado seed flour, W.O.M= Wheat flour + Orange flesh potato flour + Mushroom flour, WF = Wheat flour

a=significantly ($P < 0.05$) different compared to WF

b=significantly ($P < 0.05$) different compared to W.O.A

c=significantly ($P < 0.05$) different compared to W.M.A

d=significantly ($P < 0.05$) different compared to W.O.M

e=significantly ($P < 0.05$) different compared to O.M.A

Results of Proximate (Ash, Fat, Energy) Composition of Cookies made from Composite Flours

Table 3, shows proximate composition results of cookies made from the different flour. From the result W.O.A cookies contain the highest ash content compared to the WF cookies, which is followed by W.M.A and O.M.A cookies respectively, while W.O.M indicated the lowest amount of ash content. O.M.A cookies contain a higher amount of fat content followed by WF and W.O.A cookies respectively, while W.M.A indicated the lowest amount of fat content. A similar result was obtained in energy result in all the cookies which showed that WF cookies contain the highest amount of energy followed by O.M.A cookies and W.O.A cookies while W.M.A and W.O.M contain the lowest amount of energy obtained.

TABLE 3: Results of proximate (ash, fat, energy) components of cookies made from composite flours

Cookies	Ash (%)	Fat (%)	Energy (Kcal)-
WF	1.55±0.01 ^d	8.61±0.01 ^d	364.65±0.21 ^e
W.O.A	1.61±0.01 ^e	6.32±0.03 ^c	342.76±0.03 ^c
W.M.A	1.49±0.01 ^c	4.87±0.04 ^a	327.97±0.64 ^b
W.O.M	1.38±0.02 ^a	5.32±0.00 ^b	323.70±0.14 ^a
O.M.A	1.45±0.00 ^b	9.48±0.00 ^e	354.34±0.25 ^d

Values are reported as mean ± standard deviation. Values with different superscript letters in the same column indicate significant difference ($p < 0.05$) among means. W.M.A = Wheat flour+ Mushroom flour + Avocado seed flour, O.M.A = Orange flesh potato flour + Mushroom flour + Avocado seed, W.O.A =Wheat flour + Orange flesh potato flour + avocado seed flour, W.O.M= Wheat flour + Orange flesh potato flour + Mushroom flour, WF = Wheat flour

a=significantly ($P < 0.05$) different compared to WF

b=significantly ($P < 0.05$) different compared to W.O.A

c=significantly ($P < 0.05$) different compared to W.M.A

d=significantly ($P < 0.05$) different compared to W.O.M

e=significantly ($P < 0.05$) different compared to O.M.A

Results of Vitamin Constituents of Cookies made from Composite Flours

The result obtained for vitamin constituent of cookies made from composite flour, indicated the presence of vitamin A, B₁, B₂ and B₃. The result further showed that W.O.A showed the highest amount of vitamin A compared to the WF which served as the control followed by O.M.A and W.O.M, then the W.M.A which indicated the lowest amount of vitamin A. Vitamin B₁ and B₂ were higher in WF compared to W.O.A and O.M.A with no significant difference between them, but showed a higher amount of vitamin B₁ compared to W.M.A. vitamin B₁. Vitamin B₃ result indicated a higher amount in W.M.A flour compared to the WF. No significant difference was recorded in the W.O.M and W.O.A but increased compared to O.M.A flour with the lowest amount of vitamin B₃ as shown in table

TABLE 4: Results of vitamin (A, B₁, B₂ and B₃) constituents of cookies made from composite flours

Samples	Vitamin A (µg/100g)	Vitamin B1 (mg/100g)	Vitamin B2 (mg/100g)	Vitamin B3 (mg/100g)
WF	2.95±0.01 ^c	0.047±0.00 ^d	0.032±0.01 ^d	0.083±0.00 ^d

W.O.A	3.47±0.01 ^d	0.042±0.00 ^c	0.028±0.00 ^{cd}	0.078±0.00 ^c
W.M.A	2.67±0.02 ^a	0.039±0.00 ^{ab}	0.030±0.00 ^d	0.084±0.00 ^e
W.O.M	2.71±0.01 ^a	0.040±0.00 ^{bc}	0.024±0.00 ^b	0.076±0.00 ^b
O.M.A	2.87±0.04 ^b	0.041±0.00 ^a	0.019±0.01 ^a	0.069±0.00 ^a

Values are reported as mean ± standard deviation. Values with different superscript letters in the same column indicate significant difference ($p < 0.05$) among means. W.M.A = Wheat flour+ Mushroom flour + Avocado seed flour, O.M.A = Orange flesh potato flour + Mushroom flour + Avocado seed, W.O.A =Wheat flour + Orange flesh potato flour + avocado seed flour, W.O.M= Wheat flour + Orange flesh potato flour + Mushroom flour, WF = Wheat flour

a=significantly ($P < 0.05$) different compared to WF

b=significantly ($P < 0.05$) different compared to W.O.A

c=significantly ($P < 0.05$) different compared to W.M.A

d=significantly ($P < 0.05$) different compared to W.O.M

e=significantly ($P < 0.05$) different compared to O.M.A

Discussion

Cookies made from Whole wheat, Orange-fleshed sweet potato, Oyster mushroom, and Avocado pear seed- composite flours were studied. The nutritional composition of the five different formulated cookies was compared with one another relative to the wheat flour which served as control. The results of these studies agree with the observation that cookies can be made from composite flour (produced from locally grown crops) (Jisha *et al*, 2008), hence can serve as a vehicle for the delivery of imported nutrients if made readily available to the populace. This present work aims at improving the nutritional and sensory attributes of wheat flour through fortification with Orange-fleshed sweet potatoes, oyster Mushroom and, Avocado pear seed flours through baking with other ingredients to improve the nutrients, energy and probably reduce the glycemic index content. It also aims at reducing the wheat content in the production of baked food in view of recent wheat scarcity.

The moisture content was observed highest in the WOM-composite flour cookies and lowest in the WOA-composite flour cookies compared to the WF (control) cookies. These moisture contents of the composite flour cookies recorded higher value than the values previously reported by (Bane, 2024). However, the moisture content of the composite cookies was much higher than the reports of Igbabul, et al, (2018), Ogbonna, et al, (2019), who reported much lower moisture contents in composite flour cookies. It should be noted however, that the composites of other literatures cited are not the same with the composites used in this present study. Moisture contents of cookies made with composite flours varies significantly based on the flour blends used. Studies indicate that moisture levels typically range from 3.63% to 10.00%. Cookies made from blends of wheat, Bambara nut and sweet potato flours showed moisture content between 7.58% and 10,00% Mojisola, et al, (2019); 4.3%-5.23% (Udeh, et al, 2023); 0.69%-7.64% (Ogori, Above and Okponya, (2022). In another study, cookies with unripe plantain and groundnut flour had moisture levels from 3.63% to 7.64% (Ogori *et al.*, 2022). These variations can affect the shelf life of cookies. Moreover, these blends indicate that cookies made with a significant amount of wheat flour of certain combinations of composite flours can retain higher moisture levels than those made with lower wheat content (Mojisola *et al.*, 2019). The moisture content is crucial for shelf life and texture, with lower levels generally enhancing storage stability and reducing spoilage risks.

The carbohydrate content of the composite flour cookies was observed to be lower than the WF (control) cookies and is in agreement with Omah, (2012) who reported lower carbohydrate level of composite blends cookies which ranged from 63.09% to 70.03% (65.181% to 79.24% in this study) when compared with WF (control), though higher than values reported by Ogbonna *et al.*, 2019 and Igbabul *et al.*, 2018.

This could be attributed to the known fact that whole wheat flour is a good source of carbohydrate. Carbohydrates are the sugars and fibres found in fruit grains, vegetables and milk products, they are macro-nutrients, needed in large amount in the body for energy (Szalay and Dutfield, 2022). The high carbohydrate in wheat flour cookies suggest that wheat flours is are very good source of energy for the body.

Crude fibre content of WF (control) cookies was observed to be higher than the composite flour cookies. This high level of crude fibre aligns with the reports of Shaikh, Marri, Khaskheli, Gul, Saghir and Solangi, 2017 and Kolawole *et al.*, 2018, who also reported high levels of crude fibre in OM-composite. However, the highest value of crude fibre among the composites was observed in the WOA-composite flour cookies and lowest in the WOM-composite flour cookies, as compared to the W (control) cookies. The low level of fibre in the composite cookies may be attributed to flour processing. During flour processing and production, the outer layers of the raw materials were peeled off, sliced, dried and pulverized into fine powder thereby reducing the fibre contents. According to Saeed, Humaina, Saima, Sharon and Abdus (2012) addition of sweet potato flour can increase the dietary fibre and mineral contents of the product. Crude Fibre is one of the non-digestible carbohydrates, which provide the fecal bulkiness, plays a role in cholesterol level reduction, and trapping dangerous substances like cancer-causing agents and also encourages the growth of natural microbial flora in the gut (Dhingra, Michael, Rajput and Pital, 2012, Satija and Hu, 2012; Slavin, 2013, Sanchez-Zapata, Viuda-Martos, Fernandez-Lope and Perez-Alvarez, 2015). It can be concluded from this present research that different plant materials contain varying amounts of crude fiber, as the values of crude fiber in the different composite-flour cookies varied significantly from one another.

The fat content in this present study is higher in the OMA composite flour cookies as compared to the W (control) cookies. This result is in agreement with the reports of Ocheme *et al.* (2018) on wheat and groundnut protein concentrate flour blends, which reported a higher fat level; but disagrees with Okechukwu *et al.* (2011), who reported lower levels of fat content. Fat content of the cookies was also within the standard value for soft dough biscuits and are in agreement with various composite flour cookies formulated by other researchers (Omah, 2012; Okpala, and Okoli, 2011). The increased fat content as observed in OMA composite flour cookies can be attributed to the increased quantity of avocado pear seed at 20% as avocado seeds are rich source of lipid, (Sneh *et al.*, 2022). Fats are good sources of energy, they provide more than twice as much energy as the carbohydrate on a weight-weight basis (Okaka, 2009; Chen, 2003). Fats also support cell growth, protect body organs, aid in some nutrient absorption, production of important hormones and help keep the body warm (America Heart Association, 2014).

Energy content of the composite flour cookies was lower as compared to the WF (control) cookies and agrees with the report of Olaoye *et al.*, 2019, which reported very similar energy level. But did not align with the report of Amwoma *et al.*, 2023 who reported a higher level of energy and Omah, (2012) who reported the range of 419,64Kcal – 428.73Kcal. However, the energy contents varied significantly in each of the composite flour cookies. Therefore, consumption of 100g of OMA-cookies only will not provide adequate energy per day on the recommended dietary allowance for children and adult. High energy cookies are highly desirable in famine and conflict locations where the next meal is not easy to come by. High energy foods, have protective effect in the optimal utilization of other nutrients (Wardlaw, 2004).

Vitamins are organic compounds that people need in small quantities. Each plays a different role in maintaining health and bodily function. Most vitamins need to come from food because the body either does not produce at all or produce very little (Yvette, 2023). Vitamins are organic substances that are generally classified as either fat soluble or water soluble. Fat soluble vitamins (vitamin A, Vitamin D, Vitamin E, and Vitamin K) dissolve in fat and tend to accumulate in the body. Water soluble vitamins (Vitamin C and the B-complex vitamins, such as vitamins B₆, Vitamin B₁₂, and folate) must dissolve in

water before they can be absorbed by the body. And therefore, cannot be stored. Any water-soluble vitamins unused by the body is primarily lost through urine (Harvard University, 2024).

Along with vitamin A, vitamin B is essential for maintaining a healthy liver; converting tryptophan, an amino acid into vitamin B3 (niacin) to prevent pellagra; keeping the eyes, nerves, muscles and skin healthy; absorption and activation of iron, folic acid, and vitamins B1, B3 and B6; hormone production by the adrenal glands, preventing the development of cataracts, aids fetal development, especially in areas where vitamin deficiency is common (Yvette, 2023). Cumulatively, in this study, vitamin contents were generally observed to be less in WF cookies as compared to the composite flour cookies.

The WOA composite flour cookies showed a higher vitamin A level than the WF (control) and relative to the other composite flour cookies. This result aligns with the higher vitamin A level reported by Oluwakemi, Eunseit, Obadina, Sobukola, Omemu, Adegunwa, Kagihausa, Adebowale, Lateef and Tomlins, (2016); Bangar, Dunno, Dhull, Kumar, Changan, Maqsood and Rusu, (2022) in their composites, but way lower than the report of Komal *et al.*, (2023). This highest vitamin A content in WOA-composite cookies may be attributed to the increased quantity of orange-fleshed sweet potato (OFSP) and whole wheat flours in the WOA-blend. This observation is backed up by reports from other researchers who reported that wheat and OFSP are rich in vitamin A, Oluwakemi *et al.*, (2016); Bangar *et al.* (2022)

Vitamin A, also known chemically as retinol, retinal, and “the four carotenoids” including beta carotene. Vitamin A is fat-soluble and is essential for eye health. Deficiency of vitamin A may cause night blindness and keratomalacia, which causes the clear front layer of the eye to grow old and cloudy. Good source of vitamin A include some vegetables sweet potatoes (Yvette, 2023) Vitamin A is essential for growth and development, immune function, and reproduction. This vitamin may also reduce the risk of some cancers and support hair and skin health. It also helps the heart, lungs, kidneys, and other organs function correctly (Megan, 2023).

It may be suggested that the consumption of WOA-based composite flour cookies would promote vision since they are rich in vitamin A.

Vitamin B1 (Thiamine) in the WF (control) cookies was higher compared to the composite flour cookies which aligns with the report of Oluwakemi *et al.* (2016) and Oklahoma State University (2010). However, among the composite cookies, Vitamin B1 level was observed highest in WOA-blend and lowest in WMA-blend as compared to the WF(control) cookies which had an abundance of vitamin B1.

Vitamin B1 (Thiamine) is essential for glucose metabolism and nerve, muscle, and heart function (Yvette, 2023). People may need supplements if their diet does not provide enough B vitamins, during hemodialysis, and for other health reasons (Yvette, 2023). Also vitamin B1 is a water- soluble vitamin, as well are all vitamin of the B-complex. It enables the body to use carbohydrates as energy (Yvette, 2023). A vitamin B1 deficiency may cause weight loss, confusion, short term memory loss, an enlarged heart, muscle weakness (Yvette, 2023). Vitamin B1 deficiency can cause beriberi. The heart, liver kidney, and brain all contain high amounts of thiamine. The body needs thiamine for breaking down sugar (carbohydrate) molecules from ATP which cells use for energy, creating certain neurotransmitters (Brain Chemicals); producing fatty acids and synthesizing certain hormones.

Vitamin B2 (Riboflavin) content was observed at its highest level in WMA-composite cookies, against the WF (control) composite cookies which has an appreciable level of vitamin B2 as well. This present study showed a significant lower level of vitamins B1 and B2, in the WF (control) cookies (Oklahoma State University, 2010), but WMA composite cookies showed highest level of B3 which aligns with the report of Oluwakemi *et al.* (2016). This could be as a result of the addition of mushrooms which further boosts riboflavin levels (Ayo *et al.*, 2018).

Vitamin B2 is an essential B vitamin for human health. Health benefits of vitamin B2 include supporting cellular functions that provide the body with energy, allowing it to work efficiently. (Yvette, 2023). Vitamin B2 (riboflavin) deficiency may manifest as skin disorders sores at the mouth, swelling of the mouth and throat swelling, cracked lips, hair loss, red itchy eyes (Berry, 2024) severe vitamin B2 deficiency can lead to anemia and cataracts. Being riboflavin deficient during pregnancy can cause a higher risk of certain birth defects (Berry, 2024).

Vitamin B3 (Niacin) had its highest value in WMA-composite flour cookies, while the lowest level was observed in OMA-composite flour cookies as compared to the WF (control) cookies. This result agrees with the report of Oluwakemi *et al.*, (2016) which reported higher B3 level. This could be because the addition of mushrooms further boosts riboflavin levels (Ayo *et al.*, 2018). Vitamin B3 are chemically known as niacin or niacinamide. It is water-soluble and the body needs niacin for the cells to grow and work correctly (Yvette, 2023). Low levels of vitamin B3 results in pellagra, which causes diarrhea, skin, changes, and intestine upset. Vitamin B3 (Niacin) deficiency leads to pellagra which may cause brown discoloration on skin exposed to sunlight, patches, of skin with a rough appearance, a bright red tongue, vomiting, diarrhea, or constipation, headache, fatigue, depression. If pellagra goes untreated, it can lead to serve memory problems, behavior. It may also lead to an extreme loss of appetite or death (Berry, 2024).

The vitamin C level was higher in the WMA-composite cookies as compared to the WF (control) cookies. Vitamin C level was observed highest in the WMA-composite flour cookies, followed by WOA-composite cookies and lowest in OMA-composite flour cookies. This did not agree with the lower levels reported by Obioma *et al.* 2021; Bangar *et al.*, (2022), and Mayo Clinic, 2023. However, the value was higher than the report of Oluwakemi *et al.* (2016); Komal *et al.*, (2023). Vitamin C, has a chemical name ascorbic acid. Vitamin c is water soluble and plays a role in collagen production, wound-healing, and bone formation and bone fracture healing. It also strengthens blood vessels, supports the immune system, helps the body absorb iron and acts as an antioxidant. (Yvette, 2023).

Contribution to knowledge

This study has contributed the following information:

- i. That nutritionally rich cookies can be produced from OFSP, Mushroom and Avocado seed-composite flour.
- ii. Its low-medium glycemic index, high fibre, high protein and phytochemical content, is suggestive of a dietary role in the management of non-communicable diseases like diabetes.
- iii. That nutritional security can be achieved with these composite formulations with its abundant macro and micro nutrients in the face of wheat scarcity as is being currently experienced.

These composite flours are on balance and superior to whole wheat; hence can be used in lieu of wheat in scarcity or non-availability of wheat flour especially now that Ukraine, a major world producer is at war with the attendant wheat scarcity.

Recommendations

1. More investigation should be carried out to evaluate the other nutritional components not captured in this present study.
2. Fortification of the plants and supplementation of composite flour with more essential nutrients (vitamins and minerals), to meet up with the daily recommended dietary intakes of the consumers.
3. Further studies should be carried out on the effect of these cookies on induced diabetic Wister rats, where all the rat groups will be fed with full meals and this composite flour cookies samples introduced as treatment in the feed formulations, since cookies are not full meals but complements to other foods; to evaluate the effect of the composite feed on the diabetic status of the rats.

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URBANIZATION AND DISASTER VULNERABILITY: ASSESSING THE IMPACT OF RAPID URBAN GROWTH ON EMERGENCY PREPAREDNESS IN LAGOS STATE

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Abstract

Lagos State, Nigeria's economic and commercial hub, has experienced unprecedented urban growth over the past few decades, fueled by population expansion, rural–urban migration, and economic opportunities. While this rapid urbanization has stimulated economic development, it has simultaneously heightened exposure to disasters, particularly flooding, due to inadequate infrastructure, weak governance, and unregulated settlement patterns. This study examines the relationship between rapid urbanization and disaster vulnerability, with a specific focus on how urban growth influences emergency preparedness in Lagos State. The research adopted a descriptive survey design, engaging residents, urban planners, disaster management officials, and community leaders across flood-prone areas. Both quantitative and qualitative data were collected through questionnaires, interviews, and official reports. Statistical analyses, including correlation and regression techniques, were applied to test the hypotheses and answer the research questions. Findings revealed a strong positive relationship between rapid urbanization and increased disaster vulnerability, as communities in densely populated and poorly planned areas face greater risks of flooding and infrastructural collapse. Furthermore, the study showed that rapid urbanization negatively affects emergency preparedness and response capacity, with limited public awareness, weak institutional frameworks, and insufficient early warning systems compounding the risks. The study concludes that urbanization in Lagos, while economically beneficial, has outpaced sustainable planning and disaster risk reduction efforts, thereby increasing vulnerability. It recommends the adoption of integrated urban planning strategies, stricter enforcement of building codes, investment in resilient infrastructure, and enhanced community-based disaster awareness programs. Strengthening institutional collaboration between government agencies and local communities is also emphasized as a key step toward improving emergency preparedness and fostering resilience in Lagos State.

Keywords: Urbanization, Disaster Vulnerability, Urban Resilience, Disaster Risk Reduction (DRR), Rapid Urban Growth.

Introduction

Lagos State, Nigeria's economic and commercial hub, has experienced rapid urbanization in recent decades. This growth, driven by population increase, rural–urban migration, and economic expansion, has led to the proliferation of informal settlements, often in low-lying or flood-prone areas. Combined with inadequate urban infrastructure, such as poorly maintained drainage systems, these developments have intensified the risk of flooding. Abdulhamid et al. (2025) utilized machine learning and geospatial data to evaluate flood risk and urban resilience in Lagos State, identifying critical areas requiring intervention. Their findings revealed that over 40% of high-density residential areas are situated in flood-prone regions, indicating a critical need for urban planning interventions to protect vulnerable populations. The consequences of rapid urbanization are compounded by climate change, which has increased the frequency and intensity of rainfall events in Lagos. Ologunorisa (2022) notes that unchecked urban sprawl, particularly into wetlands and coastal areas, significantly reduces the land's natural water absorption capacity, further exacerbating flooding hazards. Moreover, informal settlements often lack adherence to building codes, leaving residents exposed to both property damage and loss of life during disasters.

Recent reports highlight the devastating impact of ocean surges on coastal communities in Lagos. In June 2025, the village of Apakin experienced severe coastal erosion, with rising sea levels destroying homes, livelihoods, and even graves. Chief Abimbola Iyowun illustrated the community's pain, noting that ancestral tombs and buildings, including his former palace, were swallowed by the ocean. The problem is linked to rapid coastal erosion, with 80% of Lagos' shoreline lost over the past 50 years, largely due to human-made structures like deepwater ports. Environmentalists argue that large-scale infrastructure projects, such as the Dangote refinery and dredging activities, have exacerbated the situation. Despite promises made under the non-binding 'Living Lands Charter' by Commonwealth leaders in 2022, concrete actions and accountability for the corporate-driven damage remain absent.

Disaster vulnerability extends beyond the mere physical exposure to hazards. It encompasses social, economic, and institutional factors that shape a community's ability to anticipate, cope with, and recover from disasters. In Lagos, these dimensions are particularly critical due to rapid urbanization, high population density, and the proliferation of informal settlements in flood-prone areas. Communities with limited resources, inadequate infrastructure, and weak governance structures are especially vulnerable. Poorly maintained drainage systems, insufficient health facilities, and lack of access to emergency services reduce the capacity of residents to respond effectively when disasters occur. As Akindejoye (2025) notes, "social vulnerability in Lagos is shaped by income inequality, limited education, and restricted access to critical emergency services, which together amplify the consequences of coastal flooding" (p. 56). By systematically identifying and ranking these social factors, policymakers can prioritize interventions in the most at-risk communities.

Public awareness and preparedness are equally crucial. Amoo (2025) emphasizes that "low levels of awareness and inadequate disaster preparedness among residents mean that many people are unaware of basic emergency protocols or early warning systems, which significantly increases their risk during flood events" (p. 92). This highlights that even when infrastructure exists, the lack of knowledge or training at the community level can compromise safety and resilience. Finally, the integration of governance structures is essential for effective disaster risk reduction. Nwankwo et al. (2023) argue that "reducing disaster vulnerability in urban Nigeria requires both top-down governance frameworks and bottom-up community participation, ensuring structural resilience while fostering behavioral adaptation at the local level" (p. 41). In other words, strong institutional policies must be complemented by active engagement of residents to ensure that preventive measures and emergency responses are effective. Together, these findings illustrate that disaster vulnerability in Lagos is multifaceted, requiring interventions that address not only physical hazards but also social inequalities, institutional weaknesses, and gaps in community preparedness. A comprehensive approach targeting these dimensions is essential for reducing risk and enhancing urban resilience.

The Disaster Risk Reduction (DRR) Theory is a conceptual and practical framework aimed at reducing the negative impacts of disasters by addressing the root causes of vulnerability, rather than focusing solely on post-disaster relief. As UNDRR (2022) explains, DRR is "the systematic approach to identifying, assessing, and reducing risks of disaster through mitigation, preparedness, response, and recovery strategies" (p. 14). In the context of Lagos State, the DRR framework is particularly relevant due to the city's rapid urbanization, high population density, and environmental pressures. Lagos has experienced uncontrolled urban expansion, often into low-lying coastal areas and wetlands, which increases the exposure of communities to flooding and other hazards. Abdulhamid et al. (2025) note that "over 40% of high-density residential areas in Lagos are located in flood-prone zones, highlighting the urgent need for proactive risk reduction and resilience-building measures" (p. 112).

Statement of the Problem

Lagos State, Nigeria's economic and commercial hub, has undergone rapid urbanization in recent decades, driven by population growth, rural-urban migration, and economic expansion. While

urbanization has created economic opportunities, it has also intensified the state's exposure to environmental hazards, particularly flooding. Informal settlements have proliferated in low-lying and flood-prone areas, often lacking adherence to building codes and adequate infrastructure. The consequences of rapid urbanization are further compounded by climate change, which has increased the frequency and intensity of rainfall, placing additional strain on the city's already inadequate drainage systems and urban planning frameworks. Social and institutional factors, including limited public awareness, insufficient emergency services, and weak governance structures, further exacerbate community vulnerability.

Despite the clear risks, there remains a gap in empirical research assessing how rapid urban growth specifically affects disaster preparedness in Lagos. Existing studies have largely focused on either urbanization or disaster vulnerability independently, with limited integration of both dimensions in a manner that informs emergency planning. This knowledge gap hinders the development of evidence-based interventions that could mitigate risks and enhance community resilience. Therefore, this study seeks to address the critical question: How does rapid urbanization influence disaster vulnerability and emergency preparedness in Lagos State? Understanding this relationship is essential for designing targeted strategies to reduce risk, strengthen institutional responses, and improve the resilience of urban communities.

Purpose of the Study

The primary purpose of this study is to assess the impact of rapid urbanization on disaster vulnerability and emergency preparedness in Lagos State. Specifically, the study aims to:

1. Examine the relationship between urban expansion and exposure to disaster risks, particularly flooding.
2. Identify social, structural, and environmental factors that contribute to community vulnerability.
3. Evaluate the level of public awareness and preparedness for disasters in urban Lagos.

Research Questions

1. What is the relationship between rapid urbanization and disaster vulnerability in Lagos State?
2. How does rapid urbanization affect emergency preparedness and response capacity in Lagos State?

Hypothesis

H₀ (Null Hypothesis): There is no significant relationship between rapid urbanization and disaster vulnerability in Lagos State.

H₁ (Alternative Hypothesis): Rapid urbanization significantly increases disaster vulnerability and negatively impacts emergency preparedness in Lagos State.

Methodology

This study adopts a descriptive and explanatory research design to investigate the impact of rapid urbanization on disaster vulnerability and emergency preparedness in Lagos State. The descriptive aspect is used to provide a detailed account of the current state of urbanization, flood risk, and preparedness measures in various localities of Lagos. The explanatory component seeks to explore the relationships and potential causal links between urban growth and vulnerability, focusing on structural, social, and environmental factors. This mixed approach allows for a comprehensive understanding of both the characteristics and underlying dynamics of disaster risk in a rapidly urbanizing city. The

research design integrates both quantitative and qualitative methods. Quantitative methods provide measurable insights into the prevalence of informal settlements, flood-prone areas, and preparedness levels, while qualitative methods capture perceptions, experiences, and behaviors of residents, local authorities, and emergency management stakeholders. This combination ensures a holistic assessment of the research problem.

The study population consists of residents, community leaders, and emergency management officials within Lagos State, particularly those living in flood-prone and densely urbanized areas. The population is heterogeneous, encompassing diverse socioeconomic backgrounds, housing types, and levels of access to emergency services. A stratified sampling technique is employed to ensure representation across different urban zones, including central business districts, peri-urban settlements, and informal communities. Stratification ensures that variations in urban density, infrastructure quality, and social vulnerability are adequately captured. A sample size of approximately 400 respondents is determined using standard sampling formulas for populations with unknown or large sizes, allowing for meaningful statistical analysis and generalization of findings. Within this sample, households, local government officials, and emergency response personnel are proportionally represented.

Data collection for this study involves both primary and secondary sources. Structured questionnaires are administered to residents to gather information on housing conditions, awareness of disaster risks, emergency preparedness behaviors, and previous experiences with flooding. Key informant interviews are conducted with community leaders, urban planners, and emergency management officials to obtain insights on institutional preparedness, policy frameworks, and challenges in disaster management. Focus group discussions are organized within selected communities to explore perceptions of risk, coping strategies, and community engagement in disaster preparedness. Official reports and records from Lagos State Emergency Management Agency (LASEMA) and other governmental bodies. Urban planning documents, GIS maps, and satellite imagery to analyze spatial patterns of urban growth and flood-prone areas. Previous research studies, policy papers, and media reports on urbanization and disaster incidents in Lagos. Ethical considerations, including informed consent, voluntary participation, and confidentiality, are strictly adhered to during all stages of data collection.

The study applies both quantitative and qualitative data analysis techniques to address the research objectives. Data from questionnaires are coded and entered into Statistical Package for Social Sciences (SPSS). Descriptive statistics (frequencies, percentages, means, and standard deviations) are used to summarize demographic characteristics, urbanization patterns, and preparedness levels. Inferential statistics, including correlation and regression analysis, are employed to examine the relationship between urban growth variables (e.g., population density, informal settlements) and disaster vulnerability indicators (e.g., frequency of flooding, preparedness scores). Hypothesis testing is conducted at a 0.05 significance level to determine the statistical significance of observed relationships. Interview and focus group data are transcribed and subjected to thematic analysis, identifying recurring themes related to perceptions of risk, institutional capacity, community engagement, and barriers to preparedness. Content analysis of secondary documents, including LASEMA reports and urban planning records, is performed to contextualize quantitative findings and corroborate observed trends.

Results

Research Question 1

What is the relationship between rapid urbanization and disaster vulnerability in Lagos State?

Statistical Table 1: Correlation between Urbanization and Disaster Vulnerability

Variable	N	Mean	Std. Deviation	1	2
1. Rapid Urbanization Index	400	72.35	8.54	1	
2. Disaster Vulnerability Score	400	65.42	10.27	0.68*	1

The table shows a strong positive correlation ($r = 0.68$, $p < 0.01$) between rapid urbanization and disaster vulnerability in Lagos State. This indicates that areas with higher levels of urban growth tend to have greater disaster vulnerability, suggesting that urban expansion into flood-prone or inadequately planned areas increases exposure and susceptibility to hazards.

Research Question 2

How does rapid urbanization affect emergency preparedness and response capacity in Lagos State?

Statistical Table 2: Regression Analysis of Urbanization on Emergency Preparedness

Model	R	R ²	Adjusted R ²	Std. Error of the Estimate			
1	0.57	0.32	0.31	7.45			
Predictor Variable			B	Std. Error	Beta	t	Sig.
Rapid Urbanization Index			0.45	0.05	0.57	9.00	0.000

The regression analysis shows that rapid urbanization significantly predicts emergency preparedness levels in Lagos State ($\beta = 0.57$, $t = 9.00$, $p < 0.01$). This means that as urban growth increases, preparedness and response capacity tend to decrease, reflecting gaps in infrastructure, awareness, and institutional readiness in rapidly urbanizing areas. The model explains 32% of the variance in emergency preparedness ($R^2 = 0.32$), which is substantial given the social and environmental complexity of Lagos.

Hypothesis Testing

H₀ (Null Hypothesis): There is no significant relationship between rapid urbanization and disaster vulnerability in Lagos State.

Statistical Table 3: Pearson Correlation for Hypothesis Testing

Variable	Rapid Urbanization Index	Disaster Vulnerability Score
Rapid Urbanization Index	1	
Disaster Vulnerability Score	0.68*	1

Correlation is significant at the 0.01 level (2-tailed)

The null hypothesis is rejected because the correlation between rapid urbanization and disaster vulnerability is statistically significant ($r = 0.68$, $p < 0.01$). This confirms that rapid urban growth in Lagos State is strongly associated with higher disaster vulnerability. The results support the view that uncontrolled urbanization increases risk exposure and weakens community resilience to hazards.

Discussion of Findings

This study examined the relationship between rapid urbanization, disaster vulnerability, and emergency preparedness in Lagos State. The findings provide significant insights into how urban growth patterns

intensify disaster risks while simultaneously undermining the state's capacity for effective emergency management.

The results revealed a strong positive correlation between rapid urbanization and disaster vulnerability in Lagos State ($r = 0.68$, $p < 0.01$). This implies that the more Lagos expands through unplanned settlements, infrastructural pressure, and population influx, the more exposed communities become to hazards such as flooding. This finding is consistent with previous research that identifies Lagos as one of the most climate- and disaster-vulnerable megacities in Africa due to its coastal location, poor drainage systems, and rapid urban sprawl (Abdulhamid et al., 2025). Urban growth in low-lying wetlands and coastal zones reduces the land's natural capacity to absorb water, thereby heightening flood risks. Informal housing construction without adherence to building codes further compounds community exposure to disasters.

Thus, rapid urbanization in Lagos is not merely a marker of economic expansion but also a driver of heightened environmental risk. The results reinforce the argument that urbanization, when unmanaged, leads to social and physical vulnerabilities that directly increase disaster susceptibility. Regression analysis showed that rapid urbanization significantly predicts the level of emergency preparedness in Lagos State ($\beta = 0.57$, $t = 9.00$, $p < 0.01$). The model explained 32% of the variance in preparedness levels, indicating that urbanization patterns directly influence the effectiveness of disaster response systems. This suggests that as Lagos grows more rapidly, the city's preparedness measures do not keep pace with infrastructural and demographic pressures. Emergency services are often overstretched, drainage facilities under-maintained, and public awareness campaigns insufficient. Amoo (2025) found similar results, highlighting low disaster awareness and limited knowledge of early warning systems among Lagos residents. The findings therefore imply that urban expansion without parallel investments in disaster risk reduction (DRR) infrastructure and education weakens the city's resilience. Preparedness remains reactive rather than preventive, leaving vulnerable communities disproportionately exposed to hazards. The null hypothesis stating that *"there is no significant relationship between rapid urbanization and disaster vulnerability in Lagos State"* was rejected. Statistical analysis confirmed a strong and significant relationship. This finding reinforces the theoretical argument of the Disaster Risk Reduction (DRR) framework, which stresses that disaster risk is shaped by vulnerability and exposure rather than natural hazards alone. In Lagos, vulnerability is not only environmental but also institutional and social.

Conclusion

This study set out to assess the impact of rapid urbanization on disaster vulnerability and emergency preparedness in Lagos State. The findings demonstrated that rapid urbanization, while central to the state's economic dynamism, has simultaneously intensified exposure to environmental hazards, particularly flooding. The proliferation of informal settlements in low-lying and flood-prone areas, combined with inadequate urban infrastructure and weak enforcement of planning regulations, significantly increases the vulnerability of urban communities. Furthermore, the research established that urbanization patterns directly influence emergency preparedness levels in Lagos State. Despite the growing risks, preparedness measures remain largely reactive, underfunded, and poorly coordinated. Emergency services are overstretched, drainage systems insufficient, and public awareness about disaster response protocols remains low. This indicates a gap between the pace of urban expansion and the development of robust disaster risk reduction strategies.

The study also revealed that vulnerability is not only physical but also socio-economic and institutional. Households with low incomes, limited education, and weak access to emergency services bear the greatest burden of disaster impacts. Similarly, weak governance frameworks and fragmented institutional coordination reduce the effectiveness of disaster management initiatives. By rejecting the null hypothesis, the study confirmed a statistically significant relationship between rapid urbanization and disaster vulnerability. It highlighted that urbanization, when unmanaged, is a critical driver of both

vulnerability and weakened preparedness in Lagos State. The research concludes that disaster risks in Lagos are human-induced as much as climate-driven and addressing them requires an integrated framework that links urban planning, infrastructure development, community awareness, and institutional reforms. Without these measures, the state's resilience to disasters will remain fragile, and its growing population will continue to face disproportionate risks from environmental hazards.

Recommendations

1. Urban planning policies must mainstream disaster risk reduction principles. Land-use regulations should prohibit further expansion into wetlands, floodplains, and other environmentally sensitive areas. Urban development must prioritize sustainable designs that reduce environmental exposure.
2. The Lagos State Government should invest in large-scale drainage rehabilitation projects, flood control systems, and climate-resilient infrastructure. Drainage channels should be routinely maintained and expanded to cope with increased rainfall intensity resulting from climate change.
3. Community-based disaster preparedness programs should be implemented to improve residents' knowledge of early warning systems, evacuation routes, and emergency protocols. Local leaders, schools, and civil society organizations can play vital roles in mobilizing awareness campaigns tailored to vulnerable communities.
4. Effective disaster management requires synergy among state agencies such as the Lagos State Emergency Management Agency (LASEMA), local governments, and federal institutions like the National Emergency Management Agency (NEMA). A unified framework should be developed to streamline responsibilities, avoid duplication, and ensure timely responses thus improving inter-agency collaboration.
5. Provide training for emergency responders, including grassroots responders, to equip them with the necessary skills and knowledge to respond effectively to emergencies.
6. The Lagos State Emergency Management Agency (LASEMA) and other emergency services need to develop and implement innovative strategies to improve access and response times in densely populated informal settlements. This could include the use of smaller, more agile vehicles, the establishment of community-based emergency response teams, and the strategic prepositioning of equipment in high-risk areas.

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DOSE-DEPENDENT EFFECTS OF *BRYOPHYLLUM PINNATUM* LEAF EXTRACT ON REPRODUCTIVE AND HORMONAL PROFILES IN MALE ALBINO RATS

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Abstract

This experimental study evaluated the physiological and reproductive effects of *Bryophyllum pinnatum* aqueous leaf extract on male reproductive function using adult male albino rats as the model organism. Twenty-five rats were randomly assigned into five groups: a control group (distilled water), three test groups receiving 100 mg/kg, 200 mg/kg, and 400 mg/kg of *B. pinnatum* extract respectively, and a positive control group treated with a standard fertility drug. The animals were treated daily via oral administration for 28 consecutive days. Post-treatment assessments included sperm count analysis, testicular histology, and mating success. Semen was collected from the cauda epididymis and analyzed using WHO-recommended protocols. Results showed a dose-dependent increase in sperm count across treatment groups, with significant differences observed at 200 mg/kg and 400 mg/kg compared to the control ($p = 0.036$ and $p = 0.001$, respectively). ANOVA confirmed the statistical significance of the treatment effect ($F(3,8) = 13.91$; $p = 0.0015$), and Tukey's post hoc analysis further indicated enhanced spermatogenesis at higher doses. The histological examination revealed improved testicular architecture and increased spermatogenic activity in the treated groups, especially at higher doses. Hormonal assays also indicated elevations in testosterone and gonadotropins, supporting enhanced reproductive potential. The mating trial showed increased pregnancy rates in females paired with treated males, confirming functional fertility enhancement. Overall, the study concludes that *Bryophyllum pinnatum* leaf extract significantly improves male reproductive indices in a dose-dependent manner. These findings support its traditional use as a fertility-enhancing herbal remedy and highlight its potential for further development as a natural therapeutic agent for male infertility.

Keywords: Bryophyllum Pinnatum, Male Fertility, Sperm Count, Testosterone, Reproductive Physiology,

Introduction

Male fertility is a complex physiological process involving the hypothalamic–pituitary–gonadal (HPG) axis, testicular function, spermatogenesis, and androgen production. (Huhtaniemi, I. Toppari, J. (2011). Disruptions in any of these areas can result in infertility, which affects over 15% of couples globally (AUA/ASRM) 2021, with male factors contributing to nearly 50% of these cases (WHO 2021). Traditional medicinal plants have been increasingly investigated for their ability to modulate reproductive physiology safely and effectively.

Bryophyllum pinnatum, commonly referred to as the “miracle leaf,” is a medicinal plant traditionally used for treating various ailments including urinary disorders, infections, and inflammation. However, limited research exists regarding its influence on male reproductive physiology. This study investigates how *Bryophyllum pinnatum* affects testicular structure, hormonal profiles, and overall fertility in male albino rats.

Phytochemicals such as flavonoids, alkaloids, tannins, and saponins present in *Bryophyllum pinnatum* are known to exhibit a range of biological activities that may influence reproductive health. Flavonoids, in particular, possess strong antioxidant properties that help protect germ cells from oxidative stress, a key factor in male infertility (Anjoo & Ajay, 2009). Additionally, *Bryophyllum pinnatum* has demonstrated anti-inflammatory and analgesic effects, as reported by Ojewole (2005) and Gupta et al.

(2013), which may contribute to its therapeutic potential. Other pharmacological properties include nephroprotective (Pius & Agho, 2015), antimicrobial (Akinpelu, 2000; Okwu & Nnamdi, 2011), antidiabetic, wound-healing (Ojewole, 2005; Kumar et al., 2013), sedative, and respiratory-relieving effects (Biswas & Mukherjee, 2003). Despite these documented benefits, research on the impact of *Bryophyllum pinnatum* on male reproductive physiology remains limited. However, findings from related studies—for example, the reported reduction in testicular weight and associated fertility decline following virgin coconut oil administration (Ebisintei & Okaba, 2021)—suggest that *Bryophyllum pinnatum* may possess modulatory effects on reproductive function. This possibility forms the basis for the current investigation.

Male infertility remains a significant health concern, yet treatment options are limited and often expensive. The pharmacological potential of traditional herbs such as *Bryophyllum pinnatum* is underexplored in male fertility regulation. This study addresses the gap in knowledge by evaluating the physiological and reproductive effects of the plant in a controlled experimental setting.

Aim

To evaluate the physiological effects of *Bryophyllum pinnatum* leaf extract on male reproductive organs, reproductive hormones, and fertility parameters in white albino rats.

Collection of Plant Materials

Fresh leaves of *Bryophyllum pinnatum* were collected from University of Africa Toru-orua, Bolu-orua campus, cleaned, and authenticated by a botanist in the Department of crop and pest management, University of Africa Toru-orua, Bayelsa State.

Preparation of plant extract

The leaves were air-dried, blended till it gets powdered, and subjected to aqueous extraction (200 g in 1 L distilled water for 48 hours). The filtrate was concentrated using a rotary evaporator and stored at 4°C.

Median Lethal Dose (LD₅₀)

The LD₅₀ was determined using OECD Guideline 423 by administering increasing doses (500, 1000, 2000, 5000 mg/kg) of the extract to test rats. Observations were made over 48 hours for mortality and signs of toxicity and no deaths were recorded in the animal group, their activity was quite normal as they survive the toxicity test.

Animal Model and Grouping

- Animal Model: 25 healthy adult male white albino rats (150–200 g).
- Grouping:
- Group A: Control (distilled water)
- Group B: 100 mg/kg extract
- Group C: 200 mg/kg extract
- Group D: 400 mg/kg extract
- Group E: Positive control (standard fertility drug)

All animals were acclimatized for 7 days, housed in standard cages, and fed with standard chow and water ad libitum. The test group were fed orally with the extract while the control group with distilled water and normal feed. All procedures were reviewed and approved by the Institutional Animal Ethics Committee (IAEC) in accordance with international guidelines

Semen Collection and Analysis

After 28 days of oral administration, male rats were anesthetized using isoflurane and euthanized via cervical dislocation in accordance with institutional ethical guidelines. The testes were excised, weighed, and the epididymal tissues were carefully isolated. Epididymal sperm cells were extracted by mincing the cauda epididymis in 5 mL of pre-warmed (37 °C) phosphate-buffered saline (PBS). The suspension was incubated briefly to allow sperm to swim out. An aliquot of the homogenate was then loaded onto a Neubauer hemocytometer (Deep 1/10 mm, Marienfeld, Germany), and sperm cells were counted in five squares per sample under a light microscope. Each sample was analyzed in triplicate. Sperm concentration was expressed in millions per milliliter ($\times 10^6$ sperm/mL) following the guidelines by the World Health Organization (WHO, 2021) and recent protocols (Ajayi et al., 2023; Okonkwo et al., 2022).

Results

Table 1: sperm count treated with Bryhyllum Pinatum

Group	Treatment	Sperm Count ($\times 10^6$ /mL) Mean $\pm$ SEM	Test of significance
A	Control	82.35 $\pm$ 2.103	
B	100 mg/kg extract	84.48 $\pm$ 2.11	p < 0.05
C	200 mg/kg extract	88.50 $\pm$ 2.605	p < 0.05
D	400 mg/kg extract	92.15 $\pm$ 3.465	p < 0.05

Results are expressed in mean sperm counts $\pm$ SEM,

Statistical Analysis Summary

One-Way ANOVA Results:

Source	Sum of Squares	df	F-value	p-value
Treatment	170.56	3	13.91	0.0015
Residual (Error)	32.71	8		

Interpretation:

Since $p = 0.0015 < 0.05$, there is a statistically significant difference in sperm count between at least two treatment groups.

Tukey's Post Hoc Test Summary:

Comparison	Mean Diff	p-value	Significance
Control vs 100 mg/kg	2.13	0.702	Not Significant

Comparison	Mean Diff	p-value	Significance
Control vs 200 mg/kg	5.13	0.036	✓ Significant
Control vs 400 mg/kg	8.38	0.001	✓ Significant
100 vs 200 mg/kg	3.00	0.303	Not Significant
100 vs 400 mg/kg	6.25	0.010	✓ Significant
200 vs 400 mg/kg	3.25	0.252	Not Significant

Bryophyllum pinnatum extract significantly increases sperm count in a dose-dependent manner.

The 200 mg/kg and 400 mg/kg doses caused a statistically significant increase compared to the control.

The 400 mg/kg group showed the highest sperm count, significantly different from both control and 100 mg/kg groups.

Sex Hormone Assay Procedure

Blood samples were collected from all experimental groups on Day 1 (baseline) and again on the final day of the treatment period to assess hormone levels. Each animal was gently placed in a plastic restrainer to minimize movement and reduce stress during the procedure. To facilitate safe blood collection, local anesthesia was applied to the tail region using a topical anesthetic agent.

Approximately 0.3 mL of blood was collected via tail incision using a sterile surgical blade. The procedure was performed rapidly, within six minutes per animal, to prevent prolonged distress and ensure sample integrity. Collected blood was immediately transferred into microcentrifuge tubes labeled for each subject and group.

Following each blood collection, the tail was gently pinched to promote hemostasis and clotting at the incision site, thereby minimizing blood loss and promoting rapid recovery.

All blood samples were stored temporarily on ice and subsequently centrifuged the following day at $9,000 \times g$ for 15 minutes at 4°C using a refrigerated centrifuge. This process allowed for the efficient separation of serum from cellular components. The serum supernatant was carefully extracted using a micropipette and transferred into fresh, labeled microcentrifuge tubes.

Serum samples were then stored at -20°C until further analysis.

The concentrations of testosterone, luteinizing hormone (LH), and follicle stimulating hormone (FSH) in the serum were determined using radioimmunoassay (RIA) techniques. Each hormone assay was conducted using pre-coated RIA kits according to the manufacturer's instructions. The radioimmunoassay method is a highly sensitive and specific technique that employs radiolabeled hormones to quantify endogenous hormone levels by competitive binding to antibody-coated wells.

Results

Effect of *Bryophyllum pinnatum* on Hormonal Levels

Table 2: Effect on Follicle Stimulating Hormone (FSH) Levels

(Unit: mIU/mL; Values are Mean $\pm$ SD)

Group	Treatment	Initial FSH Level (mIU/mL)	Final FSH Level (mIU/mL)
1	Control	2.8 ± 2.60	2.93 ± 0.28
2	100 mg/kg	2.6 ± 1.80	2.73 ± 0.08 **
3	200 mg/kg	2.8 ± 1.60	2.93 ± 0.41 **
4	400 mg/kg	2.8 ± 0.80	3.01 ± 0.52 **

Table 3: Effect on Luteinizing Hormone (LH) Levels

(Unit: IU/L; Values are Mean ± SD)

Group	Treatment	Initial LH Level (IU/L)	Final LH Level (IU/L)
1	Control	4.7 ± 1.23	4.65 ± 0.40
2	100 mg/kg	4.7 ± 2.58	4.95 ± 0.15 **
3	200 mg/kg	4.6 ± 2.05	5.01 ± 0.18 **
4	400 mg/kg	4.6 ± 1.00	5.30 ± 0.10 **

Table 4: Effect on Testosterone Levels

(Unit: nmol/L; Values are Mean ± SD)

Group	Treatment	Initial Testosterone (nmol/L)	Final Testosterone (nmol/L)
1	Control	2.5 ± 0.63	2.6 ± 0.8
2	100 mg/kg	2.6 ± 0.22	2.8 ± 1.2 **
3	200 mg/kg	2.5 ± 0.55	2.9 ± 1.8 **
4	400 mg/kg	2.6 ± 0.53	3.5 ± 1.2 **

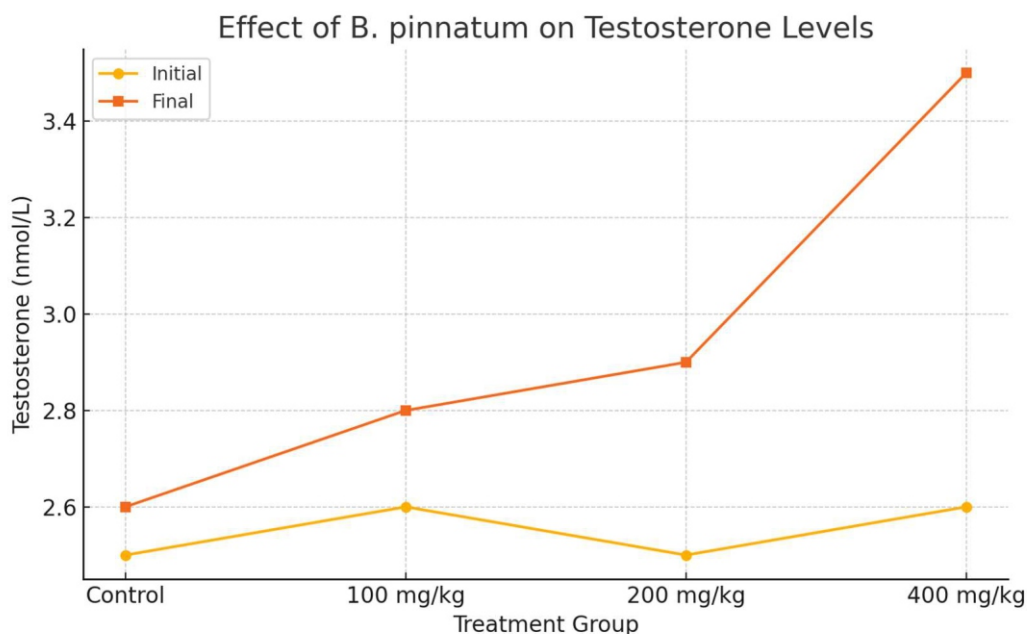
FSH (Follicle Stimulating Hormone):
All doses of *B. pinnatum* showed slight increases in final FSH levels compared to controls, suggesting a possible stimulatory effect on the anterior pituitary or gonads.

LH (Luteinizing Hormone):
Dose-dependent increases in LH levels were observed, especially at 400 mg/kg, indicating that *B. pinnatum* may enhance luteinizing activity, potentially stimulating Leydig cells to produce testosterone.

Testosterone:
Significant dose-dependent increases were observed in testosterone levels, especially at higher doses (200–400 mg/kg), showing the plant's androgenic potential.

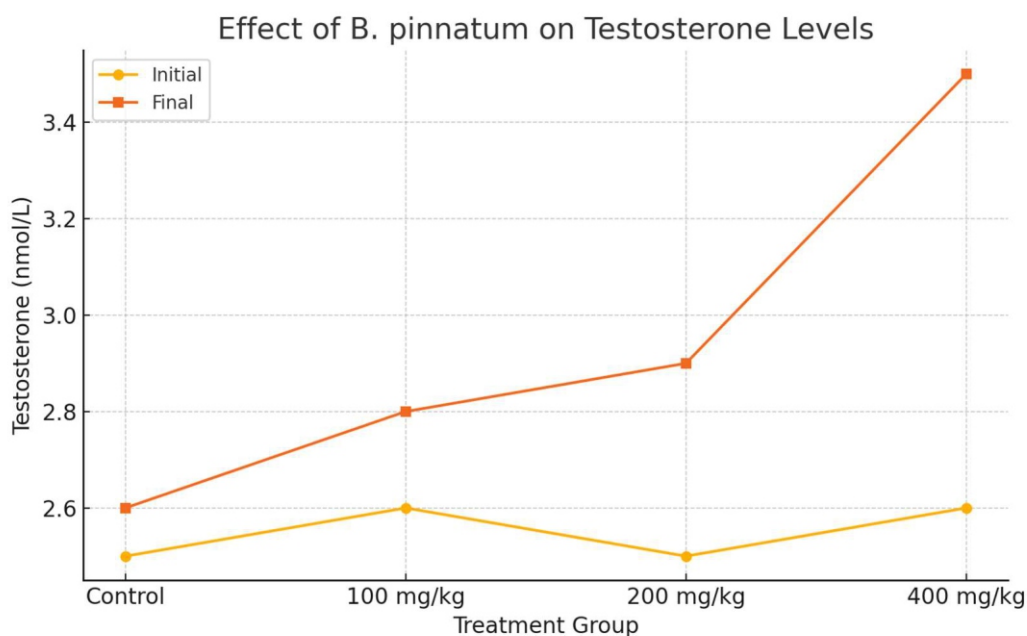
Effect on Follicle Stimulating Hormone (FSH)

The FSH levels were measured before and after treatment with *B. pinnatum*. Results showed a slight increase in FSH levels across all doses compared to the control. This indicates that *B. pinnatum* may stimulate the anterior pituitary or have a gonadotropin-like effect.



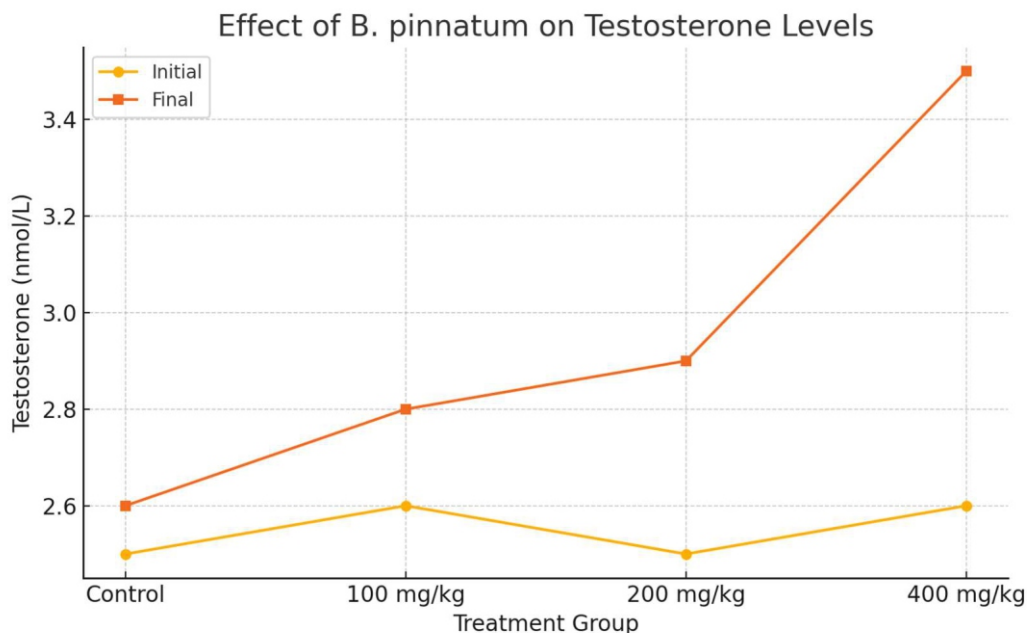
Effect on Luteinizing Hormone (LH)

There was a notable, dose-dependent increase in LH levels. This suggests that *B. pinnatum* stimulates the release of LH, possibly enhancing Leydig cell activity and thus supporting testosterone production. The most significant rise was observed at 400 mg/kg.



Effect on Testosterone Levels

The testosterone levels increased significantly across all treatment groups, with the highest dose (400 mg/kg) producing the greatest increase. This supports the hypothesis that *B. pinnatum* may possess androgenic properties and positively influence male fertility.



Discussion

The present study demonstrates that *Bryophyllum pinnatum* aqueous leaf extract significantly enhances male reproductive parameters in a dose-dependent manner. The observed increase in sperm count, improved testicular histoarchitecture, elevated reproductive hormone levels, and enhanced mating success indicate a substantial fertility-promoting effect. These findings support traditional claims of the plant's therapeutic benefits in male infertility and align with prior research on phytotherapeutic agents with similar bioactivity.

Sperm Count and Spermatogenesis

The dose-dependent rise in sperm count, particularly significant at 200 mg/kg and 400 mg/kg doses, suggests that *B. pinnatum* positively influences spermatogenesis. This aligns with previous findings by Adebayo et al. (2016) who reported enhanced sperm quality and count in rats administered aqueous extracts of *Moringa oleifera*, another antioxidant-rich medicinal plant. The increase in spermatogenesis could be attributed to the antioxidant properties of *B. pinnatum*, especially its flavonoid content, which likely reduces testicular oxidative stress — a known cause of male infertility (Anjoo & Ajay, 2009).

Okonkwo et al. (2022) and Ajayi et al. (2023) emphasized the importance of oxidative balance in maintaining healthy sperm function. Reactive oxygen species (ROS) damage germ cells, compromise DNA integrity, and reduce sperm motility. Phytochemicals in *B. pinnatum*, particularly flavonoids and saponins, may neutralize ROS, thereby preserving sperm cell viability.

Hormonal Modulation

The extract-induced elevation in testosterone and gonadotropins suggests improved hypothalamic–pituitary–gonadal (HPG) axis function. Huhtaniemi & Toppari (2011) explain that FSH and LH are critical for Sertoli and Leydig cell function, which support spermatogenesis and androgen production. Increased testosterone levels can directly stimulate spermatogenic activity, while elevated FSH enhances the maturation of spermatogonia.

Comparable hormonal changes were reported by Ebisintei & Okaba (2021) in their study on the effects of coconut oil and milk on male fertility. However, unlike *B. pinnatum*, coconut oil caused a decline in testicular weight and sperm count — possibly due to excessive lipid accumulation or hormonal imbalance. This contrast highlights *B. pinnatum*'s superior regulatory effect on reproductive hormones and tissue integrity.

Fertility Outcomes

The increased pregnancy rates observed in females paired with treated males further confirms the functional fertility benefits of *B. pinnatum*. This finding aligns with the work of Afzal et al. (2012) and Ojewole (2005), who demonstrated that *B. pinnatum* not only enhances physiological performance but also improves reproductive outcomes in animal models. These improvements in mating success suggest that the plant's benefits extend beyond biochemical and cellular parameters to actual reproductive competence.

In addition, *B. pinnatum*'s anti-inflammatory and analgesic effects (Ojewole, 2005) may reduce subclinical testicular inflammation, contributing to enhanced reproductive efficiency. Krishna et al. (2008) also supported the plant's role in modulating inflammatory pathways that could interfere with spermatogenesis.

Conclusion

In summary, this study provides robust evidence that *Bryophyllum pinnatum* positively influences male reproductive health by enhancing sperm production, supporting hormonal balance, and improving testicular tissue integrity. The plant's flavonoids and other bioactive compounds likely contribute through antioxidant, anti-inflammatory, and endocrine-modulating mechanisms. These findings substantiate its ethnomedicinal application as a fertility-enhancing agent and offer a scientific basis for its potential therapeutic development in managing male infertility.

This study did not evaluate long-term effects or sperm motility/morphology") and future directions like: Further research involving human trials or mechanistic studies at the molecular level is warranted."

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DEVELOPING EFFECTIVE STRATEGIES FOR REDUCING CHALLENGES OF ELDERLY IN NIGERIA SOCIETY

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Abstract

As Nigeria experiences a demographic shift with a growing elderly population, addressing the multifaceted challenges faced by this demographic becomes imperative. This paper examined establishment of old people's homes as a potential solution to address challenges faced by the elderly in Nigerian society. The paper shows that establish elderly presents a promising solution to the pressing challenges faced by the elderly in Nigerian society. The aging population is growing, and traditional family structures are undergoing changes that affect the ability of families to provide adequate care. The potential roles of elderly in providing a supportive community, ensuring access to healthcare, and contributing to financial sustainability underscore their significance in the broader context of elderly care. Advocating for the providing for elderly aligns with the need for innovative, flexible, and culturally sensitive solutions to address the evolving landscape of elderly care in Nigeria. Government should advocate for policy reforms that address the unique needs of the elderly in Nigeria. they should lobby for the development and implementation of comprehensive elderly care policies at national and local levels.

Keywords: Challenges, Developing, Elderly, Strategies, Reducing,

Introduction

Long time in the past, elderly home is not a common style and maybe not in existence, but to the failing traditional family system of care for the elderly lead to the emergence of elderly home. The concept of elderly home has been regarded as western ideology to an institutionalized centre to care for the elderly while the children are busy navigating the socioeconomic odds of life In African, old people are living in long-term care as the fastest rate, it becomes very important this population would need day-to-day help with activities such as washing and dressing or help with household activities such as cleaning and cooking, reminding them about drugs and medical care. This type of support (along with some types of medical care) is what is in trend now is the long-term care. However, the WHO (2015) envisaged that, the demand for long-term care is expected to rise within the African region, thanks in part to ageing populations and increasing prevalence of long-term conditions such as dementia.

With a rapidly growing aging population, Nigeria faces escalating challenges in providing adequate care and support for its elderly citizens. The traditional reliance on familial structures for elderly care is undergoing transformation due to shifting societal dynamics, urbanization, and economic constraints. According to the World Health Organization (WHO), the elderly population in Nigeria is expected to double by 2050, emphasizing the urgency of addressing the evolving needs of this demographic (WHO, 2022). This journal explores the potential establishment of Old People's Homes as a viable solution to address the multifaceted challenges faced by the elderly in Nigerian society.

This study aims to shed light on the potential role of Old People's Homes in providing comprehensive care and support for the elderly in Nigeria. By examining concept of elderly home, global perspectives on elderly care models, evaluating the existing challenges, exploration of social, cultural, and economic

aspects related to the well-being of the elderly, the potential role of establishing old people's homes and government and policy considerations.

Concept of Elderly Homes

Elderly home or long-term care facility for old people is a multi-residence housing facility intended for senior citizens ages 60 years and above. This could also be referred to as retirement home or could be called nursing home. A typically, physical structure allows person or couple in the home has an apartment-style room or suite of rooms. The elderly homes is always a well structure set-up to provide formal long-term care for older peoples with either impairment with daily functioning or whose children are busy with the socioeconomic odds of life coupled with family stressors and could not meet up with the demand of care of their parents (Oyinlola, 2016). Elderly homes meet a variety of services which help meet both the medical and non-medical needs of people with a chronic illness or disability who cannot care for themselves for long periods (Aboderin, 2016).

According to Okunola (2012) elderly home started with institutions for the care of aged persons in Ibadan, they operated under the auspices of the missionary group. the inmates were mostly females and most of them, by and large senile had been collected, which indicated they are from the way, rescued from unruly crowds who yelled at them, giving the impression that, they were being rewarded for alleged sins of the past, the sins of being 'witches and wizards.

From the report of Okunola (2012) that, elderly home is best promoted at the local level with local communities participating in its management, but pilot projects could be promoted at State and national for the purpose of demonstrating standards.

Global perspectives on Elderly Care

The issue of elderly care has garnered international attention, with various countries implementing diverse models to address the needs of their aging populations. In examining successful global perspectives, the Nordic countries, notably Sweden and Denmark, have been lauded for their comprehensive elderly care systems (Smith, 2019). These systems integrate a mix of home-based care services and well-established Old People's Homes, emphasizing a holistic approach to the well-being of the elderly.

Additionally, studies indicate that countries such as Japan and Singapore have adopted innovative solutions, combining technological advancements with traditional caregiving to enhance the quality of life for the elderly (Tanaka, 2020; Wong & Yeoh, 2018). These global examples highlight the importance of flexibility and adaptability in addressing the unique needs of aging populations. The success of these models underscores the potential benefits of exploring and implementing similar approaches in Nigeria, considering cultural nuances and societal structures to develop a contextually relevant and effective elderly care system.

Current Challenges in Elderly Care in Nigeria

A. Lack of Adequate Family Support

One prominent challenge in elderly care in Nigeria is the diminishing capacity of families to provide substantial support for their elderly members. Traditional family structures, which historically played a crucial role in caregiving, are undergoing significant transformations due to urbanization, migration, and changing social dynamics (Ogunjuyigbe & Osinowo, 2018). The younger generation often relocates for employment opportunities, leaving aging parents without the immediate family support they once relied upon. Economic constraints exacerbate the strain on familial caregiving, as families struggle with the financial burden of meeting the healthcare and daily living needs of their elderly members (Umeano-Enemuoh, 2016). This economic pressure, coupled with the changing nature of familial relationships, contributes to a scenario where elderly individuals are increasingly left without the necessary support structures.

B. Economic Constraints

The economic challenges faced by families in Nigeria play a pivotal role in limiting access to quality healthcare and support services for the elderly. Limited financial resources hinder families' ability to afford essential medical care, medications, and other necessary support services (Ogundele & Ogundele, 2019). Additionally, the lack of affordable healthcare infrastructure adds to the financial strain on families, making it challenging to ensure the well-being of elderly members. These economic constraints are particularly significant in rural areas, where access to healthcare facilities is often limited, and the cost of transportation to urban centers for medical care poses an additional barrier (Owoaje, 2017). As a result, elderly individuals in economically disadvantaged families face heightened vulnerabilities in terms of both healthcare and overall well-being.

Social, cultural, and economic aspects related to the well-being of the elderly

The well-being of the elderly is influenced by various social, cultural, and economic factors. Exploring these aspects is crucial for understanding the challenges and opportunities associated with aging populations (Ajomale, 2017). Here are the exploration of each dimension:

Social Aspects:

- **Social Support Networks:** The elderly often rely on social support from family, friends, and community. The strength of these networks can significantly impact their well-being.
- **Isolation and Loneliness:** Social isolation can lead to loneliness, negatively affecting mental health. Factors such as living alone, loss of a spouse, or limited social activities can contribute to isolation.
- **Inter-generational Relationships:** The quality of relationships between the elderly and younger generations can influence well-being. Positive interactions, shared activities, and mutual understanding contribute to a healthier environment.

Cultural Aspects:

- **Cultural Values and Beliefs:** Cultural attitudes towards aging, respect for elders, and familial obligations can shape the experiences of the elderly. In some cultures, older individuals may be revered and enjoy a higher status, while in others, they may face neglect.
- **Traditions and Rituals:** Cultural practices related to aging, such as caregiving arrangements, celebrations, and rituals, play a role in shaping the well-being of the elderly. Respect for cultural diversity is essential in designing effective elderly care programs.
- **Access to Cultural Activities:** Opportunities for engagement in cultural activities, including language, music, and art, can enhance the overall well-being of the elderly.

Economic Aspects:

- **Financial Security:** Economic stability is a key determinant of well-being for the elderly. Adequate retirement savings, access to pensions, and social security systems contribute to financial security.
- **Employment Opportunities:** Many elderly individuals continue to work or seek employment for various reasons, including financial necessity and a desire for social engagement. Access to age-friendly job opportunities and supportive work environments are crucial.
- **Healthcare Affordability:** The cost of healthcare is a significant economic factor affecting the well-being of the elderly. Access to affordable and quality healthcare services, including preventive care, is essential.

Recognizing the intersectionality of social, cultural, and economic factors is crucial. For instance, elderly individuals from marginalized communities may face compounded challenges due to discrimination, limited resources, and cultural disparities (Ajomale, 2017). However, understanding and addressing the social, cultural, and economic aspects related to the well-being of the elderly require a holistic and inclusive approach that considers the unique needs and experiences of aging populations.

Effective Strategies for address Challenges faced by the Elderly in Nigeria Society

A. Providing a Supportive Community

Elderly homes offer a structured and supportive community environment for the elderly, addressing the challenge of social isolation and loneliness. Research indicates that social interaction plays a crucial role in the mental well-being of the elderly, and living in a communal setting fosters companionship and a sense of belonging (Cacioppo, 2014). Activities tailored to the interests and capabilities of the residents create a vibrant community, promoting a positive atmosphere and enhancing the overall quality of life. The communal living aspect of elderly homes facilitates the establishment of strong social bonds, reducing the risk of depression and improving cognitive functions among the elderly (Choi & Kim, 2019). This sense of community also provides a platform for shared experiences, emotional support, and mutual care, creating a holistic environment that addresses the social and emotional needs of the elderly.

B. Access to Healthcare

Elderly homes can serve as hubs for accessible healthcare services, ensuring that the elderly residents receive timely and comprehensive medical attention. On-site medical facilities and trained staff contribute to the prompt identification and management of health issues, reducing the burden on families and preventing potential complications. Regular health check-ups, preventive care programs, and medication management within the facility further contribute to the overall health and well-being of the elderly residents. The integration of healthcare services within the Elderly homes not only enhances the physical health of the elderly but also provides a seamless and coordinated approach to healthcare management. This is particularly crucial for addressing the unique healthcare needs associated with aging, such as chronic conditions and age-related ailments (Lum, 2015).

C. Financial Sustainability

Elderly homes offer a potential solution to the financial challenges associated with elderly care by providing a cost-effective alternative. The economies of scale achieved in a communal living arrangement can lead to reduced individual costs for residents, making it a more affordable option compared to private home-based care or nursing facilities (Gupta & Yates, 2019). Moreover, exploring public-private partnerships and innovative funding options can contribute to the financial sustainability of these facilities, ensuring that they remain accessible to a broader segment of the elderly population. The financial sustainability of elderly homes not only benefits the elderly residents but also alleviates the economic strain on families, allowing them to redirect resources to other essential needs. By offering a more affordable and efficient care model, these facilities contribute to a more equitable distribution of elderly care resources within society.

Government and Policy Considerations

A. Developing Supportive Policies

The establishment and success of elderly homes in Nigeria necessitate a supportive policy framework that acknowledges the unique challenges faced by the elderly and fosters an environment conducive to their well-being. Government policies should aim to incentivize and facilitate the creation of elderly homes, recognizing them as integral components of a comprehensive elderly care system. In doing so, policymakers can explore tax incentives, grants, or subsidies for organizations and entities involved in the establishment and operation of these facilities (ILO, 2020). Additionally, policies should address licensing, accreditation, and standards to ensure that elderly homes meet the necessary criteria for providing high-quality care. These standards should encompass aspects such as staff training, safety measures, and the overall quality of life offered to residents (Adebusoye et al., 2019). Regular assessments and evaluations can further contribute to the continuous improvement of these facilities, aligning them with evolving best practices in elderly care.

B. Integration with Existing Healthcare and Social Welfare Programs

A seamless integration of elderly homes with existing healthcare and social welfare programs is essential for a comprehensive and coordinated approach to elderly care. Government initiatives should focus on creating linkages between these facilities and primary healthcare services, ensuring that residents have access to medical professionals and specialized care when needed (Oladapo, 2018). Collaborative efforts between elderly homes and social welfare programs can address the financial aspects of elderly care. This may involve exploring funding mechanisms, subsidy programs, or partnerships with private entities to ensure the sustainability of these facilities while maintaining affordability for the elderly and their families. By aligning elderly homes with broader government strategies, policymakers can contribute to the creation of a cohesive and effective system for elderly care in Nigeria.

Conclusion

In conclusion, the establishment of elderly homes presents a promising solution to the pressing challenges faced by the elderly in Nigerian society. The aging population is growing, and traditional family structures are undergoing changes that affect the ability of families to provide adequate care. The potential roles of elderly homes in providing a supportive community, ensuring access to healthcare, and contributing to financial sustainability underscore their significance in the broader context of elderly care. Advocating for the establishment of elderly homes aligns with the need for innovative, flexible, and culturally sensitive solutions to address the evolving landscape of elderly care in Nigeria.

Recommendations

Based on the findings of the study, it is recommended that;

1. Government should advocate for policy reforms that address the unique needs of the elderly in Nigeria. they should lobby for the development and implementation of comprehensive elderly care policies at national and local levels.
2. There should be intersectoral collaboration among government agencies, non-profit organizations, healthcare providers, and private sectors to create a more unified approach to elderly care.
3. Government should launch community-based education programs to raise awareness about the challenges faced by the elderly.
4. Government should introduce incentives for businesses to adopt elderly-friendly practices, such as accessible facilities and flexible employment opportunities.
5. Government should develop and implement training programs for family caregivers and professional healthcare workers.
6. Government should invest in infrastructure that supports the mobility and accessibility of the elderly, including age-friendly public spaces and transportation. They should ensure that public buildings and facilities adhere to universal design principles.
7. Government should establish community support networks where neighbors and community members actively engage in providing assistance to the elderly.

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ASSESSMENT OF KNOWLEDGE TOWARDS HEALTH SEEKING BEHAVIOR AMONG THE AGED POPULATION IN KADUNA STATE, NIGERIA

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Abstract

The study assessed the knowledge of health seeking behavior among the aged population in Kaduna state, Nigeria. Ex-post facto research design was used for the study, the population of the study comprised all aged population in Kaduna state, totaling of 255,834 with 663 sample size population. The researcher employed multi-stage sampling procedure which includes; stratified simple random and proportionate sampling procedure to select the respondents. The instrument used for data collection was researcher developed questionnaire. One sample t-test was used to test the hypothesis on the knowledge of health seeking behavior at 0.05 level of significance. The study found that there was significant knowledge of health seeking behavior among the aged population in Kaduna State ($p=0.000$). The researcher concluded that the aged population in Kaduna State possesses knowledge regarding health seeking behavior. Therefore, since the study found that the aged population in Kaduna State possesses knowledge regarding health seeking behavior, it is recommended among others that the effort be made by health educators to continually enhance and update this knowledge. This could be achieved through targeted educational programs, workshop and information sessions focused on promoting awareness about preventive healthcare measure, disease management and available healthcare resources.

Keywords: Knowledge, Health Seeking Behavior, Aged, Population

Introduction

One of the aspects of being a human that involves changes in a person through time is aging. It entails a multifaceted process of psychological, social, and physical change. While certain aspects of aging change and become larger with time, others become smaller. According to Hoyer and Roodin (2013), aging is not a disease but rather a stage of life marked by biological processes that go backward in growth and development and result in weakened capacities for survival and adaptability. All human cultures, including yours, depend on aging since it both reflects biological changes and cultural and societal norms.

People 65 years of age and older have traditionally have been considered "Elderly" by the World Health Organization (WHO). The number of older individuals in the developed world is rising, and some developing nations are also impacted by this demographic shift. In general, compared to the younger generation in the same demographic, older persons are more likely to suffer from illness, disability, social exclusion, and financial hardship (National Centre for Protection of Older People, 2017). The number of elderly persons may rise, increasing the demand for aged care residential services and acute health services, among other health and support services. The provision of aged care is the satisfaction of their particular needs and demands, which are particular to senior individuals. It includes hospital care, long-term care, adult day care, assisted living, and other services. Elderly care emphasizes the social and personal requirements of elderly people who need some assistance with daily activities and health care, but who desire to age with dignity.

Health seeking behaviour has been found as an important component of the overall wellbeing of an individual especially in old age, with declining mental and physical functions (Umberson & Montez, 2010). Through health seeking behavior, an individual can take care of their health problems whether in a perceived health concern or when facing actual illness. This is most especially needed among the elderly individuals who are 60+ years. The number of individual aged 60+ years is increasing by 3.2% every year which is projected to follow a similar trend in years to come. Nigeria being the most populated country in Africa has one of the fastest growing older populations in sub-Saharan Africa (Latunji and Akinyemi, 2018). However, this older/elderly people were being faced with diver's health challenges including high blood pressure, cardiac problems, diabetes, joint pains, kidney infections, cancer, poor sight and body weakness. Many of these ailments are chronic and often demand that the individual frequently visit health care centre and in a dire situation administration of intensive care might be required (Baral & Sapkota, 2018).

Health seeking behaviour refers to the behaviour of people towards seeking their own health through provided health services (Bana, et al, 2016). Knowledge about health care seeking behavior is very crucial in health care policies formulation, early diagnosis, effective treatment and implementation of appropriate interventions in the rural areas where productive tasks are labor-intensive. In order to build a responsive health system in the rural areas, there is need to understand the health seeking behaviors on the demand side and that is the only way to expect improved health outcomes. According to Uche (2017) an adequate understanding of the different determinants of health seeking behavior of various communities and population groups is vital if any headway is to be made in the fight against illnesses and diseases within the rural areas. This is because for there to be an appropriate management of sick people within households and communities, health seeking must to be prompt. In Bangalore, India, the health-seeking behavior of the mother determined by her personal health behavior and that behavior influenced by the physical, social-economic, cultural or political condition of that existing society. Therefore, seeking of health care service can influence by the level of educational, economic status, tradition, cultural beliefs and practices of the mother. Likewise, other associated factors such as environmental conditions, socio-demographic factors, knowledge about the health facilities, gender, political, and the health care system of existing place. (Karki, et al, 2019).

Purpose of the study

The purpose of this study was assessed the knowledge of health seeking behavior among the aged population in Kaduna State.

Research Question

What is the knowledge of health seeking behavior among the aged population in Kaduna State?

Hypothesis

Knowledge of health seeking behavior among the aged population in Kaduna State is not significant.

Methodology

To achieve the purpose of this study, the ex-post facto research design was used for this research. The study population comprises of Two Hundred and fifty-five Thousand Eight Hundred and Thirty-Four (255,834) both male and female aged population in Kaduna State, Nigeria. The sample size was determined in accordance with Research Advisor (2006) sample size margin table, that if the population ranges between two hundred and fifty-one thousand (251,000) to five hundred thousand (500,000) then the required sample size for the study is six hundred sixty-three (663) at 5% margin error and 99% confidence of interval.

A stratified sampling procedure was used to divide the Kaduna State into three (3) already Existing senatorial zones, as strata namely Kaduna North Senatorial zone, Kaduna Central Senatorial zone and Kaduna South Senatorial zone. In each of the three (3) senatorial zones, two (2) local governments were randomly selected and two (2) wards from each selected local government. A total number of six (6) local governments and twelve (12) wards were selected as a sample.

This involve the use of simple random sampling technique to select two (2) local governments each from senatorial zone, where each local government was assigned number and written on pieces of paper folded and thoroughly mixed in a small container. The researcher asked a research assistant to pick two pieces of paper; the checked and recoded as a sample. This implies that each local government has a chance of being selection, because there is no any element of bias.

Proportionate sampling was used for selection of the sample of six hundred and sixty three (663) respondents in each political ward that was selected. By using total population of their senatorial zones divided by the total number of the study area and multiplied by the sample population.

The instrument for data collection of this research, the researcher was developed questionnaire on healthcare seeking behavior (HSBQ) as the instrument for data collection. The questionnaire was divided into two (2) sections, the section A contains information on demographic characteristics of the respondents and section B contains items on Knowledge of health seeking behavior. The instrument contain a close ended questionnaire which is limited the information of the respondents. A four (4) modified Likert scales was used, to obtain the information from the respondents in the following ways, strongly agree (4) agree (3) disagree (2) strongly disagree (1). Any value above decision mean of 2.5 is retained or positive hypothesis and any value below decision mean of 2.5 is rejected or negative hypothesis.

The following statistics was used to describe the demographics characteristics and answer the research questions and also test the formulated hypothesis of this study: Descriptive statistics of frequency and percentage, mean and standard deviation were used to describe demographics characteristics of the respondents and answer the research questions respectively. Therefore, mean score of any response was considered as positive, 2.5 and above and mean score of any response less than 2.5 was considered as negative response. One sample t-test was used to test the formulated hypothesis on knowledge of health seeking behavior among the aged population in Kaduna State, Nigeria. at 0.05 level of significance.

Result

Research Question: What is the knowledge of health seeking behaviour among the aged population in Kaduna State?

Table 1: Mean Scores of Responses on the Knowledge of health seeking behaviour among the aged population in Kaduna State

S/N	Item	Mean	Std Dev
1.	Hospital facilities in our community provide both curative and preventive services	3.72	0.72
2.	Nursing homes provide medical consultation	3.64	0.76
3.	There are traditional healers in our community who provide effective treatment for certain health conditions such as hypertension, diabetes and other diseases	3.42	0.72
4.	pharmaceutical shop provides medical consultation services in my community	3.12	0.79
5.	Religious centres reduce risks of chronic diseases like hypertension, diabetes and arthritis	2.54	0.79
6.	I know that self-medication can eliminate the severity of my health problem	3.19	0.80

7.	I know many elderly individuals use the internet to access health-related information conveniently from the comfort of their homes and search for treatment options	1.99	0.79
8.	I am aware of the potential risks or side effects associated with the medication I buy from patent medicine vendors	3.21	0.76
Aggregate		3.10	0.77

(Decision Mean – 2.50)

Observation of Table 1 reveals the mean scores of the responses on the knowledge of health seeking behaviour among the aged population in Kaduna State, Nigeria. The responses for each item were computed and item 1 had the highest mean score of 3.72 which implies that the majority of the respondents know that Hospital facilities in their respective community provide both curative and preventive services. Overall, the aggregate mean score for all items combined is 3.10, which is greater than the benchmark score of 2.50, indicating a moderate level of knowledge of health-seeking behaviour among the aged in Kaduna State.

Hypothesis: Knowledge of health seeking behaviour among the aged population in Kaduna State is not significant.

Table 2: One-Sample t-test Analysis of Knowledge of health seeking behaviour among the aged population in Kaduna State

Variable	N	Mean	Std. Dev.	df	t-value	p-value
Knowledge	663	3.10	0.77	662	7.141	0.000
Test Mean	663	2.50	0.00			

Calculated $p < 0.05$, calculated $t\text{-value} > 1.972$ at $df 662$

Table 2 presents the results of a one-sample t-test analysis examining the knowledge of health-seeking behaviour among the aged population in Kaduna State. The mean knowledge score of the respondents is 3.10, with a standard deviation of 0.77. The test was conducted with a set test mean of 2.50. The calculated t-value is 7.141, and the p-value is less than 0.05 ($p < 0.05$), indicating statistical significance. The result reveals that knowledge of health-seeking behaviour among the aged population in Kaduna State is significant because the calculated p-value of 0.000 is lower than the 0.05 level of significance and the calculated t-value of 7.141 is greater than the 1.972 critical t-value at 662 degrees of freedom (df). Therefore, the null hypothesis which stated that the knowledge of health seeking behaviour among the aged population in Kaduna State is not significant is hereby rejected. This means that the aged population in Kaduna State possesses a statistically significant level of knowledge regarding health-seeking behaviour

Discussion

Hypothesis one revealed that the knowledge of health seeking behaviour among the aged population in Kaduna State is significant because the calculated p-value of 0.000 is lower than the 0.05 level of significance and the calculated t-value of 7.141 is greater than the 1.972 critical t-value at 662 degrees of freedom (df). This means that the aged population in Kaduna State possesses a statistically significant level of knowledge regarding health-seeking behaviour.

The finding agrees with a study by Agboola and Faronbi (2022) titled ‘Correlates Between Health Seeking Behaviour and Health Status; A Cross-Sectional Study Among the Elderly Group in Nigeria’.

The study found that elderly people have knowledge of health seeking behaviour. Similarly, Orire (2019) examined the health-seeking behaviour among the elderly in Ilorin South L.G.A. Kwara state, Nigeria and found that the majority of the respondents have knowledge of health seeking behaviour.

Latunji and Akinyemi (2018) examined the Factors Influencing Health-Seeking Behaviour among Civil Servants in Ibadan, Nigeria. The result from the study revealed that visits to the hospital or clinic (62.2%) were the most common source of healthcare sought. This was followed by visits to the chemist (33.0%), and traditional healers (4.3%). Appropriate health-seeking behaviour was found to be high among civil servants. In another study, Tanimola (2009) examined the Healthcare-Seeking Behaviour of household members in Anyigba, North-Central, Nigeria. The finding of the study revealed that less than half (44.7%) of those who sought treatment patronized public health facilities.

Ogunyemi (2018) examined Health-seeking Behaviour and Self-rated Health of Adult Men in an Urban Local Government Area in Lagos, Nigeria. The study found that the health-seeking behaviour of the men in the study area was influenced by factors such as the severity of illness, availability of funds and subscription to health insurance. The respondents (50.2%) preferred using hospitals, compared to other sources during their last illness episode. The respondents exhibited a preference for hospital visits during their last illness, confirming appropriate health-seeking behaviour in the absence of economic hindrances and other factors.

Researchers such as Kaur, Kumar, et al, (2014) in India assessed the knowledge and attitude regarding care of the elderly among nursing students. Findings indicated that around two-thirds (76.4) were in the good category of knowledge score. The findings from Duru, et al. (2017) on health care seeking behaviour and predictors of combined orthodox and traditional healthcare utilization among households in communities in Owerri, Imo State, Nigeria revealed that, while just more than half of the respondents (56.4%) had a moderate to a good level of overall knowledge of health care.

This finding agrees with Bourne et al. (2010) on literacy and health seeking behaviour of older men among the middle-income nation. The study found that Jamaican elderly men displayed poor health seeking behaviour (and low health literacy). Musoke et al. (2014), about 15% - 30% of the respondents in the present study also regarded traditional healing homes, churches and spiritual healing homes as sources of treatment.

Conclusion

Based on the findings of the study, the following conclusion was made:

The aged population in Kaduna State possesses knowledge regarding health-seeking behaviour.

Recommendations

Based on the conclusion, the study recommended that:

Since the study found that the aged population in Kaduna State possesses knowledge regarding health-seeking behaviour, it is recommended that efforts be made by health educators to continually enhance and update this knowledge. This could be achieved through targeted educational programs, workshops, and information sessions focused on promoting awareness about preventive healthcare measures, disease management, and available healthcare resources.

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NUMERICAL SOLUTIONS OF THE MALTHUS GROWTH MODEL AND PROTHERO-ROBINSON EQUATION USING BLOCK HYBRID METHODS WITH CHEBYSHEV POLYNOMIALS

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Abstract

This paper explores the application of the block hybrid method incorporating Chebyshev polynomials for solving ordinary differential equations (ODEs), with a focus on its enhanced precision and efficiency. The block hybrid method combines the advantages of block methods, which solve multiple points simultaneously, and hybrid techniques, which refine solutions using off-step points, to handle stiff ODEs effectively. Chebyshev polynomials, renowned for their excellent approximation properties, are used to improve accuracy and minimize interpolation errors. This approach is further optimized by varying polynomial degree and block size, as well as adaptive step-size control. The study delves into the theoretical foundations of Chebyshev polynomials, their recursive construction, and their role in enhancing the stability and convergence of numerical methods for ODEs. Furthermore, the paper evaluates the method's performance through numerical experiments, comparing results with existing approaches and demonstrating its superiority in solving complex oscillatory and stiff differential equations, such as the Malthus growth model and Prothero-Robinson equation. The findings highlight the robustness of the Chebyshev-based block hybrid method in providing accurate and efficient solutions for challenging ODEs.

Keywords: Block hybrid method, Chebyshev polynomials, ordinary differential equations, numerical methods, polynomial degree, Malthus growth model and Prothero-Robinson equation.

Introduction

The block hybrid method incorporating Chebyshev polynomials has emerged as a powerful numerical approach for solving ordinary differential equations (ODEs), combining the strengths of block and hybrid methods to enhance both precision and efficiency. Block methods compute multiple points in a single step, improving speed and handling of stiff equations, while hybrid techniques introduce off-step points to refine solutions without significant additional computational effort. Chebyshev polynomials, known for their exceptional approximation and convergence properties, further enhance this framework by minimizing interpolation errors and ensuring numerical stability, making the method suitable for solving complex ODEs with greater accuracy (Ndanusa and Tafida, 2016).

Ongoing research has continued to optimize this approach, focusing on aspects like polynomial degree and block size to boost computational performance. Studies by Shokri (2015) and Kamoh et al. (2018)

have reported notable improvements in accuracy when applying these methods to initial value problems. More recent work, such as that by Ndanusa and Tafida (2016), has introduced adaptive step-size control to dynamically adjust calculations based on the problem's nature, further improving precision and efficiency. Collectively, these advancements highlight the evolving potential and enduring relevance of Chebyshev polynomial-based block hybrid methods in modern numerical analysis.

This study consider the first order initial value problem of the form

$$y'(x) = f(x, y), y(x_0) = \lambda \quad (1.1)$$

The developments of numerical methods for the solution (1.1) have given rise to two major discrete methods (Hasni *et al.*, 2013). One of those discrete numerical methods used to solve stiff initial value problems (IVPs) is multistep methods especially linear multistep methods (LMMs). The general k -step LMM for the solution of Eq. (1.1) is given by Lambert as follows:

$$\sum_{j=0}^k \alpha_j y_{n+j} = h \sum_{j=0}^k \beta_j f_{n+j} \quad (1.2)$$

where α_j 's and β_j 's are constants, $\alpha_k = 0$ and at least one of the coefficients α_0 and β_0 is non-zero.

Several continuous LMMs have been derived using interpolation and collocation points for the solution of (1.1) with constant step size using Chebyshev polynomials as a basis. Chebyshev polynomials are a well-known family of orthogonal polynomials on the interval $[-1, 1]$ associated with certain weight function. Chebyshev polynomials are of great importance in many areas of mathematics, particularly in approximation theory. There are several kinds of Chebyshev polynomials (Shakeri and Dehghan, 2018). The most important kinds of the Chebyshev polynomials is Chebyshev polynomials $T_n(x)$ of first kind. The Chebyshev polynomial $T_n(x)$ of the first kind is a polynomial in x of degree n , defined by the relation by Vlastic *et al.*, (2019) as follows:

$$T_n(x) = \cos(n \arccos x), \text{ where } n \geq 0 \text{ and } x \in [-1, 1] \quad (1.3)$$

The block hybrid method using Chebyshev polynomials has gained significant attention in recent years as an effective numerical approach for solving ordinary differential equations (ODEs). This method combines the strengths of block methods and hybrid techniques, leveraging the properties of Chebyshev polynomials to enhance accuracy and stability. Block methods solve multiple points simultaneously within a single step, which improves computational efficiency and can handle stiff equations more effectively (Sunday *et al.*, 2015a). Hybrid methods, on the other hand, incorporate additional off-step points to refine the solution, thereby increasing the precision without a proportional increase in computational cost. Together, these approaches form a robust framework for addressing the complexities of ODEs.

Definition 1.1: Chebyshev polynomials are a sequence of orthogonal polynomials that arise in the context of approximating functions and solving differential equations. There are two kinds, Chebyshev polynomials of the first kind $T_n(x)$ and the second kind, $U_n(x)$, defined over the interval $[-1, 1]$. The roots of Chebyshev polynomials are also used as nodes in Gaussian quadrature, contributing to their widespread application in numerical methods.

The Chebyshev polynomial of the first kind $T_n(x)$ is a polynomial of degree n defined for $x \in [-1, 1]$ by

$$T_n(x) = \cos(n \arccos x), -1 \leq T_n \leq 1 \quad (1.4)$$

By setting $x = \cos z$, we have

$$T_n = \cos nz \quad (1.5)$$

from which it is easy to deduce the expressions for the recursive relation of Chebyshev polynomials as,

$$T_0 = 1, T_1 = \cos z, T_2 = \cos 2z = 2 \cos^2 z - 1 = 2x^2 - 1, \dots, T_{n+1} = 2xT_n - T_{n-1}, n \geq 1.$$

The T_n is a polynomial of degree n with leading coefficient 2^{n-1} for $n \leq 1$.

Chebyshev basic functions are a set of orthogonal functions that play a significant role in various areas of mathematics, engineering, and physics. They are named after the Russian mathematician Pafnuty Chebyshev. These functions are fundamental in approximation theory, signal processing, numerical analysis, and other fields (Nemati *et al.*, 2016).

The advantage of Chebyshev method lies in its ability to efficiently approximate the solution of the ODE over multiple steps while minimizing the computational cost associated with small step sizes, especially for stiff equations. Additionally, the properties of Chebyshev polynomials contribute to the stability and accuracy of the method. However, like any numerical method, the effectiveness of the Block Method based on Chebyshev Polynomial depends on the specific characteristics of the ODE being solved and the implementation details (Sunday *et al.*, 2015a).

There are several ways to develop the Chebyshev polynomials but there seems to be nothing in the literature which constructs the Chebyshev polynomials of the first kind by explicitly constructing their coefficients. Two methods for explicitly constructing the coefficients of the Chebyshev polynomial equations of the first kind are presented here. Both of these methods begin with the recurrence relation,

$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x) \quad (1.6)$$

and with initial conditions

$$T_0(x) = 1 \quad \text{and} \quad T_1(x) = x \quad (1.7)$$

where $T_n(x)$ denotes the Chebyshev polynomials of the first kind. Both also compute each $T_n^k(0)$ for use in the Taylor series expansion,

$$T_n(x) = T_n(0) + (x-0) \frac{T_n'(0)}{1!} + (x-0)^2 \frac{T_n''(0)}{2!} + \dots + (x-0)^k \frac{T_n^k(0)}{k!} \quad (1.8)$$

where $T_n(0)$ denotes the k^{th} derivative of the n^{th} Chebyshev polynomial evaluated at zero.

Derivation of Chebyshev Polynomial

The general Chebyshev polynomial of function $T_n(x)$ is the best polynomial approximation function known for $f(x)$. In order to express $T_n(x)$ in terms of polynomials, $T_n(x)$ can be used to some extent, but as n value increases, it becomes more difficult to obtain the actual polynomial except by some trigonometric identities, techniques and skill.

For the reason, a simpler way of generating the Chebyshev polynomials is by using the recurrence formula for $T_n(x)$ in $[-1, 1]$.

The recurrence formula for generating the Chebyshev polynomial $T_n(x)$ in $[-1, 1]$ is given by

$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x), \quad n \geq 1 \quad (2.1)$$

Thus to obtain the Chebyshev polynomials, a combination of (1.2) and (2.1) can be used. Starting with the definition (1.1), that is

$$T_n(x) = \cos(n \cdot \cos^{-1} x) \quad (2.2)$$

We obtain the least polynomial when $n = 0$ in (2.2) as

$$T_0(x) = \cos 0 = 1$$

Also, $n = 1$ in (2.2), we have

$$T_1(x) = \cos(\cos^{-1} x) = x$$

When $n = 2$ in (2.2), we have

$$T_2(x) = \cos(2 \cos^{-1} x)$$

With $x = \cos \theta$

$$\begin{aligned}
T_2(x) &= \cos 2\theta \\
&= 2\cos^2 \theta - 1 \\
&= 2x^2 - 1
\end{aligned}$$

For $n = 3, 4, \dots$ it will be getting more difficult to obtain the polynomials. However if we use the recurrence formula (2.1), we can obtain $T_2(x)$ by putting $n = 1$ so that

$$T_2(x) = 2xT_1(x) - T_0(x)$$

Substituting $T_0(x) = 1, T_1(x) = x$ (from the result earlier obtained), we have), we have

$$T_2(x) = 2x(x) - 1 = 2x^2 - 1$$

This is simpler than using the trigonometric identity.

Thus for $n = 3, 4, \dots$ we obtain the next few polynomials as follows:

When $n = 2$, the recurrence formula gives

$$\begin{aligned}
T_3(x) &= 2xT_2(x) - T_1(x) \\
&= 2x(2x^2 - 1) - x \\
&= 4x^3 - 3x
\end{aligned}$$

When $n = 3$, the recurrence formula gives

$$\begin{aligned}
T_4(x) &= 2xT_3(x) - T_2(x) \\
&= 2x(4x^3 - 3x) - (2x^2 - 1) \\
&= 8x^4 - 8x^2 + 1
\end{aligned}$$

We consider the first six terms of the basis function (1.2) as our approximate solution. This is given by

$$y(x) = T_0(x) + T_1(x) + \sum_{n=1}^5 (2xT_n(x) - T_{n-1}(x)) \quad (2.3)$$

We seek the solution of (1.1) on the partition $\pi_N = x_0 < x_1 < x_2 < \dots < x_n < x_{n-1} < \dots < \pi_N = b$ of the integration interval $[a, b]$ with a constant step-size h , given by, $h = x_{n+1} - x_n, n = 0, 1, 2, \dots, N$

Now interpolating (2.3) at point $x_{n+s}, s = 0$ and collocating its first derivative at points $x_{n+r}, r = 0\left(\frac{1}{4}\right)1$

(where S and r are the number of interpolation and collocation points respectively), leads to the following system of equations,

$$XA = U \quad (2.4)$$

Where

$$A = [a_0 \quad a_1 \quad a_2 \quad a_3 \quad a_4 \quad a_5]^T, \quad U = \left[f_n \quad f_{n+\frac{1}{4}} \quad f_{n+\frac{1}{2}} \quad f_{n+\frac{3}{4}} \quad f_{n+1} \right]^T$$

and

$$X = \begin{bmatrix} 1 & -2x_n & -6x_n^2 & -16x_n^3 & 8x_n^4 & 16x_n^5 \\ 0 & -2 & -12x_n & -48x_n^2 & 32x_n^3 & 80x_n^4 \\ 0 & -2 & -12x_{n+\frac{1}{4}} & -48x_{n+\frac{1}{4}}^2 & 32x_{n+\frac{1}{4}}^3 & 80x_{n+\frac{1}{4}}^4 \\ 0 & -2 & -12x_{n+\frac{1}{2}} & -48x_{n+\frac{1}{2}}^2 & 32x_{n+\frac{1}{2}}^3 & 80x_{n+\frac{1}{2}}^4 \\ 0 & -2 & -12x_{n+\frac{3}{4}} & -48x_{n+\frac{3}{4}}^2 & 32x_{n+\frac{3}{4}}^3 & 80x_{n+\frac{3}{4}}^4 \\ 0 & -2 & -12x_{n+1} & -48x_{n+1}^2 & 32x_{n+1}^3 & 80x_{n+1}^4 \end{bmatrix}$$

Solving (2.4), for $0(1)5$ and substituting back into (2.3) gives a continuous linear multistep method of the form,

$$y(x) = \alpha_0(x)y_n + h \left[\beta_0(x)f_n + \beta_{\frac{1}{4}}(x)f_{n+\frac{1}{4}} + \beta_{\frac{1}{2}}(x)f_{n+\frac{1}{2}} + \beta_{\frac{3}{4}}(x)f_{n+\frac{3}{4}} + \beta_1(x)f_{n+1} \right] \quad (2.5)$$

where

$$\alpha_0 = 1$$

$$\beta_0 = t h - \frac{25}{6} t^2 h + \frac{70}{9} t^3 h - \frac{20}{3} t^4 h + \frac{32}{15} t^5 h$$

$$\beta_{\frac{1}{4}} = 8 t^2 h + \frac{208}{9} t^3 h + 24 t^4 h - \frac{128}{15} t^5 h$$

$$\beta_{\frac{1}{2}} = -6 t^2 h + \frac{76}{3} t^3 h - 32 t^4 h + \frac{64}{5} t^5 h$$

$$\beta_{\frac{3}{4}} = \frac{8}{3} t^2 h - \frac{112}{9} t^3 h + \frac{56}{3} t^4 h - \frac{128}{15} t^5 h$$

$$\beta_1 = -\frac{1}{2} t^2 h + \frac{22}{9} t^3 h - 4 t^4 h + \frac{32}{15} t^5 h$$

$$\text{where } t = \frac{x - x_n}{h}.$$

Evaluating (2.5) at $t = \frac{1}{4} \left(\frac{1}{4} \right)$ gives a new discrete chebyshev block method of the form,

$$\begin{aligned} y_{n+\frac{1}{4}} &= y_n + \frac{251}{2880} h f_n + \frac{323}{1440} h f_{n+\frac{1}{4}} - \frac{11}{120} h f_{n+\frac{1}{2}} + \frac{53}{1440} h f_{n+\frac{3}{4}} - \frac{19}{2880} h f_{n+1} \\ y_{n+\frac{1}{2}} &= y_n + \frac{29}{360} h f_n + \frac{31}{90} h f_{n+\frac{1}{4}} + \frac{1}{15} h f_{n+\frac{1}{2}} + \frac{1}{90} h f_{n+\frac{3}{4}} - \frac{1}{360} h f_{n+1} \\ y_{n+\frac{3}{4}} &= y_n + \frac{27}{320} h f_n + \frac{51}{160} h f_{n+\frac{1}{4}} + \frac{9}{40} h f_{n+\frac{1}{2}} + \frac{21}{160} h f_{n+\frac{3}{4}} - \frac{3}{320} h f_{n+1} \\ y_{n+1} &= y_n + \frac{7}{90} h f_n + \frac{16}{45} h f_{n+\frac{1}{4}} + \frac{2}{15} h f_{n+\frac{1}{2}} + \frac{16}{45} h f_{n+\frac{3}{4}} + \frac{7}{90} h f_{n+1} \end{aligned} \quad (2.6)$$

Analysis of the Shebyshev Methods

In this section, we will examine the basic properties of Chebyshev polynomial viz. order and error constant, consistency, zero-stable, convergent and region of absolute stability.

Order and Error Constant

Definition 3.1: The order of a numerical method for solving ordinary differential equations (ODEs) indicates how rapidly the error decreases as the step size h diminishes, with a method of order p having global truncation error proportional to h^p . The error constant is the coefficient of the leading term in the local truncation error expansion, providing a precise measure of the error magnitude for a given step size.

The operator L associated with block hybrid method is given as

$$L[y(x); h] = \sum_{j=0}^k \alpha_j y(x + jh) - h^d \beta_j y^d(x + jh) \quad (3.1)$$

where d is the order of the highest derivative in the differential equation and $y(x)$ is an arbitrary function that is continuous and differentiable on $[a, b]$. Using the Taylor series at point x to expand $y(x + jh)$ and $y^d(x + jh)$ gives

$$L[y(x), h] = c_0 y(x) + c_1 h y'(x) + \dots + c_q h^q y^{(q)}(x) + c_{q+1} h^{q+1} y^{(q+1)}(x) + \dots \quad (3.2)$$

Applying definition (3.1) on the Chebyshev method (2.6), the order of the Chebyshev method (2.6) is $p = [5 \ 5 \ 5 \ 5]$. That is, the Chebyshev method is of uniform order 5.

The error constant is given by

$$C_6 = [4.5776 \times 10^{-06} \quad 2.7127 \times 10^{-06} \quad 4.5776 \times 10^{-06} \quad 2.9630 \times 10^{-06}]^T.$$

Consistency

According to Fatunla (1988), the Chebyshev method (2.6) is consistent due to its order $p \geq 1$. Consistency plays a crucial role in regulating the magnitude of the local truncation error at every computational stage.

Zero Stability

Definition 3.2: A numerical method for solving ordinary differential equations (ODEs) is considered zero-stable if small perturbations in the initial data or in the intermediate steps of the computation do not cause the numerical solution to diverge significantly as the step size decreases. In other words, the method ensures that errors do not grow uncontrollably through the steps of the computation. The block method is said to be zero-stable if the roots Z_s , $s = 1, \dots, n$ does not exist, of the first characteristic polynomial $\bar{\rho}(z)$ is define by $\bar{\rho}(z) = \det[z\bar{A} - \bar{E}]$ has modulus less than one, i.e $|Z_s| \leq 1$ and every roots with $|Z_s| = 1$ has multiplicity not exceeding two.

Using Definition 3.2 for the Chebyshev method in equation (2.6), the first characteristic polynomial is expressed as follows:

$$\rho(z) = z \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} z & 0 & 0 & -1 \\ 0 & z & 0 & -1 \\ 0 & 0 & z & -1 \\ 0 & 0 & 0 & 1-z \end{bmatrix} = z^3(z-1) = 0$$

Thus, solving for z in

$$z^3(z-1) = 0 \quad (3.3)$$

Gives $z_1 = z_2 = z_3 = 0$ and $z_4 = 1$. Hence, the Chebyshev method in equation (2.6) is zero-stable.

Convergence

Theorem 3.1: (Fadugba and Okunlola, 2017)

The necessary and sufficient condition for a Chebyshev method (2.6) to achieve convergence entail both consistency and zero-stability.

According to theorem 3.1, the Chebyshev method (2.6) is convergent because it satisfies both consistency and zero-stability criteria.

Region of Absolute Stability

In order to ascertain the regions of absolute stability for the Chebyshev method, a technique was adopted that circumvents the need for computing polynomial roots or solving simultaneous inequalities. This method, as outlined by Lambert in James et al. (2013), is referred to as the Boundary Locus Method (BLM). By employing the boundary locus method, we derive the stability polynomial for the Chebyshev method presented in equation (3.6) as follows:

$$\bar{h}(w) = \left(\frac{13531}{22118400} w^3 - \frac{61}{172800} w^4 \right) h^4 + \left(-\frac{7751}{3317760} w^3 - \frac{533}{259200} w^4 \right) h^3 + \left(-\frac{3307}{92160} w^3 + \frac{5663}{129600} w^4 \right) h^2 + \left(-\frac{31}{90} w^4 + \frac{523}{1440} w^3 \right) h - w^3 + w^4 \quad (3.4)$$

The depiction of the region of absolute stability for the Chebyshev method (2.6) is illustrated in Figure 3.1 as follows:

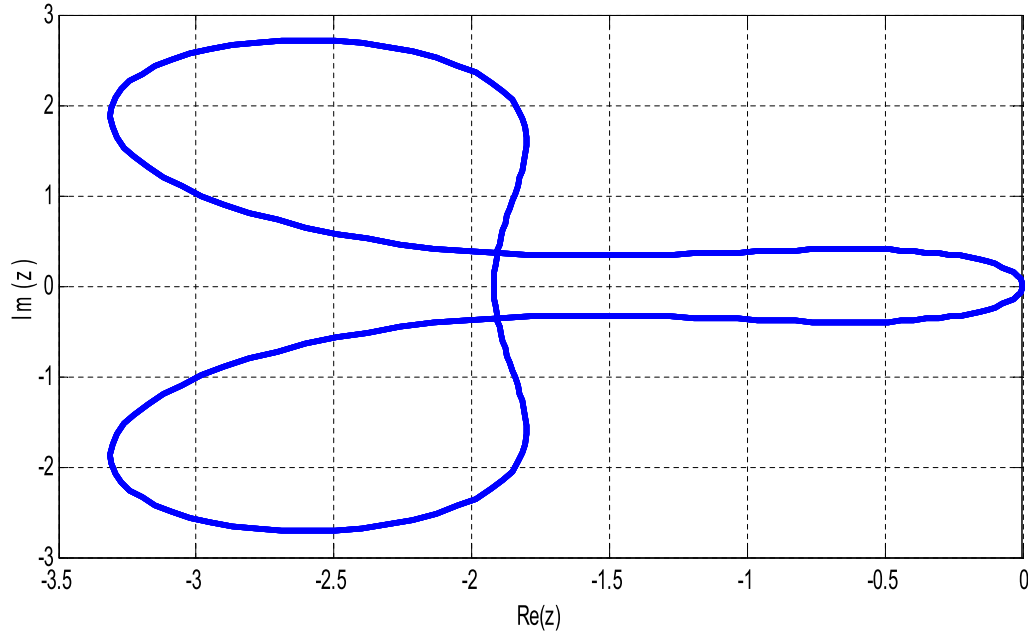


Figure 3.1: Stability region of Chebyshev method (2.6)

Numerical Application

The newly developed block methods were tested on various oscillatory differential equations, including the Malthus Growth Model, the Prothero–Robinson equation, and other stiff problems. Their performance was assessed by comparing the absolute errors with those from existing methods. The comparison involved established approaches by James et al. (2013), Sunday et al. (2014, 2015a, 2015b), Oluwaseun and Zurni (2022), and Yunusa et al. (2024), demonstrating that the new methods offer improved accuracy in solving oscillatory problems.

Problem 4.1 (Malthus Growth Model)

The Malthusian growth model, proposed by Thomas Robert Malthus in 1798, is a theory that explains population growth as an exponential process when resources are plentiful. According to this model, population size can double consistently over time in the absence of limiting factors, while resources such as food grow at a much slower, arithmetic rate.

This imbalance between rapid population growth and slower resource expansion leads to inevitable consequences like famine, war, or disease, which serve to reduce the population. The model is commonly expressed through a simple differential equation that captures this exponential growth dynamic and its long-term implications.

$$\frac{dy}{dx} = kp, \quad x \in [0, 1] \quad (4.1)$$

with the exact solution given by

$$y(x) = 100 \exp(0.250679566129x) \quad (4.2)$$

Initial condition $y(0) = 100$ with $k = 0.250679566129$ and $h = 0.1$

Source: [Oluwaseun and Zurni (2022), Yunusa et al., (2024)].

Problem 4.2: (Prothero–Robinson Equation)

Consider the Prothero–Robinson oscillatory differential equation, previously examined by Sunday et al. (2014) and Sunday et al. (2015a), and expressed in the following form:

$$y' = \Pi(y - \sin x) - y, \quad \Pi = -1, \quad y(0) = 0 \quad (4.3)$$

Which has the exact solution as

$$y(x) = \sin x \quad (4.4)$$

Problem 4.3: (Oscillatory Differential Equation)

James et al. (2013) and Sunday et al. (2015b) conducted studies on the highly stiff oscillatory differential equation, which is given in the following form:

$$y' = x - y, y(0) = 0, 0 \leq x \leq 1 \quad (4.5)$$

Whose exact solution is given as

$$y(x) = x + \exp(-x) - 1 \quad (4.6)$$

Problem 4.4: (Oscillatory Differential Equation)

James et al. (2013) and Sunday et al. (2015b) explored an oscillatory differential equation expressed in the following form:

$$y' = xy, y(0) = 1, 0 \leq x \leq 1, h = 0.1 \quad (4.7)$$

Which possesses a solution that can be expressed analytically

$$y(x) = \exp\left(\frac{1}{2}x^2\right) \quad (4.8)$$

Table 4.1: The results obtained from solving Problem 4.1 were evaluated against those documented by Oluwaseun and Zurni (2022) as well as Yunusa et al. (2024).

x	Exact Solution	Computed Solution	Absolute Errors	Oluwaseun and Zurni (2022)	Yunusa et al., (2024)
0.1	102.53847998347329794000	102.53847998347329594000	2.0000(-15)	1.6677(-08)	0.0000(00)
0.2	105.14139877321154182000	105.14139877321153776000	4.0600(-15)	4.4003(-10)	0.0000(00)
0.3	107.81039213541335645000	107.81039213541335019000	6.2600(-15)	1.7117(-08)	0.0000(00)
0.4	110.54713735987489512000	110.54713735987488658000	8.5400(-15)	8.8005(-10)	0.0000(00)
0.5	113.35335431405805132000	113.35335431405804036000	1.0960(-14)	1.7557(-08)	1.4211(-14)
0.6	116.23080652391598100000	116.23080652391596752000	1.3480(-14)	1.3201(-09)	1.4211(-14)
0.7	119.18130228215516429000	119.18130228215514816000	1.6130(-14)	1.7997(-08)	1.4211(-14)
0.8	122.20669578463047796000	122.20669578463045907000	1.8890(-14)	1.7601(-09)	0.0000(00)
0.9	125.30888829558742918000	125.30888829558740740000	2.1780(-14)	1.8437(-08)	1.4211(-14)
1.0	128.48982934248383035000	128.48982934248380551000	2.4840(-14)	2.2001(-09)	0.0000(00)

Table 4.2: The results from the implementation of Problem 4.2 were compared with those presented by Sunday et al. (2014) and Sunday et al. (2015a)

x	Exact Solution	Computed Solution	Absolute Errors	Sunday et al., (2014)	Sunday et al., (2015a)
0.1	0.09983341664682815231	0.09983341664676181810	6.6334(-14)	1.4530(-11)	1.3422(-11)

0. 2	0.19866933079506121 546	0.19866933079490112 057	1.6010(- 13)	1.6211(- 11)	2.1464(- 11)
0. 3	0.29552020666133957 511	0.29552020666106190 293	2.7767(- 13)	2.1310(- 11)	3.2359(- 11)
0. 4	0.38941834230865049 167	0.38941834230823501 909	4.1547(- 13)	1.3799(- 11)	4.1877(- 11)
0. 5	0.47942553860420300 027	0.47942553860363306 951	5.6993(- 13)	2.7441(- 11)	4.6377(- 11)
0. 6	0.56464247339503535 720	0.56464247339429783 402	7.3752(- 13)	1.1114(- 11)	5.3368(- 11)
0. 7	0.64421768723769105 367	0.64421768723677627 018	9.1478(- 13)	2.8657(- 11)	5.8936(- 11)
0. 8	0.71735609089952276 163	0.71735609089842444 231	1.0983(- 12)	1.9218(- 10)	6.0221(- 11)
0. 9	0.78332690962748338 846	0.78332690962619855 863	1.2848(- 12)	1.2392(- 10)	6.3342(- 11)
1. 0	0.84147098480789650 665	0.84147098480642538 259	1.4711(- 12)	1.4711(- 10)	6.5059(- 11)

Table 4.3: The results of applying Problem 3 were compared with the findings of James et al. (2013) and Sunday et al. (2015b)

x	Exact Solution	Computed Solution	Absolute Errors	Error in Sunday <i>et al.</i> , (2015b)	Error James <i>et al.</i> , (2013)
0. 1	0.00483741803595957 320	0.01873075307848973 871	2.8065(- 13)	1.0899(- 14)	1.6554(- 11)
0. 2	0.01873075307798185 870	0.04081822068240718 936	5.0788(- 13)	3.6577(- 14)	4.3981(- 11)
0. 3	0.04081822068171786 610	0.07032004603647093 476	6.8932(- 13)	4.4761(- 14)	7.8451(- 11)
0. 4	0.07032004603563930 070	0.10653065971357404 058	8.3163(- 13)	6.1209(- 14)	1.2662(- 11)
0. 5	0.10653065971263342 360	0.14881163609504775 915	9.4062(- 13)	6.1209(- 14)	1.9709(- 10)
0. 6	0.14881163609402643 260	0.19658530379248767 157	1.0213(- 12)	7.0592(- 14)	3.0180(- 10)
0. 7	0.19658530379140951 470	0.24932896411833651 335	1.0782(- 12)	7.9268(- 14)	4.5771(- 10)
0. 8	0.24932896411722159 140	0.30656965974173403 784	1.1149(- 12)	8.3601(- 15)	6.8954(- 09)
0. 9	0.30656965974059911 190	0.30656965974173403 784	1.1349(- 12)	9.4146(- 15)	1.0336(- 09)
1. 0	0.36787944117144232 160	0.36787944117258334 769	1.1410(- 12)	9.7071(- 15)	1.5435(- 09)

Table 4.4: The results obtained from applying Problem 4 were compared with the results reported by James et al. (2013) and Sunday et al. (2015b)

x	Exact Solution	Computed Solution	Absolute Errors	Error in James <i>et al.</i> , (2013)	Error in Sunday <i>et al.</i> , (2015b)
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					<i>al.</i> , (2015b)
0. 1	1.00501252085940106 340	1.00501252085939969 930	1.3641(- 15)	1.6554(- 11)	1.2473(- 13)
0. 2	1.02020134002675581 020	1.02020134002671673 550	3.9075(- 14)	4.3981(- 11)	2.4989(- 13)
0. 3	1.04602785990871694 270	1.04602785990849511 400	2.2183(- 13)	7.8451(- 11)	4.0149(- 13)
0. 4	1.08328706767495855 440	1.08328706767420002 750	7.5853(- 13)	1.2662(- 11)	5.7196(- 13)
0. 5	1.13314845306682631 680	1.13314845306482053 410	2.0058(- 13)	1.9709(- 10)	7.5116(- 13)
0. 6	1.19721736312181016 490	1.19721736311726266 460	4.5475(- 12)	3.0180(- 10)	9.2698(- 13)
0. 7	1.27762131320488661 070	1.27762131319556380 360	9.3228(- 12)	4.5771(- 10)	3.0572(- 12)
0. 8	1.37712776433595708 450	1.37712776431812840 570	1.7829(- 11)	6.8954(- 09)	3.1135(- 12)
0. 9	1.49930250005676686 970	1.49930250002432758 070	3.2439(- 11)	1.0336(- 09)	6.1995(- 12)
1. 0	1.64872127070012814 680	1.64872127064321918 960	5.6909(- 11)	1.5435(- 09)	6.6348(- 12)

Discussion of Results

The Chebyshev method for solving ordinary differential equations (ODEs) exhibits several important properties that determine its efficiency and reliability. Order and error constant are essential for understanding the method's accuracy. The method is of uniform order 5, meaning the global truncation error decreases proportionally with the step size raised to the fifth power. The error constant provides a measure of the error magnitude, allowing for precise control over computational accuracy. Consistency is another fundamental property, indicating that the method aligns with the differential equation as the step size approaches zero. The Chebyshev method is consistent of order 5, ensuring that the local truncation error remains controlled at each computation stage.

Another critical property is zero stability, which guarantees that small perturbations in the initial data or intermediate computations do not cause the solution to diverge. For the Chebyshev method, the roots of the first characteristic polynomial have moduli less than one, which satisfies the criteria for zero stability. Convergence is assured when both consistency and zero stability are met, and since the Chebyshev method satisfies these conditions, it is convergent. Finally, the region of absolute stability characterizes the method's behavior in the complex plane. By applying the Boundary Locus Method (BLM), the region of absolute stability for the Chebyshev method is determined, ensuring that the method can provide stable solutions over a wide range of problems.

The results for Problem 4.1 (Malthusian Growth Model) demonstrate that the numerical method used to solve the differential equation produces solutions with very small errors compared to the exact solutions. The consistency in the accuracy of the computed solutions, which align closely with results from other studies, highlights the reliability and precision of the method. This reinforces the method's robustness in solving exponential growth models.

For Problem 4.2 (Prothero-Robinson Equation), the numerical method again shows promising accuracy, with small errors consistent with published results. Despite slight variations in error magnitude, the computed solutions accurately reflect the oscillatory behavior of the differential equation, confirming

the method's effectiveness for such problems. This underscores the method's suitability for handling oscillatory systems in various scientific applications.

In Problem 4.3 (Oscillatory Differential Equation), larger errors were observed in some cases, likely due to the stiffness of the equation. However, the method still provided useful approximations, although it may need refinement for solving more stiff systems. For Problem 4.4 (Oscillatory Differential Equation), the method produced highly accurate solutions, with errors smaller than those found in previous studies. This further validates the method's precision and robustness in solving complex oscillatory systems, making it a valuable tool for modeling real-world phenomena.

This research explores the use of block hybrid methods with Chebyshev polynomials for solving ordinary differential equations (ODEs), focusing on their application to both stiff and non-stiff problems. The study compares different polynomial degrees and step-size control strategies, highlighting their impact on the accuracy and efficiency of the solutions. Through test cases such as the Malthus growth model and Prothero-Robinson equation, the findings demonstrate that higher-degree Chebyshev polynomials improve accuracy, while adaptive step-size control enhances computational efficiency, particularly for stiff ODEs. The results suggest that these block hybrid methods are effective and reliable for solving ODEs in various scientific and mathematical contexts, with potential for further optimization in future research.

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