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Aims and Scope

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Original Article

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Dietary Intake, Physical Activity and Prevalence of Central Adiposity among Middle Age Adult Females in Nigeria

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Abstract

Dietary intake and physical activity are factors causing fat accumulation under the skin around the abdominal area. The study determines relationship between feeding pattern, physical activity and occurrence of central adiposity. This is a descriptive study involving 1050 respondents randomly selected within 18 Local Government Areas of Ondo State between August, 2019 and February, 2020. Self- administered questionnaires were used to determine socio-economic status, dietary assessment and physical activity of the respondents. Nutri-survey software was used to determine the mean energy intake. Anthropometric indicators such as Waist Hip Ratio (WHR), Waist Circumference (WC) and Waist Height Ratio (WHtR) were used to ascertain the central adiposity and Pearson correlation was used to determine the level of correlation. The socio-economic status showed that only 14.91% earned ≥₦50,000 monthly (104.17$) (1USD at ₦480). The mean energy intake (3241±78.6Kcal. and 2981.00±64.4Kcal. respectively) was higher than the Recommended Dietary Allowance (RDA). Central adiposity was high (WHR; 35.54%, WHtR; 76%) among the respondents. There was a significant correlation between feeding pattern (WHR; $r = 0.54$; $p < 0.00$) and those who involved in less (≤ 30 minutes) or no physical activity (WHR; $r = 0.58$; $p < 0.00$). This study showed positive relationship between feeding pattern and physical activity with prevalence of central adiposity in Nigeria.

Keywords: Females, middle age adults, feeding pattern, physical activity, central adiposity

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Introduction

There was an increase of 20% in the rate of obesity between 2002 and 2010 in Nigeria (WHO, 2010). The trend in obesity among Nigerians is still of public health concern. The obesity found at the central part of the body known as central adiposity also called abdominal obesity, is a form of obesity that configures an individual shape to an apple shape-like due to the area of the fat concentration (Bacon and Aphramor, 2011). Central adiposity has been shown to be related to imbalances in energy intake and the energy expenditure. However, research has suggested that genetic, physiological and behavioral factors play a significant role in the etiology of central adiposity (Heianza and Qi, 2019)

According to Heianza and Qi (2019), central adiposity is associated with a number of disease conditions, including hypertension, type 2 diabetes mellitus, cardiovascular diseases, cancer, gallstones, respiratory system problem and sleep apnea. Central adiposity, independent of Body Mass Index, is associated with esophageal inflammation (EE), metaplasia (BE) and neoplasia (EAC) (Seiji *et al*., 2016). The increase in the risk of diseases associated with central adiposity is thought to be due to the hormonal action of visceral fat, which can actively excrete adipokines, which mostly impair glucose tolerance (Bacon, 2013).

In Nigeria, non-communicable diseases are now overtaking communicable diseases and this factor is the leading causes of morbidity and mortality rate in the region (Oladapo *et al*., 2010). The changing in the disease pattern has also been attributed to food in transition which includes changes in diet, alcohol consumption, and inadequate exercise (Chukwuonye *et al*., 2013). Physical activities and eating behaviors of the adults in Nigeria have been shown as the major causes of accumulation of fats among this age group. More than 80% of urban, professional Nigerian adults do not meet the WHO recommendations of physical activity. Urbanized Africans had low levels of leisure-time physical activity, independent of age, sex and body-mass index. This has major implications on the prevalence of non-communicable diseases among this population (Akarolo-Anthony *et al*., 2014). There was a socio-demographic correlates carried out by Adegoke and Oyeyemi (2011) among the adults in the Southern and Northern parts of Nigeria, it was revealed that only 41% were physically active and that the females in the Northern part of Nigeria were more likely less active.

The prevalence of abdominal obesity and general obesity has increased tremendously globally, especially during adulthood (Ejike and Ijeh, 2012). According to WHO (2020), approximately 1.2 billion people in the world are overweight and at least 300 million of them were obese comprising both general and central obesity. In Nigeria, the prevalence of overweight individuals ranged from 20.3%–35.1%, while the prevalence of obesity ranged from 8.1%–22.2% and this condition has been attributed to increase in non-communicable diseases rate. The objective of the study was to determine the relationship between feeding pattern, physical activity and occurrence of central adiposity.

Materials and methods

Sampling Procedure

This was a descriptive study design in which purposive sampling method was used to assess middle age female adults. Random sampling method was thereafter used to select the total number for the sample size. This was carried out to determine incidence of central adiposity and its correlation with

physical activity and feeding pattern. A total number of 1050 middle age adults were randomly selected in eighteen Local Government Areas (LGA) of Ondo State. Informed consent was signed by the respondents before the assessment was carried out on each individual and the participation was voluntary. A semi-structured-questionnaire was sectionalized to elicit information of the respondents on socio-demographic/economic status such as age, sex and marital status, place of residence, educational status and level of income per month.

Assessment of dietary intake

To assess the dietary intake of the respondents, two relevant dietary assessment tools (24hr-dietary recall and food frequency questionnaire were used). The 24 hours dietary recall questionnaire was used in line with estimates of food serving sizes and quantity of food eaten by the respondent. These were based on available food models, house hold measuring tools and market prices. The mean energy intake of the food consumed in the last 24 hours was recorded and the mean energy intake was determined using the Nutri-survey (2007) software. The software was used to analyse nutrient intake, especially, carbohydrates, protein and fats.

A food frequency questionnaire (FFQ) was adapted and validated for the assessment of the respondents' feeding pattern in this study. The questionnaire was concerned with the frequency of consumption of selected commonly consuming local foods and food products. This comprises food items from roots and tubers, fish and meat products, fats and oils, fruits and vegetables. The vegetables were categorized into two (2); those that could be eaten without passing through boiling process and those that passed through boiling and made into soup. The frequency of consumption of each food items was assessed and recorded on a 4 points scale (daily, weekly, monthly or rarely) with number of time the food was consumed.

Assessment of Physical activity

The respondents' physical activities were assessed based on two forms of questions. The first question was on the frequency of physical activity which was categorized on (i) 1-2; (ii) 3-4times per week; (iii) more than 4 times per week. The second question was based on time/duration of the physical exercise to determine the intensity of the physical exercise which was categorized as follows (i) ≤ 30 minutes (low intensity) (ii) 1-2 hrs (average intensity) (iii) ≥3hrs (high intensity). The total number of hours was added and converted to total minutes spent on physical exercise per week based on WHO (2020) physical activity recommendation for age 18-64 years.

Anthropometric measurement

Waist circumference (WC), Waist Hip Ratio (WHR) and Waist Height Ratio (WHtR) assessments were carried out using anthropometric instruments such as tape rule and height-o-meter. The assessments were taken using standard procedure by Helen (2018), Gharakhanlou *et al*. (2011) and Chih-Chiang *et al*. (2015). The WC measurement was taken in a standing position, with a tape measure within an accuracy of 0.1 cm, midway between the rib and the iliac crest. WC value was calculated as ≥94 cm for males and ≥80 cm for females. WHtR was also used, with the value ≥0.5 indicating the prevalence of obesity. WHtR was calculated according to the formula of waist circumference (waist (cm)/height (cm). However, for the purpose of WHR (according to the formula waist circumference (cm)/hip circumference (cm)), border points' value was applied according to WHO for female adults (≥0.85) and central obesity was determined. The collected data were analysed using SPSS version 22.1 for

inferential and descriptive statistics. Pearson correlation was used to determine the correlation significant level. A significant level of P ≤0.05 with any of the variables is termed a significant factor.

Results

The Socio demographic characteristics as shown in Table 1 revealed that 554 out of the 1050 respondents (52.76%) were 46 to 55 years of age and the mean age of the respondents is 46.25. The marital status showed that 78.66% were married, and more than half (55.43%) resided in the rural area. It was further observed in Table 1 that less than a quarter of the respondents (23.04%) had a degree/HND, meanwhile 32.66% had OND/NCE. Majority (61.43%) was petty trader, just 14.91% earned above ₦50,000 monthly.

Table 1: Socio demographic and economic status of the respondents

Socioeconomic status	Frequency(1050)	Percentage (%)
Age		
36-45	496	47.24
46-55	554	52.76
Marital status		
Single	52	4.95
Married	826	78.66
Separated /divorced	136	12.95
Widow	36	3.44
Place of residence		
Rural area	582	55.43
Urban area	468	44.57
Educational level		
No formal education	15	1.43
Primary/secondary education	450	42.86
NCE/OND	343	32.66
Degree /HND	242	23.04
Occupation		
Business woman	56	5.33
Petty trader	645	61.43
Farming	232	22.10
Civil servants	105	10.00
Unemployed	12	1.14
Average monthly income		
≤₦30,000	244	23.23
₦31,000-₦35,999	241	23.00
₦36,000-₦40,999	408	38.86
≥₦50,000	157	14.91
Access to food		
Enough money to buy food		
Yes	832	79.23
No	218	20.77

The food frequency showed the food usually consumed by the respondents. Daily intake of roots and tubers was the highest as it was categorized on number of times; once (19.90%), 2-3times (32.47%) and while some take this food groups more than 4 times daily (34.48%). The least consumed daily food among the respondents was vegetables (raw consumption); at least once daily (4.10%), 2-

3times daily (2.20%) and none eat more than 4 times daily.

Table 2: Food frequency of the respondents

Food groups	Food frequency						
Root and tubers	Never or <1/ month (%)	1-3 per month (%)	1 per week (%)	2-4 per week (%)	1 per day (%)	2-3 per day (%)	4+ per day (%)
Cassava, yam, cocoyam or some other foods made from root and tubers	8 (0.76)	12 (1.14)	11 (1.05)	107 (10.19)	209 (19.90)	341 (32.47)	362 (34.48)
Cereals and cereals products							
Millets, corn, sorghum, rice, wheat, or some foods made from cereals e.g custard, bread, biscuits	25 (2.38)	90 (8.57)	34 (3.24)	73 (6.95)	743 (70.76)	62 (5.90)	23 (2.19)
Nuts and seeds							
Groundnuts, melon seeds, coconuts, tiger nuts, cashew nuts or food made from nuts. e.g melon seeds soup, groundnut seeds soup, tiger nuts milk, coconut milk	102 (9.71)	108 (10.29)	114 (10.86)	124 (11.81)	518 (49.33)	59 (5.62)	26 (2.48)
Legumes							
Cowpeas, soybeans or foods made from legumes e.g*moinmoin* (steamed bean pudding with oil)*, ekuru* (steamed bean pudding without oil), beske (soyabeans cake with oil), soy milk	274 (26.10)	214 (20.38)	96 (9.14)	205 (19.52)	261 (24.86)	-(0.00)	-(0.00)
Fish and fish products							
Fresh, dried fish, white crayfish, brown crayfish	4 (0.38)	54 (5.14)	106 (10.10)	208 (19.81)	432 (41.14)	164 (15.61)	82 (7.81)
Organ meat							
Kidney, liver, heart and other organ meats	274 (26.09)	88 (8.38)	116 (11.05)	156 (14.86)	182 (17.34)	189 (18.00)	45 (4.29)
Flesh meat							
Beef, goat, rabbits, lamb, duck, game, chicken other birds and edible insects and worms	22 (2.10)	128 (12.19)	129 (12.29)	141 (13.43)	518 (49.33)	64 (6.10)	48 (4.57)
Milk and milk products							
Evaporated milk, skimmed milk, local cheese and yogurt	146 (13.90)	101 (9.63)	194 (18.48)	156 (14.85)	123 (11.72)	167 (15.90)	163 (15.52)
Fruits							
Mongo, pineapple, papaya, orange and fruit drinks	110 (10.48)	231 (22.00)	186 (17.71)	167 (15.90)	143 (13.62)	132 (12.58)	81 (7.71)
Vegetables for raw consumption							
Cabbage, cucumber, carrots, lettuce, beetroots, broccoli	327 (31.14)	468 (44.57)	127 (12.09)	62 (5.90)	43 (4.10)	23 (2.20)	- (0.00)
Vegetables for soup							
Amaranths, jute leaves, okro, spinach, mushrooms	143 (13.61)	126 (12.00)	242 (23.05)	245 (23.33)	172 (16.33)	102 (9.71)	20 (1.90)
Fats and oils							
Red oil, palm kernel oil, margarine, butter and other saturated fat and oil	-(0.00)	-(0.00)	134 (12.76)	232 (22.10)	456 (43.43)	126 (12.00)	102 (9.71)

Abbreviation: Percentage - %

The feeding pattern and frequency of fatty foods consumptions reveals that more than a three-quarter of the respondents (85.62%) ate between 3 to 4 meals per day. It was only 11.62% that skipped meals which is majorly breakfast. About 72.48% ate dinner after 6pm, majority (69.61%) ate vegetable with red oil stew or melon seed soup with fufu,

more than half (56.57%) visited fast foods joint, less than half (42.67) preferred plant food sources, and just 16.38% ate fruits and vegetables regularly (Table 3).

Table 3: Feeding pattern and frequency distribution of foods

Variables	Frequency (1050)	Percentage %
Number of meals per day		
1-2	122	11.62
3-4	899	85.62
Above 4 times	29	2.76
Usually skip meals?		
Yes	122	11.62
No	928	88.38
If yes, which meal		
Breakfast	79	64.75
Lunch	25	20.49
Dinner	18	14.76
Food usually take for dinner		
Before 6pm	289	27.52
After 6pm	761	72.48
Intake of high calorie local delicacy for dinner		
Okro with *fufu*	187	17.82
Beansporridge	132	12.57
Eforiro(vegetable with red oil stew) / melon seed soup with fufu	731	69.61
Always visit fast foods joint		
Yes	594	56.57
No	456	43.43
Food sources you like best		
Plant food sources	448	42.67
Animal food sources	602	57.33
How often do you eat fruit and vegetables		
Rarely	256	24.38
Once per week	622	59.24
Regularly	172	16.38

The data representation of the physical activity and lifestyle of the respondents as seen from the table below (Table 4), reveal that just 182 of the 1050 respondents (27.33%) engaged in some form of physical exercises which mostly is jugging/brisk walking (30.77%). Majority of the respondents (50.55%) exercised between one and two hours daily, mostly (46.70%) for three to four times weekly.

Table 4: Physical activity and lifestyle of the respondents

Variables	Frequency (1050)	Percentage (%)
Do you engage in any physical exercise?		
Yes	182	27.33
No	868	82.67
If yes, which of these exercises?		
Jugging /brisk walking	56	30.77
Skipping	43	23.63
Dancing	51	28.02
Table tennis	20	10.99
Volley ball	12	6.60
Minutes/intensity of exercise		
≤30 minutes (low)	58	31.87
1-2hrs (average)	92	50.55
3hrs(high)	32	17.58
Times of exercise weekly		
1-2 times	52	28.57
3-4 times	85	46.70
>4 times	45	24.73

A mean energy intake score by age group of the respondent shows that between the ages of 36 and 45, the average energy intake was 3241±78.6 kcal which was significantly higher than the ages of 46 – 55 whose mean energy intake was 2981±64.4 kcal as revealed in Table 5.

Table 5: Mean energy intake by age group of the respondents

Variable (Age)	Carbohydrates (g)	Proteins (g)	Fats (g)	Mean Energy	%RDA
36-45	517.00	103.00	84.60	3241.42±78.6	120.05
46-55	483.00	97.00	73.44	2981.00±64.4	110.41
Difference	34.00	6.00	11.16	260.42	9.64

Abbreviation: RDA – Recommended Dietary Allowance

Based on the WHR measurement, 35.34% of the respondents were at high risk of central obesity. About the same percentage (35.43%) were at high risk according to the WC measurement. However, most (76%) of the respondents were at high risk for central obesity according to the WHtR measurement.

Table 6: Distribution of Female adults by WHR, WHtR and WC

Variables	Frequency (1050)	Percentage (%)
WHR		
Low risk/ normal at 0.80	287	27.33
Moderate risk (0.81-0.85)	392	37.33
High risk (>0.85)	371	35.34
Wc		
Low risk/ normal at <80	288	27.43
Moderate risk (80-0.87)	390	37.14
High risk (≥88)	372	35.43
WHtR		
Low risk/ normal <0.5	252	24.00
High risk >0.5	798	76.00

Abbreviations: Waist-to-Hip Ratio (WHR); Waist-to-Height Ratio (WHtR); Waist Circumference (Wc).

Pearson Correlation showed the relationship between some variables compared against the three anthropometric measurements used for the Central Adiposity of the respondents. The result as shown in Table 7 shows that at p ≤0.05, there was positive significant relationship between all the variables involved. The time at which dinner was taken among the respondent also showed significant relationship with WHR (r=0.34, p=0.04) and WHtR (r=0.44. p=0.00).

Table 7: Pearson Correlation of central adiposity of the respondents with some variables

Variables	WHR		WC		WHtR	
	r	p-value	r	p-value	r	p-value
Age	0.46	0.00	0.48	0.00	0.42	0.00
Income	0.37	0.01	0.57	0.00	0.37	0.01
Feeding pattern/frequency	0.56	0.00	0.66	0.00	0.46	0.00
Time taking dinner	0.34	0.04	0.44	0.00	0.44	0.00
Intake of fattening local delicacy for dinner	0.54	0.00	0.56	0.00	0.48	0.00
Eating food from animal food sources	0.42	0.00	0.42	0.00	0.52	0.00
Time spent on exercise	0.58	0.00	0.48	0.00	0.48	0.00
Type of exercise	0.47	0.00	0.46	0.00	0.36	0.02

Abbreviations: Waist-to-Hip Ratio (WHR); Waist-to-Height Ratio (WHtR); Waist Circumference (Wc).

Note: r – correlation: p-value (P= 0.005)

Discussion

This study captured the prevalence of central adiposity among the female middle age adults. The socio-demographic and economic attribute revealed that majority of the females were married and were occupied with a particular occupation especially petty trading. They were low-income earners as most of the females were petty traders and this was in line with Akinrinmade *et al.* (2019) which showed that over 40% of mothers in Ondo State lived below ₦50,000 monthly (104.17$) (1USD at 480 naira). The study showed that most of the female had tertiary education. This corroborates Onafowokan and Rufai (2014) which stated

that 47.1% of females in the state had tertiary education.

The feeding behavior as related to feeding pattern and food frequency distribution of the respondents showed that majority fed on local dishes such as *fufu,* a common local food usually made of cassava. Cassava is one of the energy dense foods from plant origin. Montagnac *et al*. (2009) showed that 100g of cassava flour contains 160 kcal with low fibre content of 1.8g. Meanwhile, de. Jong (2021) showed that 100g of cassava flour contains 350 kcal of energy which is interpreted to 1463 kg of energy. This shows that the respondents consume local foods which are rich in calories and this could be stored in the body, if the body energy expenditure is lower than the body energy intake.

The fufu is usually consumed with local soup which majorly are *efo riro* (cooked vegetable soup with red oil), *efo elegunsi* (cooked vegetable with melon seeds soup and red oil) and okro soup with red oil. These local soups were mostly cooked with red oil which is normally noticeable in the soups. Most of the females preferred these meals for dinner. Boateng (2016) revealed that red oil contains high saturated fat like the fats from animals. The author stated that red oil contains 94-98% of triglycerides and that red oil is 80% more saturated than oil from the palm kernel seed. Pénicaud *et al.* (2000) stated that **adipocyte** metabolism is mostly regulated by sympathetic nervous system and hormones catecholamines, which leads to lipolysis that consists of **triglyceride** breakdown.

The combination of red oil and melon seeds for soup increased the total energy intake of the respondents. Igbene (2021) and Charrondiene *et al*. (2012) showed that 100g of melon seed contains 593 calories due to high contents of fat (47.9 g). The *efo riro* (cooked vegetable soup) is characterized with overcooked vegetables and red oil. The effects of too much of heats on vegetable fibre by Zia-ur-Rehman *et al*., (2003) showed that too much of heat reduce the dietary fibre's cellulose, hemicellulose and the natural detergent fibre. The intake of cooked vegetables such as Amaranths is high among the respondents. The vegetables have to pass through cooking process before the consumption. Effects of cooking on vegetables have been shown to reduce fibre capacity such as cellulose, hemicelluloses, lignin and pectin (Vasishitha and Srivastava, 2013). The same process was followed by the respondents in the cooking of the okro soup. The vegetable intake of the respondents was low and even when taking the fibre in the vegetable soup has been over cooked.

The respondents' dietary pattern also showed that majority of the women preferred food from animal sources such as beef, poultry, goat and game. Daily fleshy meat consumption is high as majority takes fleshy meat daily even twice or more daily. Meanwhile, Vergnaud *et al*. (2010) stated that processed meat, red meat, and poultry consumption had association with weight gain especially abdominal obesity. De Moura e Dias *et al*. (2021) revealed that high fat diet with high concentration of saturated fatty acids, have a high caloric density, which stimulates weight gain and body fat gain.

Majorly, the regular food intakes among the correspondents were low in raw and uncooked vegetables such as cucumber. Olatona and Obrutu (2018) revealed that there was low intake of vegetables and fruits among people living in South-west Nigeria. Low intake of fibre is regarded as lack of vegetable intake in the diet of the respondents; this could make the female middle age adults in Ondo State to be prone to central adiposity. Lin *et al*. (2018) showed that dietary fibre is a leading factor in the

prevention of obesity. The author stated further that dietary fibre as the residue of plant foods resistant to hydrolysis by human enzyme increased the bulkiness of stool and feacal mass thereby lowering the transit time. In addition, it was stated that, water soluble fibre can produce gas and short chain fatty acids causing longer lasting satiety and lowering the glycemic index of a food. The feeding pattern of the respondents explained above, are pointers to the accumulation of fats around the stomach among the respondents even with low economic status.

Physical activity of the respondents was poor, it was recorded that one fifth of the responded participated in a physical exercise. Among the total number recorded for physical activity, jugging and walking was recorded to be the most form of exercise usually participated by the respondents. Cox (2017) showed that individuals who are less physically active are more likely to gain weight. Redman *et al*. (2007) in a research to determine weight loss among some overweight participants revealed that those participants in weight loss group achieved 10% weight loss through physical activity. Also, Ross *et al.* (2000) showed that obese men (BMI 31.3±2.0kg/m^2) demonstrated 7.5 kg weight loss over three months of exercise.

Inability of the respondents to involve in physical activity coupled with intake of high calorie diet could be the leading cause of high risk of central adiposity among the female adults in the state. Cox (2007) stated that, in achieving weight loss, it is important to recognize the challenge of monitoring dietary intake and exercise intensity. For those that were participating in physical exercise, the intensity of ≤30 minutes was the highest and this was recorded as low intensity. Meanwhile majority were not participating in any form of physical exercise in accordance to the food intake to reduce the weight accordingly in the body system.

Conclusion

The study showed that most of the female respondents were married while trading activities was their occupation. Fufu was observed as the common food among the respondents and it is rich in high calories. It is consumed mostly with different soup such as, *efo riro*, *efo elegusi*, and *okro soup* which are rich in red oil. The prevalence of central adiposity was higher among the age between 36-45years than age 46-55years. Also, the mean energy intake of the respondents was higher among the lower age (36-45) than age 46-55years. Feeding pattern and low physical activity were associated with the occurrence of central obesity among the respondents. The study concluded that positive relationship exists between the feeding pattern and physical activity with prevalence of central adiposity in the study area.

Recommendation

The study therefore, recommended regular physical exercise with higher intensity since the local foods is rich in dietary energy and the foods are taking two to three times daily.

There should be reduction in the intake of red oil, fufu and fleshy meats which are the main sources of high dietary energy intake among the middle age female adults, in order to avoid unnecessary accumulation of fat. Intake of fresh vegetables should be encouraged as this has been proved by researchers to assist in facilitating of bowel movement which can as well reduce the bowel load.

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Conflict of interest

There is no conflict of interest during this study and after this study

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Impact of African Yam Beans (*Sphenostylis stenocarpa*) Flour Incorporation in Wheat Flour for Composite Noodles Production

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Abstract

Composite flour prepared from African yam bean (AYB) was supplemented in wheat flour (WF) at varied concentration (15 %, 30 % and 45 %) to produce composite noodles while 100 % WF prepared noodles was used as the control. The cooking characteristics (cooking time, cooking loss, volume and weight), the proximate analysis, total phenol, antioxidant property and the sensory evaluation of the prepared noodles were determined. WF noodles had the highest cooking time, cooking loss, volume increase and weight followed by AYBF-30 while AYB-45 noodles had the least of values (6.22 minutes, 6.72 %, 80.00 % and 59.00 % respectively). The AYB-45 noodles had the highest ash (1.09 %), fat (0.98%), moisture content (2.61%) and DPPH property. There was significant difference ($P < 0.05$) in the total phenol content of AYB-30 in comparison to WF (100 %) and other AYBF noodles. However, AYB-30 had the highest value of total phenol. The subjective sensory evaluation of consumers accepted AYB flour noodles at all composite percentage, however, scores for the AYB flour noodles were lower than WF noodles. WF (100 %) was most preferred. Nevertheless, the values of cooking characteristics observed in AYBF-30 noodles were closer to the values that obtained in WF noodles. It could therefore be suggested that AYBF-30 composite noodles could be successfully used in the nearest future as one of the enhanced simple fast foods to consume and also its nutritional and antioxidant potentials could be of paramount importance especially in this present time of assessing food insecurity and malnutrition.

Keywords: Wheat flour, African yam bean, total phenol, DPPH, cooking characteristics

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Introduction

Extrusion produced food such as noodles is one of the categories of pasta that is known to be commonly consumed by Asians (Gulia *et al*., 2014). Noodles belong to groups of quick cooking foods that are progressively gaining acknowledgement in Nigeria. Sequel to this is the observed increase in the level of its acceptance more so that children prefer it and even enjoy it better than most traditional diets. The adaptable nature of noodles arrays from long shelf life, to convenience, fast means of preparation especially as breakfast and sometimes eaten as snacks are characteristics that are mostly appreciated among urban residents (Okafor *et al*., 2015). The foremost ingredient of noodles is wheat flour which is mixed with a precise volume of water to produce pasta extrusion that contains starch that is slowly digested and absorbed (Wolever *et al*., 2013). The micronutrients content of wheat flour is very small compared to the flour from legume such as African yam beans. Legumes augmented cereals have been noted for their nutritional advantages and also as a means of enhancing dietary diversity to combat the challenges postured by food insecurity (de Onis and Branca, 2016). From the economy point of view, the incessant importation of wheat flour has led to the depletion of Nigeria's gross domestic product (GDP), hence the need to look towards the direction of patronizing the locally produced underutilized legume to arrest food related health issues among susceptible Nigerians (FAO, 2011).

African yam bean (AYB) (*Sphenostylis stenocarpa*), is an underutilized legume that possess the ability to provide nutritious food for the progressive increase of population in Nigeria (Ekop *et al*., 2006). According to collected data, Nigeria is one of the highest producers of AYB (Potter, 1992) in the world. Currently, Nigerians are increasingly demanding for ready-to-eat, convenient and fast food. The paradigm shift in the current style of eating has precipitated the condition of malnutrition due to deficiency in food quality, coupled with hidden hunger. This has contributed to the death of more than half a million new born and growing children (Onyezilli, 1999). AYB can be incorporated in cereal based extruded food to augment nutritional contents (both micronutrients and macronutrients) that must have been lost during processing (Nwadi *et al*., 2020).

African yam bean is a plant that has small lipid content. Hence, it is considered as a pulse. AYB also contains saturated fatty acids like oleic acid and polyunsaturated fatty acids like linoleic and linolenic fatty acids (Ade-Omowaye *et al*., 2015). The presence of these essential fatty acids is imperative in human meals for the overall wellness of human body. The condition that it cannot be synthesized by the body necessitates its supply via diet (Abioye *et al*., 2015). The earlier analysis of African yam bean had revealed the presence of ash content which is an indication of mineral content (Baiyeri *et al*., 2018).

In addition, the AYB has also been reported to be a rich source of polyphenolic compounds that impact health benefits to consumers in the prevention of lifestyle diseases (Duodu and Apea-Bah, 2017). AYB is a plant with prolong time of cooking due to its hard-to-cook nature (George *et al*., 2020). However, the conversion of AYB to a ready-to-eat product through incorporation in wheat flour will provide the desired composite mixture as the sensory characteristics of the end product will not be perceptibly changed and most importantly will be economically inexpensive to people with low income. On

the long run, AYB would serve as a potential solution to the consequences of hidden hunger among Nigerians. This study thus sought to produce nutritious composite noodles by incorporating AYB in wheat flour at varied concentrations (15 %, 30 %, and 45 %) and to evaluate proximate composition of WF-AYBF blends, as well as cooking attributes, total phenol content, antioxidant potential, and sensory attributes of the noodles, with the aim of promoting utilization of AYB.

Materials and Methods

Materials

African yam bean (AYB) seeds were purchased from Osele market, Ikare-Akoko, Ondo State, Nigeria (7.5248 ºN, 5.7669 ºE). The bean seed was identified and authenticated as *Sphenostylis stenocarpa* (Hochst ex A. Rich) with designated Voucher Number- 257 in the herbarium of Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria. The beans were picked to remove farm dirt and all other impurities, milled into flour in a hammer mill 3,100 (Perten Instruments AB, Huddinge, Sweden), then sifted through a 250-µm sieve and was stored until further use. Also from the same market, commercial wheat flour was purchased from flour shop. All chemicals and reagents used were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO), while the water was glass distilled.

Preparation of blends

Preparation of noodles blends was carried out at varied percentage of African yam bean flour incorporation (15 %, 30 % and 45 %) in wheat flour. Wheat flour (100 %) was used as control and are presented in Table 1.

Table 1. **Blending ratios of WF and AYBF**

Samples	WF	AYBF
WF-100	100	0
AYBF-15	85	15
AYBF-30	70	30
AYBF-45	55	45

Keys: WF= Wheat flour. AYBF= African yam bean flour. AYBF-15: 15% of AYBF and 85% of WF. AYBF-30: 30% of AYBF and 70% of WF. AYBF-45: 45% of AYBF and 55% WF. Each blend totalled 100%.

Production of noodles formulated from AYBF and WF

The production of Noodles was according to the method of Ritika *et al*. (2016). Two hundred grams (200 g) of flour, 75 mL of water and 2 g of salt as the standard ingredients were mixed for 5 minutes through the use of noodle making machine (La Monferrina, Italy) which has dough making section that mixed and kneaded the ingredients together. The dough was sheeted with noodle press by maintaining a gap of 2.5 mm which was folded and rolled three times each through successively decreasing roller gaps of 2.04 mm, 1.65 mm, and 1.10 mm. The dough sheet was finally cut into 2.0 mm wide noodles with a roller cutter, air dried at room temperature (27 °C) for 12 hrs and then

stored at room temperature in polythene bags for further use (Figure 1).

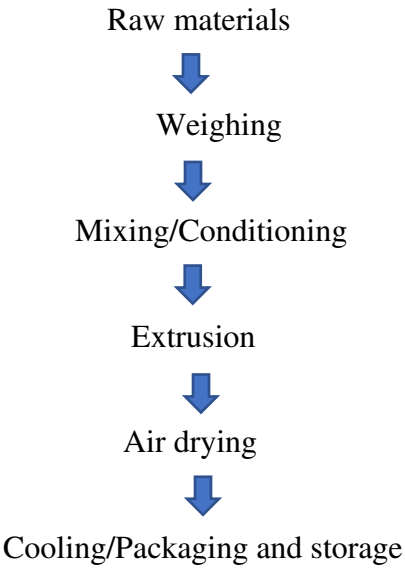


Figure 1: Steps for the production of noodles

Determination of proximate composition

The moisture content, protein, fibre, ash, and fat content were determined according to the procedures described by AOAC (2010). Carbohydrate was evaluated by deduction of the summed parameters from 100.

Sensory evaluation

Sensory evaluation of the noodles was carried out through a twenty-five-man semi trained panel using a 9-point hedonic scale ranging from 1 (extremely disliked) to 9 (extremely liked) and were requested not to eat spicy and pungent foods before the analysis. The panellists were instructed to score the coded samples for texture, taste, colour, aroma and overall acceptability. Each panellist adopted multiple comparison test system for each sensory attribute. The data generated from the panellist's evaluation on texture, taste, colour, aroma and overall acceptability were analyzed using analysis of variance.

Cooking characteristics of noodles formulated from AYBF and WF

The cooking characteristics were determined according to the method of Galvez and Resurreccion (1992).

Cooking time of noodles formulated from AYBF and WF

The cooking time was determined by cooking noodles (10 g) in 200 mL of boiling distilled water in a 250 mL beaker until disappearance of white core is confirmed when the noodles get easily pressed between two glass slides.

Cooked weight of noodles formulated from AYBF and WF

The cooked weight of noodles was determined by taking noodles (10 g) in 300

mL water for 5 minutes and then cooking in water bath for 5 minutes. The beaker was covered with aluminium foil to minimize the loss of water due to evaporation. The cooked noodles were drained for about 2 minutes, rinsed with distilled water in a buchner funnel and cooked weight was determined by weighing wet mass of noodles.

Cooking loss of noodles formulated from AYBF and WF

The cooking loss was determined by evaporating the cooking water to constant weight at 110 ^{o}C and expressed as the percentage total amount of substance passing into water.

Aqueous extract preparation

Aqueous extract preparation was carried out according to Shodehinde and Oboh (2012) with slight modification. Ten gram of each sample noodles was soaked in 100 mL of distilled water for about 24 hrs. The mixture filtered and the filtrate was centrifuged for 10 minutes to obtain a clear supernatant liquid. The extract was stored at 4 ^{o}C and used for further analysis. The antioxidant tests and analyses were performed in triplicate and results were averaged.

Determination of total phenolic content (TPC)

The total phenolic content (TPC) was determined by spectrophotometry, using Gallic acid as standard, according to the method described by Singleton *et al*. (1999), with some modifications. Briefly, 1.0 mL of the sample extract was transferred to separate tubes containing 5.0 mL of a 1/10 dilution of Folin-Ciocalteu's reagent in water. Then, 4.5 mL of sodium carbonate solution (7.5% w/v) was added. The tubes were then allowed to stand at room temperature for 60 minutes before absorbance at 765 nm was measured using a UV/Vis spectrophotometer. The TPC was expressed as Gallic acid equivalents (GAE) in mg/g.

DPPH radical scavenging activity

The free radical scavenging activity of the extracts, based on the scavenging activity of the stable 1,1-diphenyl-2- picrylhydrazyl (DPPH) free radical was determined by the method described by Braca *et al*. (2001). Sample extract (0.1 mL) was added to 3 mL of a 0.004 % methanol solution of DPPH. Absorbance at 517 nm was read after 30 minutes, and the percentage inhibition activity was calculated from [(A0–A1)/A0] x100, where A0 is the absorbance of the control, and A1 is the absorbance of the extract/standard.

Data analyses

The results of triplicate readings were pooled and expressed as mean ± standard deviation. One-way analysis of variance was used to analyse the mean and the post hoc treatment was performed using Duncan multiple range test. Significant difference was accepted at $P < 0.05$.

Results and Discussion

Proximate composition (%) of noodles formulated from AYBF and WF

The proximate composition (%) of prepared noodles from the flours of African yam bean and wheat is presented in Table 2. There was significant difference ($P < 0.05$) in the moisture content of all noodle samples. AYBF-45 had the highest value (2.61%) while AYBF-15 had the least value. However, the values of moisture content for all samples were within the acceptable range for storage (Dhull and Sandhu, 2018). The result indicated that the prepared noodle samples will have a long shelf life and will not easily go bad.

The values of protein content of the sample noodles ranged from 12.25 - 19.20 % (Table2). There was significant difference (P <0.05) in the protein content of the WF and AYBF noodles. All AYBF noodles exhibited higher protein values than WF noodles. However, AYBF-45 had the highest protein value (19.20 %) while WF noodles had the least value (12.25 %). This finding supports the general fact that beans contain more protein than wheat (Kouris-Blazos and Belski, 2016).

The ash content of noodles samples ranged from 0.41 % - 1.09 % and is presented in Table 2. There was significant difference (P < 0.05) as the highest ash content was displayed by AYBF-45 noodles (1.09 %) while WF noodles had the least value (0.41 %). The ash content indicates the presence of minerals which are necessary for the normal functioning of biochemical processes (Sanni *et al*., 2007).

The fat content of the noodle samples ranged from 0.59 % – 0.98 % (Table 2). As observed in this finding, there was significant difference (P < 0.05) in fat content as AYBF-45 had the highest value (0.98 %) followed by AYBF-15 (0.84 %). There was no significant difference in the values that obtained in WF noodles (0.59 %) and AYBF-30 (0.55 %). Fat is a known flavour retainer that improves the sensory qualities of baked products (Fasasi, 2009).

The fibre content of noodle samples ranged from 1.42 % to 3.02 % and was shown to be significantly (P < 0.05) higher in AYBF noodles than the value that obtained in WF noodles (Table 2). This result corroborates the work of Hama-Ba *et al.* (2018) in which higher content of fibre was reported in non-wheat flour products than in wheat flour products.

The carbohydrate content of noodle samples ranged from 73.10 – 82.99 % (Table 2). The significant difference (P < 0.05) in carbohydrate content showed that WF noodles had the highest value of carbohydrate (82.99 %) while AYBF-45 had the least value (73.10 %). This finding supports the earlier work of Oghbaei and Prakash (2013) in which wheat flour was reported to be concentrated in starch than in legumes.

Table 2. **Proximate composition (%) of the noodle samples**

Noodles	M.C	Protein	Ash	Fat	Fibre	CHO
WF-100	2.34^{b}±0.03	12.25^{d}±0.02	0.41^{d}±0.01	0.59^{c}±0.03	1.42^{b}±0.03	82.99^{a}±0.03
AYBF-15	1.67^{d}±0.05	15.72^{c}±0.03	0.62^{b}±0.02	0.84^{b}±0.03	2.06^{c}±0.03	79.09^{b}±0.01
AYBF-30	2.00^{c}±0.03	18.25^{b}±0.03	0.54^{c}±0.01	0.55^{c}±0.03	2.38^{b}±0.02	76.28^{c}±0.02
AYBF-45	2.61^{a}±0.03	19.20^{a}±0.02	1.09^{a}±0.03	0.98^{a}±0.03	3.02^{a}±0.03	73.10^{d}±0.03

Values are mean ± SD of triplicate reading. Means within the column with different superscript were significantly different (P < 0.05). Keys: WF= Wheat flour. AYBF= African yam bean flour. AYBF-15: 15 % of AYBF and 85 % of WF. AYBF-30: 30 % of AYBF and 70 % of WF. AYBF-45: 45 % of AYBF and 55 % WF. M.C= Moisture content. CHO= carbohydrate.

Sensory scores of the AYBF and WF noodles

The sensory evaluation scores of noodles made from composite mixture of AYBF and WF is given in Table 3. The overall acceptability of AYBF noodles ranged from 18 to 26. The scoring was observed to have decreased with increase in the incorporation of AYBF from 15 % to 45%. This may be as a result of the beany flavour and the drastic contrast in colour from white to light dark brown which progressively increases to very dark brown (Plate 1) compared to the score of WF noodles (35). All the noodles were accepted based on the assessed parameters. However, the sensory evaluation scores showed that 100 % wheat flour noodles (WF) had the highest score followed by AYBF-15, AYBF-30 and AYBF-45 of AYBF in that order.



Plate 1: Pictures of noodle samples

Table 3. Sensory scores of the noodles samples

Noodles	Colour	Flavour	Taste	Texture	Overall Acceptability
WF-100	9	9	8	8	35^{a}
AYBF-15	7	6	6	7	26^{b}
AYBF-30	5	5	5	6	21^{c}
AYBF-45	5	4	4	5	18^{d}

Values are mean ± SD of triplicate reading. Means within the column with different superscript were significantly different ($P < 0.05$). Keys: WF= Wheat flour. AYBF= African yam bean flour. AYBF-15: 15 % of AYBF and 85 % of WF. AYBF-30: 30 % of AYBF and 70 % of WF. AYBF-45: 45 % of AYBF and 55 % WF.

Cooking characteristics of noodles formulated from the AYBF and WF

Noodles of a satisfactory quality is considered a good type once the evaluated cooking time is short with low level of solid

loss during cooking (Prerana and Anupama, 2020). The cooking time of noodles in this present study showed that WF noodles significantly had the highest value (8.52 minutes) while the subsequent values in other AYBF noodles (7.52, 8.30 and 6.22 minutes) as in AYBF-15, AYBF-30, and AYBF-45 respectively exhibited a decrease in cooking time with increase in incorporation of the AYBF (Table 4). The observed decrease in cooking time in varied percentage incorporation of AYBF could be attributed to the interference in the continuity of gluten network (Manthey *et al*., 2004) which aids quick water penetration and consequent reduction of cooking time. The concept of determining the cooking time is also very paramount to prevent undercooking and overcooking of noodles in order to maintain their structural stability and to be able to handle with a fork or chopsticks when served as meals (Prerana and Anupama, 2020).

The cooking loss determination in noodles is a measurement of the dry matter that leached into cooking water. The cooking loss of these studied noodles ranged from 6.72 to 7.36 % in samples. A very high value of cooking loss is not desirable due to the fact that it is an indication of high solubility that will produce turbid liquid during boiling (Wandee *et al.*, 2014). The cooking loss values obtained in this work showed no significant difference ($P < 0.05$) in WF and AYBF noodles. This revealed that interactions between wheat flour and AYBF have not lacked much resilience to maintain the level of viscoelasticity of noodles strands in cooking water up to 45% inclusion.

The cooked weight and volume of WF and AYBF noodles samples as shown in Table 4 showed a significant difference ($P < 0.05$) in their parameters. There was an observed decrease in the cooked weight and volume of noodles with increase in the substitution of the composite African Yam Bean flour. WF (100%) had the highest values of cooked weight (80.40 %) and volume (150 %) while AYBF-45 had the least values of 59 % and 80 % for cooked weight and volume respectively. These findings followed the trend of values that obtained for the cooking time and cooking loss as there was an observed decrease as the rate of the substitution of WF with AYBF increased. According to tradition, an increase in legume substitution increases cooking time, cooking loss, cooking weight, and cooking volume as a result of dilution of gluten matrix that reduces its elasticity (Sobota and Zarzycki, 2013).

The results of these present findings however run contrary to earlier reported impact of composite flour incorporation. Although there is little or no information about the reasons for the observed decreased cooking characteristics of produced AYBF noodles mainly due to the gross underutilization of African yam beans in food preparation. However, it could be suggested in line with the report of FAO/WHO (1991) in which amino acid profile in AYB was rated to be higher than those present in other legumes including soybean and was also presented to compare favourably with whole hen's egg. Going forward, further study of AYB could become a new avenue of research to unveil other important unknown facts for the benefit of consumers.

Table 4. **Cooking characteristics of the noodles samples**

Noodles	Cooking time (minutes)	Cooking loss (%)	Volume Increase/decrease(%)	Weight (%)
WF-100	8.52[a]	7.36[a]	150.00[a]	80.40[a]
AYBF-15	7.25[c]	6.90[c]	105.00[c]	73.30[b]
AYBF-30	8.30[b]	7.01[b]	140.00[b]	71.80[c]
AYBF-45	6.22[d]	6.72[d]	80.00[d]	59.00[d]

Values are mean ± SD of triplicate reading. Means within the column with different superscript were significantly different ($P < 0.05$). Keys: WF= Wheat flour. AYBF= African yam bean flour. AYBF-15: 15 % of AYBF and 85 % of WF. AYBF-30: 30 % of AYBF and 70 % of WF. AYBF-45: 45 % of AYBF and 55 % WF.

The contribution of phenolic compounds in the protection of the human body from free radical formation is associated with the strong capability of antioxidants by removing free radicals, chelate metallic catalysts, inhibit oxidases, activate antioxidant enzymes was well as reduce the generation of α-tocopherol radicals (Aguilera *et al*., 2014). The determined total phenol contents in noodles samples are given in Figure 2. There was significant difference ($P < 0.05$) in the total phenolic content of the noodles. The AYB-30 noodles had the highest total phenol (3.14 mg/g GAE) compared to that of WF noodles (2.46 mg/g GAE). An earlier researched work on African yam bean (AYB) had identified the presence of polyphenols such as flavonoids and phenolic acids (Soetan *et al*., 2018) indicating that the inclusion of AYB in diets can be adopted in the production of functional foods that can partake in the modification of lifestyles and prevention of degenerative diseases.

Not only have earlier studies (Soetan *et al*., 2018) revealed polyphenols as strong antioxidants that inhibit the processes of oxidation. They have been documented to improve sensorial acceptability (Sengul *et al*., 2009) and to improve shelf life of food (Carocho *et al*., 2018).

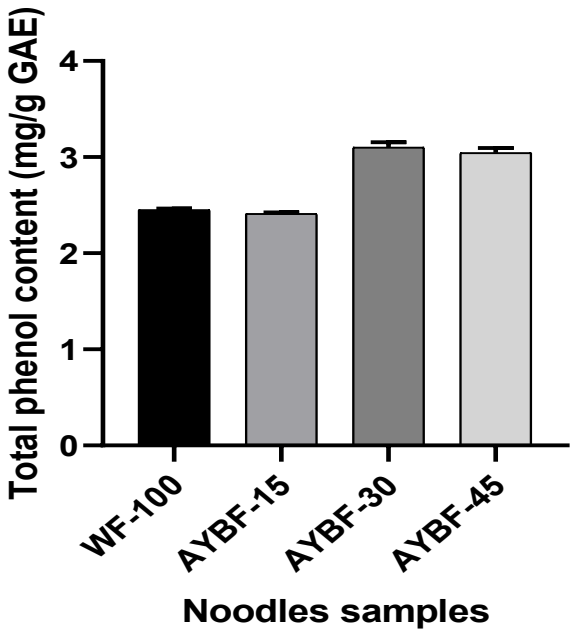


Figure 2. Total phenol content of noodles samples

Keys: WF= Wheat flour. AYBF= African yam bean flour. AYBF-15: 15 % of AYBF and 85 % of WF. AYBF-30: 30 % of AYBF and 70 % of WF. AYBF-45: 45 % of AYBF and 55 % WF.

A free radical such as DPPH donates or accepts an electron or hydrogen to maintain its stability and its inhibition is often used to determine free radical-scavenging ability of different kinds of food components (Burits and Bucar, 2000). The DPPH radical scavenging ability of the sample noodles are given in Figure 3. The values of the DPPH radical scavenging ability ranged from 2.04 % to 6.32 %. The composite noodles (AYBF-45) had the highest radical scavenging ability (6.32 %) while WF noodles had the least (2.04 %). There was no significant difference ($P < 0.05$) in the values reported for AYBF-15 and AYBF-30 at 4.65 % and 4.09 % respectively. Higher content of polyphenols in AYB is an indication of higher antioxidant activities thus partaking in scavenging free radicals and reducing oxidative stress (Soetan *et al*., 2018).

The overall findings of this experiment have showcased the tendency of AYBF to be incorporated in wheat flour for noodles production. However, the results of the analyses on varied percentage of AYBF in WF in the production of noodles had presented a promising conclusion that satisfactorily compared with 100% WF. More importantly, this composite product will form part of envisioned plan as the world is looking ahead for plants with many diverse functional uses hoping to beat the trials of food insecurity to cessation.

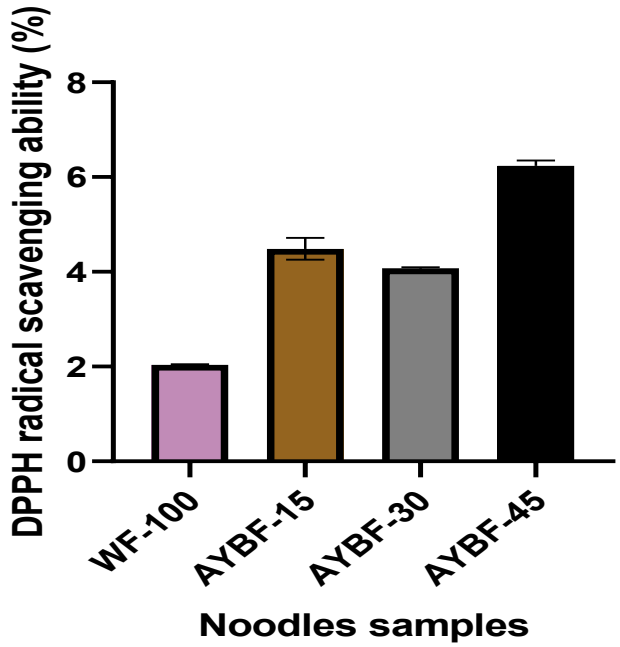


Figure 3. DPPH radical scavenging ability of noodles samples

Keys: WF= Wheat flour. AYBF= African yam bean flour. AYBF-15: 15 % of AYBF and 85 % of WF. AYBF-30: 30 % of AYBF and 70 % of WF. AYBF-45: 45 % of AYBF and 55 % WF.

Conclusion

This present study has demonstrated the possibility of incorporating AYBF in wheat flour for the preparation of noodles which were acceptable by consumers. This present study suggested that the incorporation of AYBF in wheat flour up to 30% was suitable to maintain cooking characteristics considering the observed closeness of its values to that of WF (100%) unlike the regular deviance observed in 45% AYBF inclusion. Nevertheless, the recommendation of AYB as one of the underutilized natural sources of antioxidants can be exploited for human consumption.

Conflict of interest

The authors declare that there are not conflicts of interest.

Ethics

This study does not involve Human or Animal Testing.

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Effects of Land Preparation Methods and Cropping Systems on Maize (*Zea mays* L.) Viral Diseases

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Abstract

Maize is an important staple crop utilized by both rural and urban communities in sub-Saharan Africa. However, its production is limited by biotic and abiotic factors, and viruses are one of the major biotic factors reducing maize yields. The study investigated the effects of land preparation methods (slash and burn; herbicide application) and cropping systems (intercrop and monocrop) on the incidence and concentration of *Maize streak virus* (MSV) and *Maize stripe virus* (MStV). Oloyin (ART98-SW1) maize variety was planted in three locations (Ibadan, Ilora and Ile-Ife) during 2015 and 2016 cropping seasons using split-plot design with replications. The incidence of MSV was very low in 2015 compared to 2016. In 2016, the highest MSV incidence (57.3%) was obtained from the herbicide-sprayed plot in Ibadan while the least incidence (12%) was recorded from Ilora under slash and burn system. Under the cropping system, highest MSV incidence (69%) was obtained from Ibadan under sole cropping while the least was obtained from intercropped plot in Ilora with a value of 7.5%. There was no mixed infection by MSV and MStV in 2015 and 2016 in all the locations. Positive and significant correlation occurred between MSV incidence and MSV titers (0.605**) as well as MStV incidence and MStV titers (0.346*). The study concludes that methods of land preparation and cropping systems are integral part of Integrated Disease Management (IDM) strategies. However, holistic approach involving all the IDM methods coupled with favourable climatic condition would give the best management approach.

Keywords: Incidence, intercropping, maize, slash and burn, virus titer

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Introduction

Maize (*Zea mays* L.) is an important cereal crop ranking third in production after wheat and rice with an annual mean production of 1,127 million tons (OECD/FAO, 2019). Its cultivation covers approximately 100 million hectares of land and about 70% of the total production is from low and lower middle income countries (FAO, 2012). In Nigeria, its production was about 10.7 million metric tons in 2015 (FAO, 2017). Due to the broad range of uses of maize in sub-Saharan Africa (SSA), it was projected that in year 2000, the annual demand would be 500 million tons (Olaniyan, 2015; IFPRI, 2000).

Stresses induced by diseases and insect pests are among the primary biotic factors responsible for yield losses in maize production (Lodha *et al*., 2013). Viral diseases of maize are a major constraint responsible for low productivity (Fajinmi *et al*., 2019). Globally, over 50 viruses have been reported to infect maize (Wijayasekara and Ali, 2021). However, in tropical Africa, seven viruses including *Maize streak virus* (MSV) and *Maize stripe virus* (MStV) were reported in maize (Sunday *et al*., 2011).

In Africa, maize streak disease (MSD) caused by *Maize streak virus* is regarded as the most economically important viral disease of maize (Rybicki, 2015). *Maize streak virus* belongs to the genus *Mastrevirus* and family Geminiviridae (Monjane *et al*., 2011). It is transmitted by leafhoppers of the genus *Cicadulina (*Homoptera: Cicadellidae) in a semi persistent manner (Mazengia, 2016). White, yellow or even red lesions are induced on maize leaves infected with *Maize streak virus.* Other symptoms include formation of continuous parallel chlorotic streaks, stunting and incomplete cob and seed formation which result in severe yield reduction (Shepherd *et al*., 2010). Another important virus of maize in Africa is *Maize stripe virus* (MStV). It belongs to the unusual plant virus genus *Tenuivirus* in the family Phenuiviridae (Abudurexiti *et al*., 2019). Transmission of MStV is by the planthopper; *Peregrinus maidis* in a persistent-propagative manner (Singh and Seetharama, 2008). Symptoms induced include stippling between leaf veins of maize which later coalesce into continuous chlorotic stripes (Bolus *et al*., 2021).

Cropping system is a cultural practice involving the pattern of crop cultivation on a piece of land over a fixed period of time (NIOS, 2012). Intercropping is defined as the cultivation of two or more crops on a piece of land within the same period (Sullivan, 2003). It is a common practice in subsistence agriculture in the tropics (Gliessman, 2007; Lithourgidis *et al*., 2011). Common intercropping practices include legumes and cereals, and it is of importance in reducing pest and disease incidence (Hauggaard-Nielsen *et al*., 2008). In contrary, sole cropping or monocropping is the cultivation of a single type of crop on a piece of land at a particular period of time (Mohammed, 2020).

Method of land preparation adopted by farmers on the field influences the response of crops to attack by pests and pathogens. Resource-poor farmers in Sub-Saharan Africa make use of slash and burn as a method of land preparation. It is a method of land preparation used by subsistent farmers in the tropical rain forest regions of West Africa, South America and Southeast Asia (Kotto-Same *et al*., 2000). It involves slashing of vegetation, drying and burning before crop cultivation (Hauser and Norgrove, 2013). Slash and burn influences the physicochemical properties of the soil (Are *et al*., 2009; Béliveau *et al*., 2015; Thomaz *et al*., 2014). On the other hand, herbicide application is a modern way of land

preparation in conservation tillage involving the killing of unwanted plant or vegetation (Rose *et al*., 2016). Glyphosate is the most widely used herbicide in the world (Coupe *et al*., 2012) because of its effectiveness and ability to inhibit the shikimic acid metabolic pathway in plants and some microorganisms (Duke *et al*., 2003).

The dearth of information on the effect of land preparation methods and cropping systems on virus incidence and titers in maize has necessitated this study. Therefore, the study compared slash and burn with herbicide application and also compared intercropping with sole cropping. Their overall effect on virus incidence and virus titers was also evaluated.

Materials and Methods

Experimental sites

Field studies were conducted between May and August, 2015 and 2016 planting seasons under rain-fed condition. Three experimental stations of the Institute of Agricultural Research and Training (I.A.R.&T), Nigeria were used for the study. The description of the locations and the climatic conditions are presented in Table 1 below.

Table 1. Location and average climatic condition during the experimental period

	Ibadan	**Ile-Ife**	**Ilora**
Ecology	Transition zone	Rain forest	Derived savanna
Latitude of experimental site	7°22′N	7°33′N	7°48′N
Long. of experimental site	$3^0$50′E	$4^0$33′E	3°48′E
Altitude (m.a.s.l)	182	290	278
2015			
Mean temperature (°C)	25.75	27.88	25.63
Rainfall (mm)	155.00	114.10	198.25
2016			
Mean temperature (°C)	26.13	25.38	26.63
Rainfall (mm)	159.50	162.75	196.75

m.a.s.l = meters above sea level

Treatments and experimental design

Oloyin (ART98-SW1) maize variety obtained from the Maize Improvement Programme for Southern Ecologies, I.A.R.&T., Ibadan, Nigeria was grown in a randomized complete block design (RCBD) with three replications. Plant spacing of 0.75 m x 0.25 m was used in each location. Land preparation methods including herbicide application (using glyphosate) and slash and burn were employed. Slash and burn system was achieved by using cutlass to slash the natural vegetations on the experimental sites. Then, the plant residues were left for about 15 to 20 days to dry up and later burned down. Herbicide application involved pre-planting application of glyphosate herbicide on weeds or vegetation growing on the sites and the plant residues were left on the soil surface without burning.

Each site was further splitted into two sub-plots. The first plot consisted of sole cropping of maize while the second plot consisted of intercropping maize with cowpea. Factors used as main effects were location (3 levels), year (2 levels) and land preparation method

(2 levels). Data were obtained under the two cropping systems (sole and intercrop) for virus incidence and virus titers. Virus incidence was expressed as a percentage of infected plant to the total number of plants on each plot. The first fertilizer application was at 2 weeks after planting using NPK 15:15:15 while the second application occurred before tasseling using urea. Weeding of experimental plots was carried out at four weeks intervals.

Determination of virus concentration in maize using double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA)

In order to determine the presence of MSV and MStV in maize plants, leaf samples showing symptoms characteristic of MSV (streaking on leaves) and MStV (stripping on leaves) were collected before tasseling. Serological assay using direct double antibody sandwich enzyme-linked immunosorbent assay (DAS ELISA) was carried out in duplicate wells by making use of kit obtained from Agdia Inc. Elk, USA. The assay of the two viruses was determined by following the manufacturer's protocol and as described by Taiwo et al. (2007). Positive and negative (healthy maize plant) controls were included in the microtiter plates. Virus titers were obtained by measuring the absorbance values at 405 nm using ELx800 microtiter plate reader. Titer values that are twice the mean values of the negative control were considered positive.

Data analysis

Data obtained were subjected to analysis of variance (ANOVA) using the statistical package for social sciences (SPSS) version 20. New Duncan multiple range test was used for mean separation at $p \leq 0.05$. Correlation between disease traits was also determined.

Results

Effect of land preparation methods on virus occurrence in maize as determined by ELISA

The effect of land preparation methods on maize plants grown in 2015 showed that MSV was absent under slash and burn as well as when sprayed with herbicide. MStV was also absent under the two land preparation methods except Ile-Ife grown maize sprayed with herbicide. There was no evidence of mixed infections in 2015 (Table 2). In 2016, MSV was present in the three locations irrespective of the land preparation methods. However, MStV was absent in all the plants grown under the two land preparation methods. Neither the plants grown under slash and burn nor the ones grown under herbicide treatment had mixed infection of MSV and MStV in 2016 (Table 2).

Table 2. Effect of land preparation methods on single and mixed infection of Maize streak and Maize stripe viruses in the three locations in 2015 and 2016

Land preparation method	Location	MSV[a] 2015	MStV[a] 2015	Mixed infection	MSV[a] 2016	MStV[a] 2016	Mixed infection
Slash and burn	Ibadan	-	-	-	+	-	-
	Ile-Ife	-	-	-	+	-	-
	Ilora	-	-	-	+	-	-
Herbicide	Ibadan	-	-	-	+	-	-
	Ile-Ife	-	++	-	+	-	-
	Ilora	-	-	-	+	-	-

MSV = Maize streak virus, MStV = Maize stripe virus; a = single infection

Effect of cropping systems on virus occurrence in maize as determined by ELISA

In 2015, MSV was completely absent in maize grown at the three locations under sole and mixed cropping systems whereas MStV was only present in Ile-Ife under sole cropping system. There was no mixed infection in all the locations under the two cropping systems in 2015 (Table 3). During 2016 planting season, MSV was present in all the three locations under sole and mixed cropping systems with maize grown in Ilora under sole cropping system having the highest MSV concentration. None of the maize plants grown at the three locations was infected with MStV in 2016 under the two cropping systems and no mixed infection was recorded in 2016 (Table 3).

Table 3. Effect of cropping systems on single and mixed infection of Maize streak and Maize stripe viruses in the three locations in 2015 and 2016

Cropping system	Location	MSV[a] 2015	MStV[a] 2015	Mixed infection	MSV[a] 2016	MStV[a] 2016	Mixed infection
Mixed cropping	Ibadan	-	-	-	+	-	-
	Ile-Ife	-	-	-	+	-	-
	Ilora	-	-	-	+	-	-
Sole cropping	Ibadan	-	-	-	+	-	-
	Ile-Ife	-	+	-	+	-	-
	Ilora	-	-	-	++	-	-

MSV = Maize streak virus, MStV = Maize stripe virus; a = single virus infection

Effect of land preparation methods on the incidence of *Maize streak* and *Maize stripe viruses* in maize

During 2015 cropping season, results of MSV incidence revealed that there was no significant difference ($P \leq 0.05$) in the land preparation methods except for maize grown in Ilora under herbicide treatment which was significantly higher than others with a mean incidence of 20.8%. In 2016, the highest MSV incidence (57.3%) was recorded in herbicide-treated field grown in Ibadan. This was followed by plants grown in Ilora under

herbicide treatment and then Ibadan under slash and burn with incidence values of 43.8% and 40.3% respectively. The least MSV incidence (12%) was obtained from Ilora under slash and burn (Table 4).

Results obtained from MStV incidence in 2015 showed that maize grown under herbicide treatment in Ile-Ife and Ilora had the least incidence of 4.3% and 4% respectively. However, in 2016, the least MStV incidence (12.8%) was recorded in Ibadan under slash and burn while the highest incidence (27.3%) was obtained in Ilora under slash and burn (Table 4).

Table 4. Influence of land preparation methods on maize virus incidence in three locations

		Incidence (%)			
Land preparation method	Location	MSV 2015	MSV 2016	MStV 2015	MStV 2016
Slash and burn	Ibadan	5.3 ^{b}	40.3^{b}	13.8^{b}	12.8^{b}
	Ile-Ife	6.8 ^{b}	22.2^{c}	29.3^{a}	18.8^{ab}
	Ilora	5.5 ^{b}	12.0^{d}	15.3^{b}	27.3^{a}
Herbicide	Ibadan	4.5 ^{b}	57.3^{a}	17.4^{b}	20.3^{ab}
	Ile-Ife	8.0 ^{b}	21.5^{c}	4.3^{c}	19.8^{ab}
	Ilora	20.8^{a}	43.8^{b}	4.0^{c}	21.5^{ab}

Means followed by the same letter along the column are not significantly different according to New Duncan multiple range test (NDMRT) at P ≤ 0.05.

Effect of land preparation methods and cropping systems on the incidence of *Maize streak* and *Maize stripe viruses* in maize

The incidence of MSV was significantly low in 2015 under the two cropping systems except for maize grown in Ile-Ife under sole cropping system and the value was 25.3%. In 2016, the MSV incidence was significantly higher in the sole cropped maize plants than the mixed cropped plants and Ibadan had the highest incidence (69%) (Table 5). The incidence of MStV in 2015 under mixed cropping system ranged from 3.5% to 26.5% while the incidence of the sole crops ranged between 4.8% and 19.5%. The incidence of MStV in 2016 revealed that maize grown in Ilora under mixed cropping system had the highest incidence followed by Ibadan under the same cropping system. The least MStV incidence (4.25%) was recorded under sole cropping system in Ibadan (Table 5).

Table 5. Influence of cropping system on maize virus incidence in three locations

Cropping system	Location	MSV 2015	MSV 2016	MStV 2015	MStV 2016
Mixed cropping	Ibadan	4.5^{b}	28.5 ^{c}	26.5^{a}	28.8 ^{b}
	Ile-Ife	5.0^{b}	7.5^{d}	3.5 ^{c}	35.8 ^{a}
	Ilora	6.5^{b}	19.5^{c}	14.0 ^{b}	19.75 ^{c}
Sole cropping	Ibadan	5.3^{b}	69.0^{a}	4.75 ^{c}	4.25 ^{d}
	Ile-Ife	25.3^{a}	44.3^{b}	15.8 ^{b}	13.0 ^{cd}
	Ilora	8.3^{b}	24.5^{c}	19.5 ^{b}	18.8 ^{c}

Means followed by the same letter along the column are not significantly different according to New Duncan multiple range test (NDMRT) at P ≤ 0.05.

Correlation between viral disease traits

There was a positive and significant correlation (0.605**) between MSV incidence and MSV titers so also MStV incidence and MStV titers (0.346*). A negative and non-significant correlation existed between MSV incidence and MStV incidence (Table 6).

Table 6. Relationship between virus disease traits

Disease trait	MSV incidence	MStV incidence	MSV titer	MStV titer
MSV incidence	1	-0.266^{ns}	0.605**	-0.144 ^{ns}
MStV incidence		1	0.080 ^{ns}	0.346*
MSV titer			1	-0.259^{ns}
MStV titer				1

MSV = Maize streak virus, MStV = Maize stripe virus; **Significant at 1% level of probability, *Significant at 5% level of probability, ns = not significant

Discussion

The absence of MSV in 2015 and its presence in 2016 as revealed by ELISA results implied that the method of land preparation and cropping systems alone do not determine the tolerance or susceptibility of crops to diseases but other important factors such as the environmental condition, virus strain and the host plant also come into play. Taiwo *et al*. (2007) reported that the tolerance of a cultivar to diseases is a combination of so many factors including the virus isolate, presence of another virus, cultivar tolerance and plant age at the time of infection.

Slash and burn controlled MSV in 2015 but not in 2016 which implied that it is not a sustainable agricultural practice to be used for disease management. Harrison (2002) has reported that the use of slash and burn, application of pesticides and fertilizer do not contribute to agricultural sustainability.

The absence of MStV under slash and burn could be supported by the fact that the vectors of the virus were killed during burning. This result supports the report of Menzies and Gillman (2003) which stated that burning reduces pests. However, the presence of MStV in Ile-Ife as shown by ELISA under herbicide treatment and sole cropping system in 2015 could be attributed to the fact that during the spraying of the herbicide, the vectors of MStV (*Peregrinus maidis*) might have flown to neighbouring vegetation and then come back after the process. In addition, the virus is transmitted in a persistent manner, which means that the virus was not lost during the period in which the vector was away from the field. Also the temperature of Ile-Ife in 2015 was higher compared to other locations and this could have contributed to higher replication of the MStV in maize plant during that period. Zhang *et al*. (2012) as well as Prasch and Sonnewald (2013) reported that higher temperatures facilitated the replication and spread of *Turnip crinkle virus* and *Tobacco mosaic virus* respectively.

The absence of mixed virus infection in the two years indicated that the maize variety used in this study has a level of resistance to mixed virus infection. Magenya *et al*. (2009) reported that breeding for resistance is considered as cost-effective, environmental friendly and efficient approach to managing and preventing losses associated with MSV infection.

MSV incidence in 2015 was generally low in all the locations. The high incidence of MSV under sole cropping system in 2016 could

imply that planting of maize using sole cropping system allowed easy transmission of the virus. Hailu *et al*. (2018) reported that control of stem borer and fall armyworm in maize was better in intercropped than monocropped maize.

The high incidence of MSV in Ibadan in 2016 could be as a result of the geographical location of Ibadan being a transition zone. The work of Asare-Bediako *et al*. (2017) revealed the incidence and severity of maize streak disease (MSD) in maize plants to be significantly higher in the transition zone than in the forest eco-zone during two years cropping seasons in Ghana. The study of Fajinmi *et al*. (2011) also reported the contribution of agroecological distribution and cropping system on viral disease incidence and insect vector dynamics in cultivated fields.

The high incidence of MStV in inter-cropped maize in the three locations in 2016 could be due to the fact that maize being a tall companion crop served as virus sink, in which all virus vectors deposit the viral particles that they carry, thus, preventing the virus from gaining access to the dwarf companion crop which is cowpea. The study of Fajinmi and Odebode (2010) revealed that maize served as a trap or buffer crop for insect-transmitted viruses when intercropped with dwarf companion crops.

The significant correlation between virus titer and virus disease incidence could be attributed to the fact that the quantity of virus and its incidence in plants among other factors determine the susceptibility or resistance of plants to virus infections. Oloyede-Kamiyo *et al*. (2018) have reported a positive correlation between virus titers and virus incidence in maize plants.

Conclusion

Plant viruses are responsible for yield losses and are a major threat for sustainable agriculture. The use of slash and burn as well as glyphosate for land preparation should be used with caution as virus vectors might fly away during the treatment and resurface after the effect has subsided. Cropping system based on sole cropping predisposes plants to pests and pathogens as it encourages the spread of diseases in plant population. Therefore, breeding for maize variety that has resistance to both MSV and MStV and the use of integrated pest/disease management are suggested for improved production of maize.

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Evaluation of Maize (*Zea mays* L.) Seed Germination and Seedling Growth on Drilled Well Mud Soil

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Abstract

Drilled well mud can alter plant growth and soil properties because of petroleum residues, alkalinity, and soluble salts. Pollution due to indiscriminate disposal of drilling fluids (muds) has required that the effects of drilling muds on the ecosystem be known. Maize (*Zea mays* L.) seed germination and seed growth in drilled well mud soil was evaluated. Ten seeds of *Z. mays*; SITUKA variety were sown in each plastic pot containing 2 kg of drilled well mud soil. Eight replicates of these were set up and each watered with 400 ml of water twice a week. Controls were set up with same number of seeds also planted in the same size of plastic containers with 2 kg of loamy soil. Germination percentage, number of leaves, plant heights and leaf areas were measured every two days for eighteen days. The concentrations of extractable elements in both the drilled well mud and loamy soils were analyzed. The drilled well mud soil significantly reduced the percentage germination, plant heights and increased the concentrations of Calcium, Magnesium, Sodium, Copper and Chlorine ($P < 0.05$). Too much soluble salts or too high exchangeable sodium percentage was the major cause of reduced plant growth. This research will produce a baseline information for soil contamination management and for understanding the responses of soil properties to drilled well mud. Future research should be carried out up to yield level to determine the sustainability of mud soil for agronomic use and means of disposal of drilled well mud soil and to protect the environment.

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Key words: drilled well mud, percentage germination, plant heights, leaf area, soil contamination

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Introduction

The indiscriminate disposal of drilling fluid (mud) is alarming and concern about the environment deemed it necessary that its effects on the soils and plants in the areas be known. According to American Society of Mechanical Engineers (ASME) (2005), drilling fluid is used for lubrication of the bit and cooling of the drilling apparatus, transporting formation cuttings to the surface, and sealing porous geologic formations. Drilling fluid on the other hand is a water-clay chemical mixture while produced water is a water-sand chemical mixture (Argonne National Laboratory, 2010). Drilling fluid and drilling mud often contain salts (Na and Cl), barite, waterbased surfactants or diesel, and montmorillonite (Miller and Pesaran, 1980).

Various methods can be used to dispose of drilling waste. These include underground injection, onsite burial, land treatment (land spreading, land farming, and road spreading), evaporation from sump storage, surface discharge, recycling, and off-site disposal at commercial disposal facilities (Zvomuya *et al.*, 2011). In Nigeria, land farmingis a common disposal technique of drilling fluid and produced water (Hossain and Wajheeuddin, 2016). In the land farming process, amendments of fluid are repeatedly applied to the soil surface following completion of the well (Bauder *et al*., 2005).

Plant growth and soil chemical properties may be altered by additions of drilling fluid, because of alkalinity, salinity, trace elements, and petroleum residue contained in waste (Yao and Naeth, 2015).The concentrations of soluble salts, trace elements, and the high pH of drilling mud have the potential to reduce plant growth (Zvomuya *et al.*, 2011). High soil salinity has negative effects on plant growth (Dashti *et al.*, 2009; Swigart *et al.*, 2021). Others in previous studies of soils amended with drilling fluids and drilling mud have concluded that increased salinity was the major factor that inhibited plant growth (Bauder *et al*., 2005; Athar and Ahmad, 2002; Miller and Pesaran, 1980). Miller and Pesaran (1980) reported that high exchangeable sodium percentage (ESP) was a major cause of reduced plant growth. Chloride is essential for photosynthesis and serves other critical roles in plant functions. Plants take up chloride as Cl^- anion, which is very mobile in the soil and is subject to leaching. In high concentrations, however, chlorides will inhibit plant growth, and they are specifically toxic to some plants (Chen *et al*., 2009; Nelson *et al.*, 1984).

The objective of this study was to evaluate the responses of Maize (*Zea mays* L.) seed germination and seedling growth on drilled well mud soil and determination of traceable elements that could inhibit plant growth.

Materials and Methods

Study site

The study was carried out using drilled well mud soil collected form Kuje Area Council; an urban area in the Federal Capital city of Abuja. A place of settlement of immigrants from different areas with formal and informal jobs.

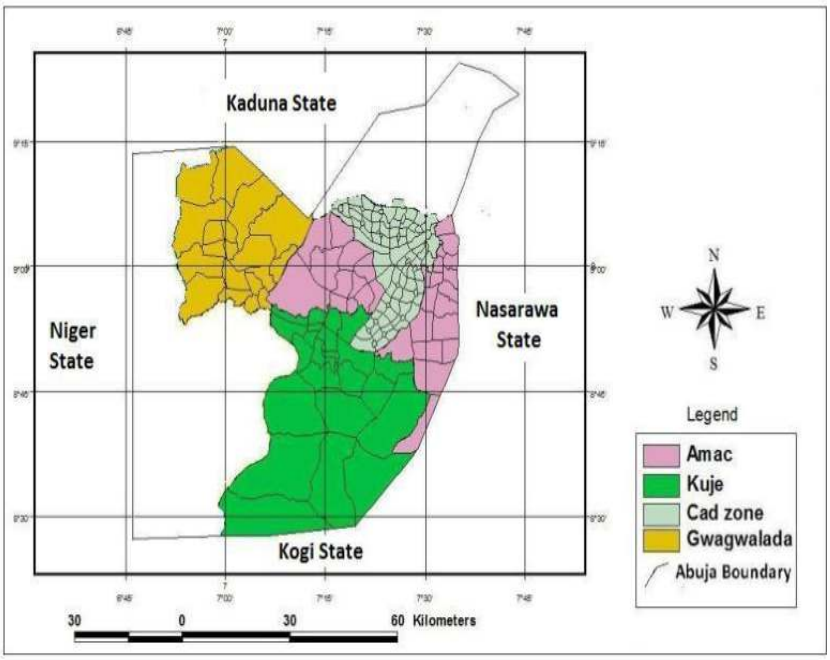


Figure 1: Map Showing Abuja Municipal, Kuje and Gwagwalada Area Councils
Source: Department of Geography and Environmental Management, University of Abuja

Ten seeds of *Z. mays*, SITUKA variety were sown in each plastic pot containing 2kg of drilling well mud soil. Eight replicates of these were set up and each watered with 400 ml of water twice a week. Controls were set up with same number of *Zea mays* seeds also planted in the same size of plastic containers with 2 kg of loamy soil. Germination percentage, plant heights, number of leaves and leaf areas were measured every two days for eighteen days. The concentrations of extractable elements; Calcium, Magnesium, Sodium, Copper and Chlorine (Ca, Mg, Na, Cu and Cl) in both the drilled well mud soil and loamy soil were also determined using Atomic Absorption Spectrophotometer (Pansu and Gautheyrou, 2006).

Analysis of Data

Data were analyzed using descriptive statistics (frequency counts and percentages) and analysis of variance (ANOVA) at 5% level of significance.

Results and discussion

The percentage germination of the maize seeds in both loamy soil and drilled well mud soil are shown in Figure 2. Germination commenced on the fourth day with 20% germination for seeds sown on loamy soil and 10% germination for seeds sown on drilled well mud soil. The rate of germination was faster in the germination for seeds sown on loamy soil which attained maximum germination of 90% on the tenth day. Seeds sown on drilled well mud soil attained the maximum germination of 80% also on the tenth day. There is no significant difference in the percentage germination of the seeds sown in loamy soil and drilled well mud soil.

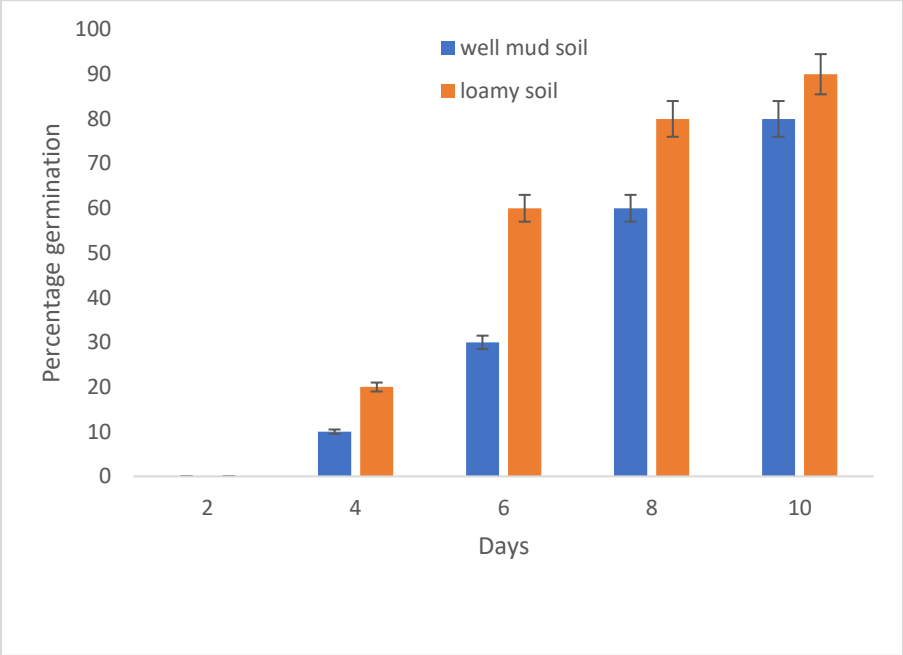


Figure 2: Percentage germination of the maize seeds in loamy soil and drilled well mud soil. Values shown are Mean ± SE.

The number of leaves per maize plant in loamy soil and drilled well mud soil are shown in Figure 3. Leaf counts were taken for twelve days. The first foliage leaves developed on the fourth day on both soil types. There was a gradual increase in the number of leaves from 3 to 13 in plants grown on loamy soil and from 2 to 10in plants grown on drilled well mud soil. Plants grown on loamy soil recoded more leaves at all periods of count. This is in agreement with the findings of Zvomuya *et al.* (2011). There is however no significant difference in the number of leaves of the plants grown in loamy soil and those grown in drilled well mud soil.

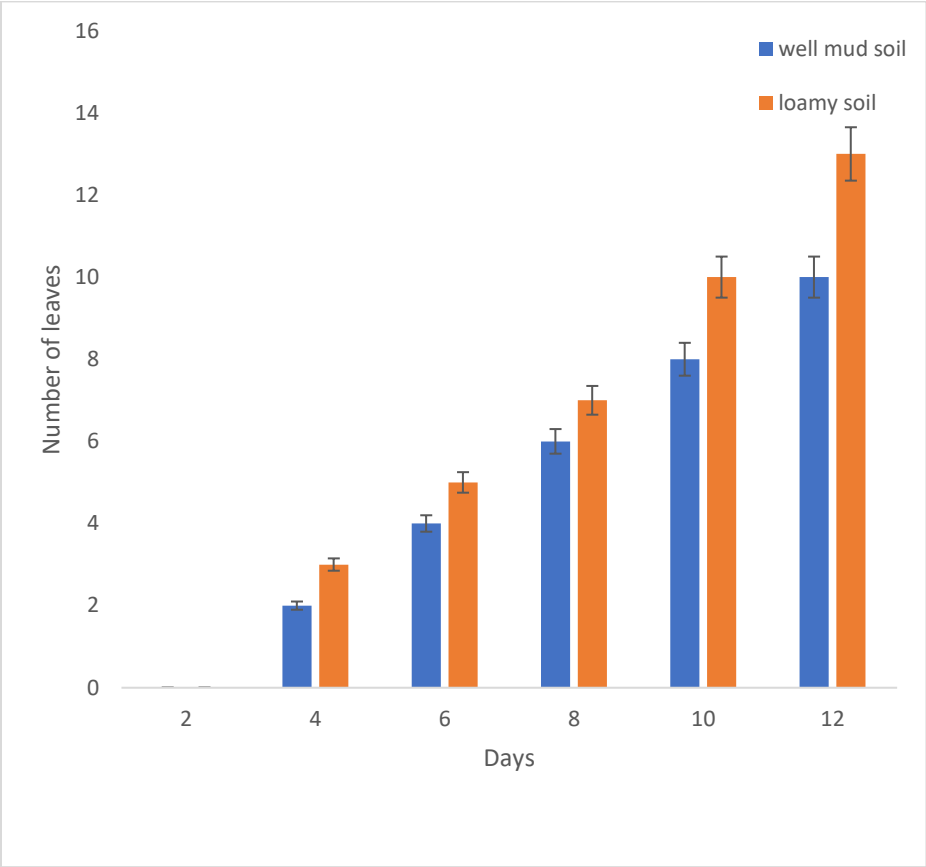


Figure 3: Number of leaves per maize plant in loamy soil and drilled well mud soil. Values shown are Mean ± SE.

Heights of maize plants grown in loamy soil and drilled well mud soil are shown in Figure 4. The heights of plants grown on loamy soil ranged from 8.3 cm on the eighth day to 38.3 cm on the eighteenth day while the heights of plants grown on drilled well mud soil ranged from 4.9 cm on the eighth day to 21.9 cm on the eighteenth day. Plants grown on loamy soil recoded higher heights throughout the period of study probably because of the reduced salt contents of the soil. This is in agreement with the findings of Dashti *et al.*, 2009. Significant differences were seen in the height of the plants grown in loamy soil and those grown on drilled well mud soil beyond fourteen days after planting.

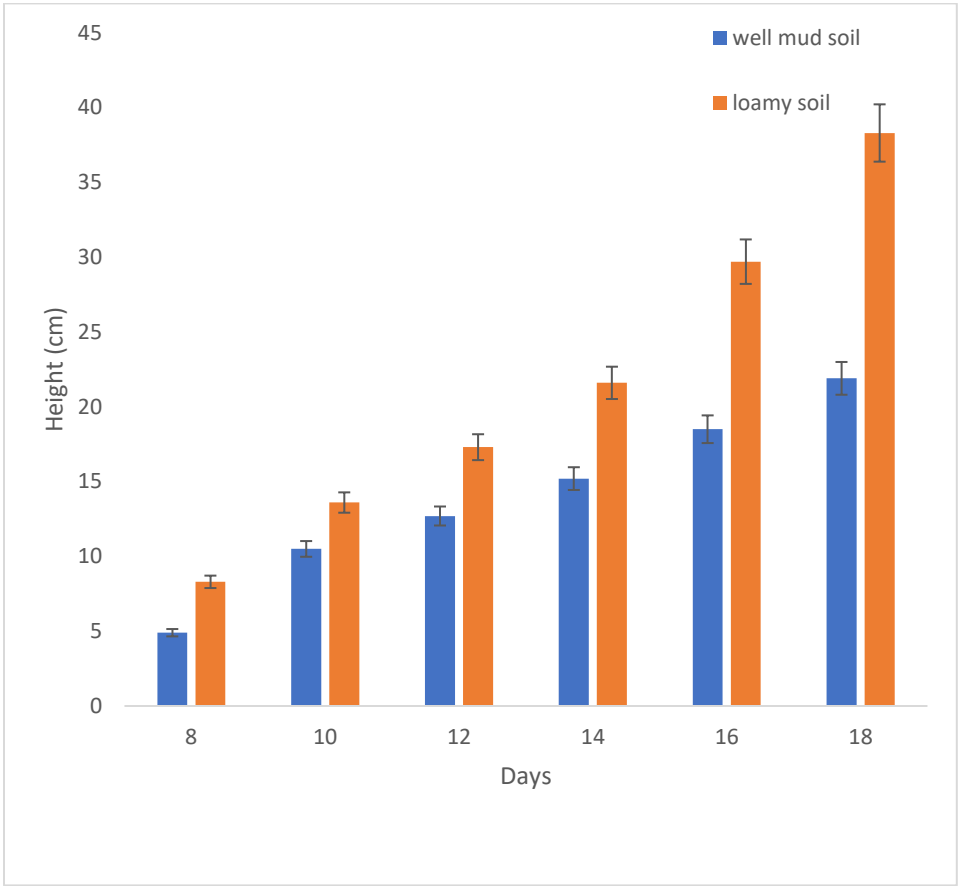


Figure 4: Heights of maize plants grown in loamy soil and drilled well mud soil. Values shown are Mean ± SE.

Leaf areas of maize plants grown in loamy soil and drilled well mud soil are shown in Figure 5. The Leaf areas of plants grown on loamy soil ranged from 12.2 cm^2 on the eighth day to 70.8 cm^2 on the eighteenth day while the heights of plants grown on drilled well mud soil ranged from 8.6 cm^2 on the eighth day to 48. 3 cm^2 on the eighteenth day.

Plants grown on loamy soil recoded higher leaf areas throughout the period of study. This is also in agreement with the findings of Dashti *et al.* (2009). There is no significant difference in the leaf areas of the plants grown in loamy soil and those grown on drilled well mud soil.

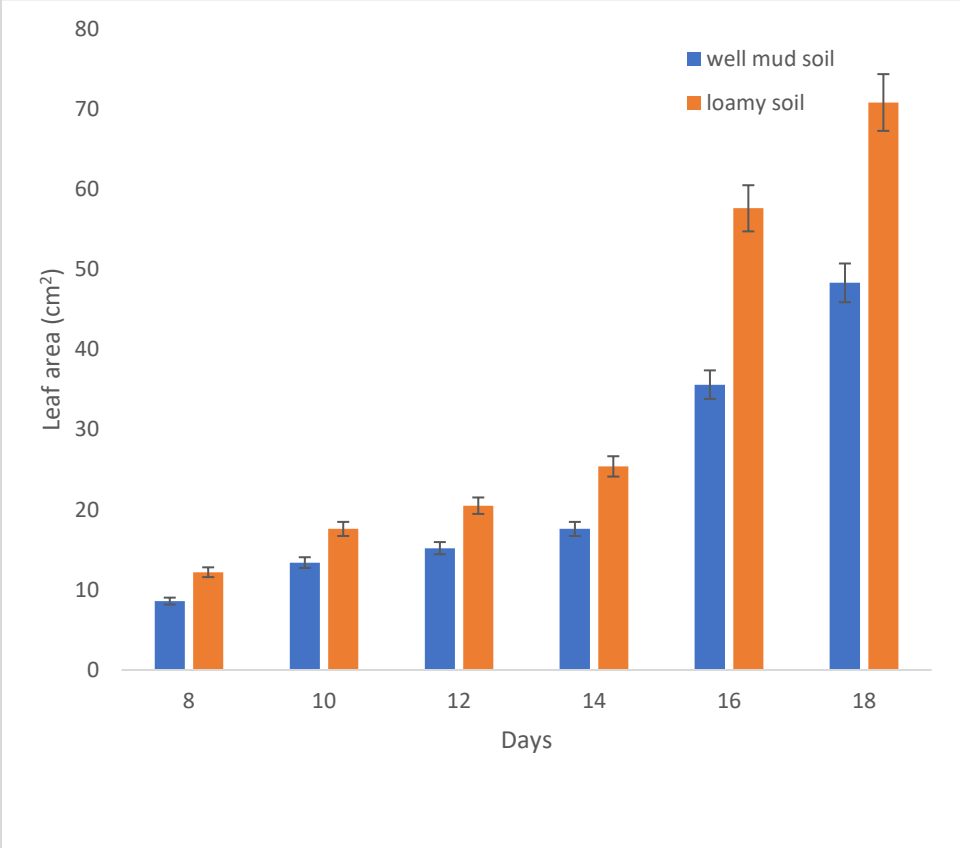


Figure 5: Leaf areas of maize plants grown in loamy soil and drilled well mud soil. Values shown are Mean ± SE.

The concentrations of extractable Ca, Mg, Na, Cu, and Cl were significantly higher in drilled well mud soil (Table 1). The increased soil extractable concentrations of Ca, Mg, Na, Cu and Cl in drilled well mud soil probably resulted in increased soil salinity which inhibited the plants growth. There was a reduced germination rate, number of leaves, plant heights and leaf areas. This is in agreement with the findings of Bauder *et al*., 2005 and Athar and Ahmad, 2002.

Table 1: Extractable chemical concentrations of total elemental analysis of drilled well mud soil and loamy soil

Element	Drilled mud extractable (mg/Kg)	Loamy soil extractable (mg/Kg)
Ca	4,760.00	2,170.00
Mg	418.00	286.00
Na	3,880.00	10.00
Cu	10.00	1.80
Cl	4.50	0.15

Conclusion

Drilled well mud brought about changes in the soil chemical properties. Plant percentage germination and other growth parameters indicated that the drilled well mud soil increased soil salinity and Na and Cl concentrations to levels that had negative impacts on the growth of *Zea mays*. Future research should be carried out up to yield level to determine the sustainability of mud soil for agronomic use and means of disposal of drilled well mud soil and to protect the environment.

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Farmers' Awareness Level and Knowledge of Aflatoxin Contamination of Food in Ondo State, Nigeria

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Abstract

The aim of this study is to determine farmers' knowledge and awareness level of aflatoxin contamination of food in Ondo state. This study used survey method in form of structured questioners to assess the farmers knowledge and awareness level of aflatoxin contamination of food. Qualitatively, a standard questionnaire was developed, pre-tested and disseminated to 100 farmers (60 female adult farmers, 10 female youth farmer, 20 male adult farmers and 10 male youth farmers) in Akure South and Ifedore Local government areas in Ondo State to gather information: on farmers' awareness level of aflatoxin contamination of food and the conditions that favor aflatoxin contamination during drying and measures taken to prevent contamination during storage, effects of aflatoxin on foods and health in general. The results obtained show that both educated and non-educated farmers were not aware about aflatoxin contamination in food and also the exposure of human to aflatoxin health related diseases. This study recommends that more work needs to be done in order to create awareness about the health implications of consuming aflatoxin contaminated food and to orientate farmers about good agricultural farming practices.

Key words: Aflatoxin, Awareness, farmers, food

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Introduction

Aflatoxin contamination in crop is conceived along laterally with the food chain during plant development, harvesting, storage and processing (Jallow *et al*., 2021; Mahato *et al*., 2019). Aflatoxin contamination of human may either be through direct ingestion of plant products contaminated with the toxins, or indirectly through the intake of animal product having residual amounts of aflatoxin consumed by the food producing animal; mould can contaminate the skin of animals or infected substrate and contamination can occur through inhalation of spore borne (Jallow *et al*., 2021). Contamination and exposure of aflatoxin are often unavoidable because the levels of awareness and knowledge of aflatoxin are very low among the majority of people (Udomkun *et al*., 2018). This explains why over 5 billion people in developing countries worldwide are in danger of chronic exposure to aflatoxin through contaminated foods (Nakavuma *et al*., 2020). Aflatoxin is not visible to the naked eye; and can not be detected through flavor, therefore, it is not easy to convince consumers about their existence in food (Hyde *et al*., 2019; Mahato *et al*., 2019). There are many simple ways to prevent aflatoxin contamination but due to low level of awareness (Jallow *et al*., 2021; Mahato *et al*., 2019) about aflatoxin contamination, it is difficult to carry out prevention of aflatoxin among farmers. Aflatoxins are of economic and health importance due to their ability to contaminate human food and animal feeds, and several spices have also been associated with aflatoxins contamination (Kumar, *et al*., 2017). The Food and Agricultural Organisation (FAO, 2020) estimates that 25% of the world's crops are affected by mycotoxins, of which the most notorious are aflatoxins *(Eskola et al*., 2020). Aflatoxin-losses to livestock and poultry producers from aflatoxin-contaminated feeds include death and more subtle effects of immune system suppression, reduced growth rates, and losses in feed efficiency (Kumar *et al*., 2021). Therefore, the objectives of this study is to determine the level of famers' awareness and their knowledge about aflatoxin contamination of food in Ondo State, Nigeria using Akure South and Ifedore Local government areas as a case study.

Materials and Methods

Study area

The study was carried out in five villages of Akure South and Ifedore local government of Ondo State, in Nigerian. The population of Ondo State is about 3.461, Ondo State enjoys a tropical climate broadly divided into two seasons which are the rainy season which begin in April till October and the dry season of which is from November to March.

This study adopted cross-sectional survey method to assess farmers' awareness level about aflatoxin contamination of food. Qualitatively, a standard questionnaire was developed, pre-tested and disseminated to 100 farmers (60 female farmers, 20 male adults, 10 female youths, 10 male youths) in Akure South Local Government in Ondo State to gather their information on farmers' awareness level of aflatoxin contamination of food, conditions that favor aflatoxin contamination during storage, measures taken to prevent contamination during storage and effects of aflatoxin on foods and health in general. Observations were also employed in assessing the farmers' storage.
The questionnaire was related with their settlement, qualification, age, previous knowledge about aflatoxin, health hazard and how to preserve their food against aflatoxin etc. Face-to-face data collection was also

used. Five villages surveyed are Igusin village, Ibule village, Aule camp, Alabametta village and Abaoyo in Akure South and Ifedore Local Government Areas, in Ondo state.

Data Collection

The primary source of data was basically through questionnaires. The questionnaire was administered to farmers on different farmlands within the villages. Farmers who could read and write were allowed to fill the questionnaire on their own. However, help was provided for those that could not read or write.

Data Processing

Simple percentage and frequency were used to analyze the data. Table and graph were made from the data collected to ensure adequate interpretation of the questionnaires based on responses given by the respondents. The respondents were arranged into the following categories: male adult farmers, female adult farmers, youth male farmers, and youth female farmers. The data was extracted based on these categories and assigned into statistical package for Social Sciences (SPSS) software for further processing. Descriptive statistics was used to analyze data that relates to assess of farmers' awareness of aflatoxin contamination in Akure South and Ifedore Local Government Areas, Ondo State.

Results

The Igusin village head was formally informed which enabled the farmers to listen and respond to the questionnaire. Also in Aule village, there were lots of farmers comprising of both educated and non-educate.

The socio-demographic characteristics (Age and gender) of the population

The socio-demographic characteristics of the population were presented in Table 1. Statistically, 60% of female adult (n=60) in this study were within the age group of 35-55 years as compared to 20% of male adults respondents (n=20) which were within the same age group (35-55 years), while 10% of both female and male youth respondents were within the age group of 18– 25 years respectively. The frequencies of the sex of the respondents showed that the highest percentage of the respondents were female (60%) over the male (20%). Therefore, this finding shows that female are dominant in the agricultural production in Ondo State. It was also noted that most of the farmers that responded to the questionnaires are mostly women.

Table 1: Farmers Age Distribution.

Sex	Age	Percentage
Female Adult	35 -55	60
Male Adult	35 -55	20
Female Youth	18-25	10
Male Youth	18-25	10
Total		100

Level of education among the farmers

Figure 1 shows the level of education attained by the respondent. It was observed that 40% of female adults at Ibule village had no formal education, 10% of male adults had primary education, while both female and male youth farmers (3.3% and 6.6 %) had primary, secondary, tertiary education respectively. The female adults of 33.3% at Aule village did not have formal education while 16% of male adult had secondary education. The percentage of the youth that were present in the study area was 5.5%. At Alabametta village, 31.0% of female adults have primary education, both male and female youths have 23.5% in the study area. In Igusin village, 23.0% of the female adults interviewed had no formal education, 23.5% of the female adults had primary education while the percentage of male that did not have formal education is 11.0%. About 15% of female did not have formal education at Abaoyo village.

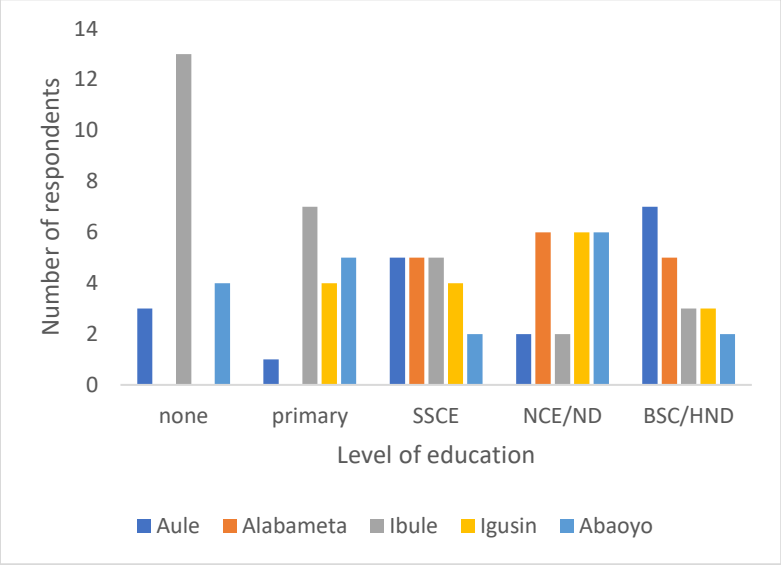


Figure 1: Education level of the respondents

Knowledge of aflatoxin contamination in food

The awareness level and knowledge of aflatoxin contamination in food by the farmers were as shown in Figure 2. It was observed that in AULE village, only 5% of male youth and 30% of female youth were aware of aflatoxin while both male and female adults had no previous knowledge about aflatoxin contamination. Sixty three percent (63%) of the respondents were not previously aware of mycotoxin contamination of cocoa while 37% had previous knowledge about mycotoxin contamination of cocoa. About 70% of the respondents had no knowledge about the health implications of consuming mycotoxin infected crops while 30% had previous knowledge of the health implications. About 90% of the respondents admitted that they have been visited by the Agricultural extension workers while 10% of them have not been visited. The categories of those that have attended training or seminars related to harvesting, handling, drying and storing methods of cocoa were 57% while 43% of the respondent did not attend any form of training.

In Aule village, it was discovered that male adults were not aware about aflatoxin contamination in food while only 5% of male youth had a previous knowledge about aflatoxin contamination and about 30% of female youth also had a previous knowledge about aflatoxin contamination in food.

In Ibule, 6.6 % of male adult and 3.3%, female adult respondents had a prior knowledge about aflatoxin contamination of food (23.3%) and female youth (11%). It was observed that female adult respondents in Ibule village have the highest number of previous knowledge on awareness of aflatoxin contamination in food followed by female youth respondents. At Alabametta village, male adult respondents were not aware about aflatoxin while 6.25% male youth and 6.25% female adult respondents are not aware about aflatoxin contaminations in food.

The awareness level at Igushin village revealed 5.8% male adult and male youth, with 11.7% female youth respondents, having previous knowledge about aflatoxin contamination. However, it was discovered that female adult had no previous knowledge about aflatoxin contamination of food. In Abaoyo village, 21% male youth, 5.2% of male adults, 10.2% of female adult and 5.2% female youth respondents were aware about aflatoxin contaminations in food.

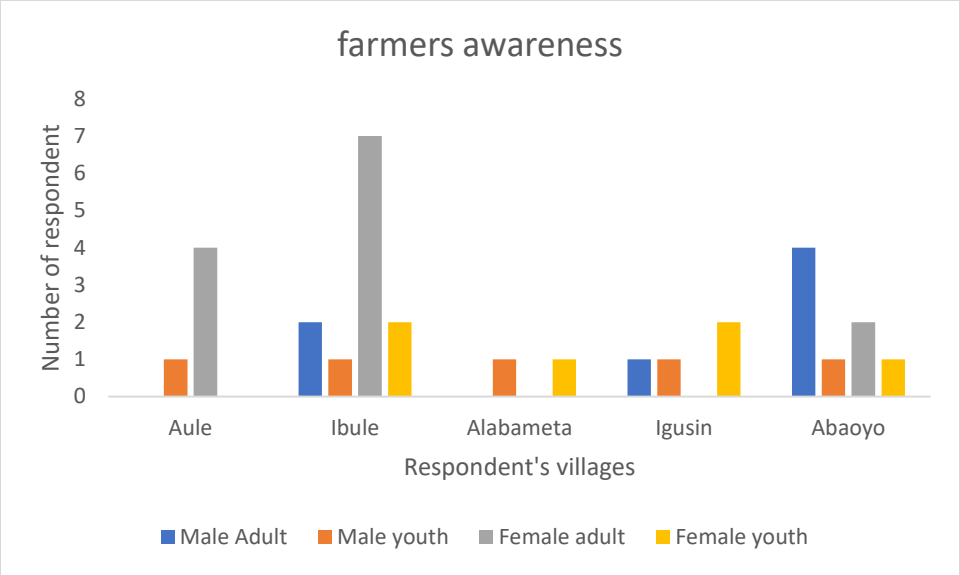


Figure 2: Level of awareness of aflatoxin contamination in food

Level of unawareness of aflatoxin contamination in food among farmers

Figure 3 shows the level of unawareness of aflatoxin contamination in food among farmers. At Aule village, it was observed that female adult had the highest number of unawareness of aflatoxin followed by male adult while male youth had the lowest number.

In Ibule village, the unawareness of aflatoxin contamination in food among male adult was 13%, male youth recorded 3% and female adult was 43%. Female youth are not aware of aflatoxin contamination in food in the study area. Female adult have the highest number of unawareness of aflatoxin in the study area.

At Alabametta village, the level of unawareness of aflatoxin among male adult was 13%, male youth recorded 6%, furthermore among female adult 63% while only 6.25% was discovered among female youth in the study area.

The level of unawareness of aflatoxin among famers respondents at Igushin village was 12% male adult and 6% of male youth as well as 21% of female youth and female adult respondents had no prior knowledge about aflatoxin contamination. At Abaoyo village, 32% of male adult, 5% of male youth, 42% of female adult and 5.2% of female youth respondents had no prior knowledge about aflatoxin contamination.

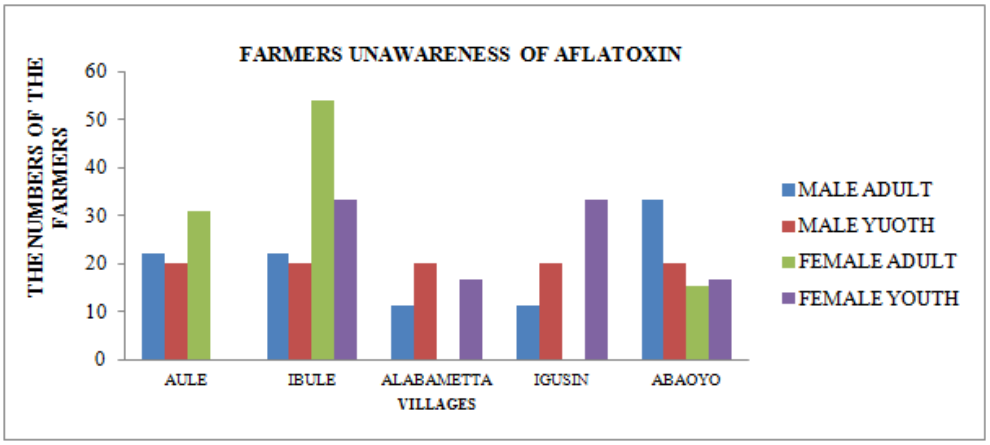


Figure 3: Farmer's unawareness of aflatoxin

Farmer's awareness and knowledge of health implications caused by aflatoxin contaminations

Figure 4 shows that most respondents were not even aware about health implications of consuming food contaminated with aflatoxin.

Percentage of farmers respondents that dry their maize on ground along roadside

The results of the percentage of farmers respondents that dry their maize on ground along roadside is shown in Figure 5. At Aule village, the percentage of farmers that dry their maize on ground along road-side include: 16.6% of male adult, 11.1% of male youth, 55.5% of female adult, and 11.1 % of female youth. At Ibule village, the percentage of farmers that dry their maize on ground along road side include: 16.6 % of male adult, 6.6% of male youth, 53.3% of female adult and 6.6% female youth respondents. At Alabametta village, the percentage of farmers that dry their maize on ground along road side include: 12.5% of male adult, 12.5% of male youth, 62.5% of female adult and 12.5% of female youth. At Igushin village, percentage of farmers' respondents that dry their maize on ground along road side include: 11.7 % of male adult, 11.7% of male youth, 58.8 % of female adult and 11.7% of female youth. At Abaoyo village, the percentage of how farmers respondents dry their maize on ground along roadside include: 26.3% of male adult, 10.5% of male youth, 52.6% of female adult and 10.5 % of female youth.

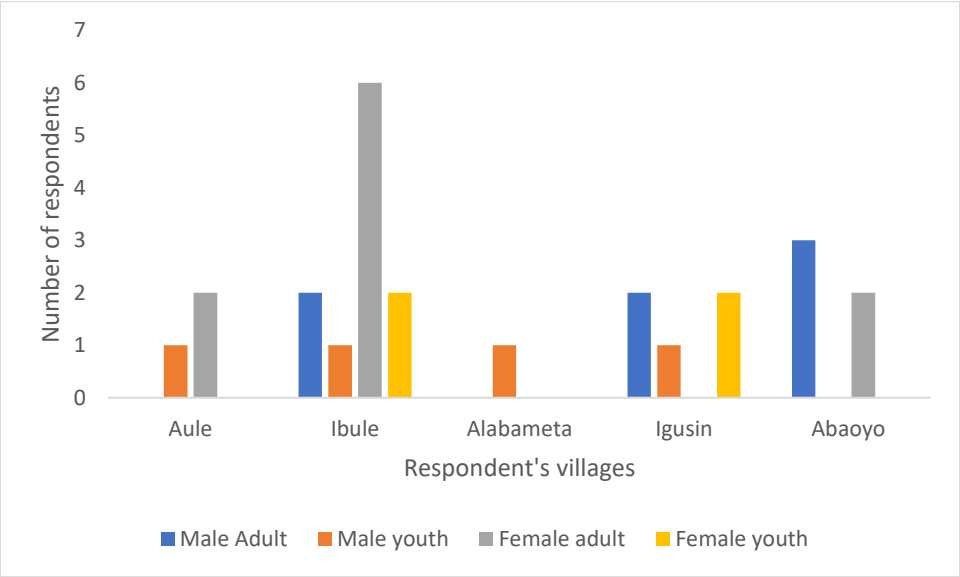


Figure 4: Farmer's awareness of aflatoxin health related disease

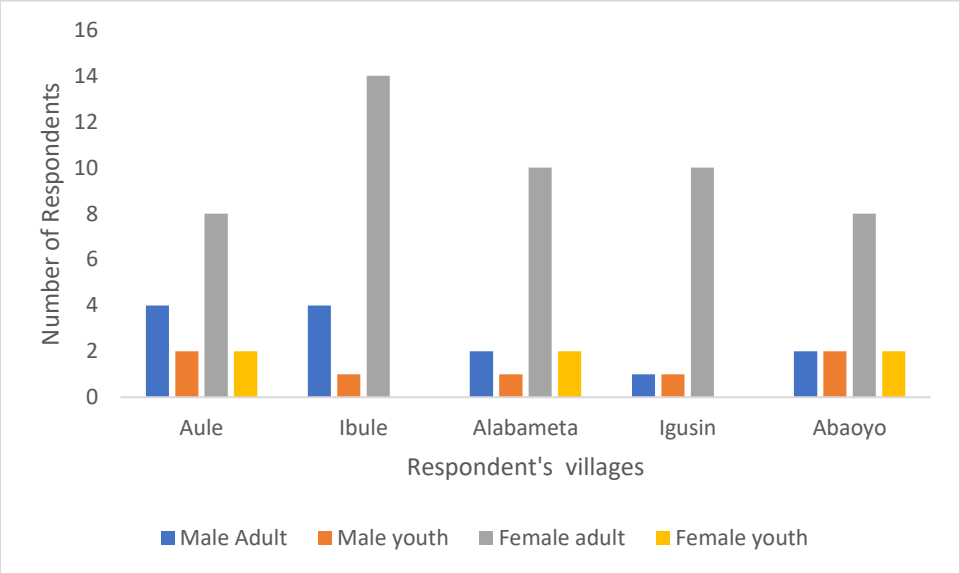


Figure 5: Farmers that dry their maize on the ground along road side

Discussion

The socioeconomic characteristics data generated in this study indicated that several economic activities are carried out by different categories of gender groups. More female participated in the interview, a phenomenon related to the tendency that majority of the household heads are men which is in contrary to the findings of (Osarenren *et al.*, 2009). Osarenren observed that the gender distribution in his report indicated that the majority of the respondents where predominantly males accounting to 88.9% of the respondents while the females only accounted for 11.1% in farming actives. The findings in this study portray the role of women in farm management, decision making, as they often play a minimal part in making economic decisions which affect them directly or indirectly (Hunt and Samman, 2016) but they are involved in major farming role (Satyavathi *et al.,* 2010). The data generated in this report had more farmers with low education than those of high education, probably due to the socioeconomic set-up in the area, such as resource scarcity and farming activities as a replacement for employment.

This study has revealed that in Ondo state, the level of awareness of aflatoxin is very low and there is need to create more awareness of aflatoxin contamination and the health implication of consuming food contaminated with aflatoxin. Since aflatoxin is very dangerous and carcinogenic in nature which can lead to damage of liver and result to untimely death among human being and animals (Kumar *et al*., 2021; Kumar *et al*., 2017). Small consumption of aflatoxin can also lead to various type of diseases such as hepatitis, liver cancer, and hemorrhage etc (Kumar *et al*., 2017). This is the reason why it is important to create awareness about aflatoxin contamination among human most especially among farmers and food processors.

The report on the level of awareness of aflatoxin contaminations of food showed that only very few respondents have a pre-knowledge about aflatoxin contamination. This level of awareness is very low and similar to the level of awareness by some researchers (James *et al*., 2007; Udomkun *et al.*, 2018).

Conclusion and Recommendation

The entire 100 respondents in the study area are residents of Ifedore and Akure South Local Government areas in Ondo state. According to the data collected from this research it reveals that female adult respondents were more than male respondents. It is to be noted that 20 of them are male adult representing 20% while 60 of them were female representing 60%, also both male youth and female youth were 20 in number representing 20% in the study area.

This research study pointed out that even the educated respondents were not aware about aflatoxin contamination of food in the villages. The awareness of aflatoxin in the study area is very low due to the fact that their level of education is very low. The level of awareness of aflatoxin health related diseases was low in the five villages of the study area. Most farmers were not aware of health related disease associated with the consumption of aflatoxin contaminated food. Furthermore, it was observed that most of the female adults dry their food on ground by the roads side.

Harvesting of food in farming system varies, due to the type of food and the season (Tan et al., 2020). According to this research, some farmers harvest maize in one month and some two months after maturity. This research identified the absence of Agricultural Extension workers

in the study areas. This is likely to be the reason why farmers are not aware of aflatoxin contamination in food, thus exposes them to aflatoxin health related diseases. Based on the findings of this study, it can be concluded that female farmers are dominant in farming activities within the study area with low educational level and considering the level of awareness about aflatoxin contamination of food indicated that majority of the respondents were not previously aware of aflatoxin contamination of food. Therefore, the following recommendation will be useful to policy makers in improving farming activities in Ondo State. Farmers should be enlightened on the health risk associated with aflatoxin contamination of food. During harvesting, it is advisable to allow agricultural crops to reach maturity stage before they are harvested. The harvested crops should then be dried as quickly as possible and removal of damaged products also helps. The crops should also be stored at proper temperature and humidity to reduce mould growth. Food manufacturers should also ensure that the aflatoxin level in raw materials they receive complies with the safety standards. Farmers should store food under dry and cool condition and discard food with signs of mould infestation (Victor, 2014).

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Climate Change, Agricultural Output and Economic Growth in Nigeria: Any Nexus?

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Abstract

The study examined the impact of climate change on agricultural output and economic growth in Nigeria for the period of 1981- 2016. Secondary data sourced from the Central Bank of Nigeria (CBN) statistical bulletin and Nigerian Meteorological Agency (NIMET) publications were analysed using Augmented Dickey- Fuller (ADF) for unit root test and pairwise Granger causality test. The results indicate that all variables were integrated of order one (1) and have long run relationship. The Error Correction Model (ECM) shows that about 89% of disequilibrium would be corrected each year by changes in the variables of climate change. Results also showed that rainfall, temperature and carbon emission have significant impacts on the economic growth and agricultural output of Nigeria. Result from the pairwise Granger causality test revealed that climate change has unidirectional causality on agricultural output and economic growth. The study concluded that in the long run relationship, climate change has significant effect on agricultural output and economic growth of Nigeria. Therefore, the study recommends that the Nigerian government should evolve policies to encourage the use of environmental friendly techniques towards having a sustainable economic growth and all the stakeholders involved in the global phenomenon need to increase public awareness, promote research and establish an agency that will handle issues related to climate change.

Keywords: Climate change, Agricultural output, Augmented Dickey-Fuller, economic growth,
JEL: Q, C13, F43, O47

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Introduction

Climate is an essential input to agricultural production and output. Often times, studies of agricultural output seem to ignore climate, assuming it to be static. However, IPCC (2012) noted in its assessment report that the impacts of a warming planet are now becoming obvious and these impacts are expected to accelerate in the future. Knowledge of these impacts as well as the potential future impacts of climate change on agriculture has become an entire field of scientific studies in our contemporary society. The country ranks 4th among the countries of the world that are expected to be severely affected by climate change (Ferner and Varul, 2018). It should be noted that, it is upon the agriculture sector that large part of her economy depends for livelihoods, even when large proportion of her revenue is from the petroleum resources.

Many African countries, which have their economies largely based on weather-sensitive
agricultural productions systems like Nigeria, are particularly vulnerable to climate change (Dinar *et al.*, 2006). Ojemade *et al.*, (2020) estimated the maximum impact of climate change on Nigeria's GDP to be 11% in 2020, which could reach 30% by 2050. Climate change is having serious impacts on agriculture and may require on-going adaptation, short-run threats to global food security are also crucial for developing countries. The results confirmed that there is a long-run relationship between agricultural productivity and climate change variables (Ozdemir, 2021).

Agricultural output can be defined as a measure of efficiency in an agricultural production system which employs land, labour, capital and other related resources. The measurement of agricultural productivity deals with the relationship between output and input in agricultural production. The valuation of agricultural output with respect to weather conditions has attracted the attention of scholars working in different disciplines like, geography, agricultural economics and more recently petroleum and energy economics. The reason is that agriculture is indeed often considered as the most weather-dependent human activity (Hansen, 2002). Economic growth can be defined as an increase in the production of economic goods and services, compared from one period of time to another.

There is dearth of literatures on the nexus among climate change, agricultural productivity and economic growth in Nigeria using time series data. Relevant existing studies are limited in their data points and thus, require more insight into the present impact of the climate change on the agricultural output and economic growth. In addition, the issues of climate change and its effects on agricultural production and its attendant effect on an economy has become an issue of great concern to most environmentalist and economists.

The impacts of climate change are being felt by both developed and developing countries, including Nigeria. These impacts are currently being experienced on

agricultural production, health, biodiversity, social, economic, manufacturing and energy sector. The outcome of the study will serve as a policy guide to governments at various levels on the extent of impacts of climate on agricultural output and economic growth. This study focused on the relationship among climate change, agricultural output and economic growth over the period of 35 years (1981- 2016). As at the time of writing, data on climate change was available only up till 2016.

It was also observed that variables used in previous studies were agricultural production outputs, rainfall, climate change and temperature but excluded carbon emission which the present study intend to capture with a view to improving the robustness of this research (Ayinde *et al.,* 2010). In furtherance to this, most studies did not examine the relationship among climate change, Agricultural output and Economic growth (Ebele and Emodi, 2016).

The broad objective of the study is to determine the relationship among climate change, agricultural output and economic growth in Nigeria. The specific objectives are to: examine the effects of climate change on agricultural output and economic growth in Nigeria during the period under review and determine the causal relationship among climate change, agricultural output and economic growth in Nigeria.

Methodology

The study captured the relationship among the variable of interest to generate the magnitude of impact of the independent variables on the dependent variable using secondary data. The model specification for the study is as stated below:

Model One: Impact of Climate change (CC) on Economic Growth

Economic growth= f (Climate change [CC]) (1)

Economic growth was measured by real gross domestic product (RGDP) while climate change was represented by temperature (TEM), carbon emission CO_2 (CAE), average total annual rainfall (RAF) while agricultural output was proxied by output from the agricultural sector.

This is implicitly expressed as;

RGDP= F (TEM, CAE, RAF) (2)

Equation (2) is explicitly rewritten as;

$RGDP_t = \beta_0+\beta_1 TEM_t+\beta_2 CAE_t+\beta_3 RAF_t+ e_t$ (3)

Model Two: Impact of Climate change (CC) on Agricultural output (AGO)

This is implicitly expressed as;

AGO= f(TEM, CAE, RAF) (4)

Rewritten equation 4 explicitly to become:

$AGO_t = \Theta_0 + \Theta_1 TEM_t+ \Theta_2 CAE_t+ \Theta_3 RAF_t+e_t$ (5)

Expressing Equation (3 & 5) in logarithm form became;

$LOGRGDP_t = \beta_0+\beta_1 LOGTEM_t+\beta_2 LOGCAE_t+\beta_3 LOGRAF_t+e_t$ (6)

$LOGAGO_t = \Theta_0+ \Theta_1 LOGTEM_t+ \Theta_2 LOGCAE_t+ \Theta_3 LOGRAF_t+e_t$ (7)

where;

RGDP= Real gross domestic product (₦ 'Billion)
TEM= Temperature (℃)
CAE= Carbon emission (metric tons per capita)
RAF= Average total annual rainfall (mm)
AGO= Agricultural output (metric tons)
f()=functional definition
et = is the error term
LOG = Logarithm
β_o, $\Theta_{0=}$ are the intercept
β_1-β_3, Θ_1- Θ_3= parameters to be estimated
t= is the time periods between (1981-2016)

***Apriori* expectation**

β_1, β_3, Θ_1 and Θ_3 have unrestricted sign. Temperature and rainfall can have positive or negative impact on the economy.
$\beta_2>0$, $\Theta_2>0$ as carbon emission is expected to have negative impact on the economy.

Methods of data analysis

Augmented Dickey-Fuller (ADF) was employed to test for series stationarity while Co-integration was used to determine if there was existence of long run equilibrium relationship among the variables. Unit root test was carried out on the series to determine the levels of significance as well as the order of integration for the variables. The method of Augmented Dickey fuller (ADF) test for stationarity was adopted to do this because it takes care of possible serial correlation in the error term by including the lagged difference of the dependent term.

A process is said to be stationary when it has a constant and time independent mean, a finite and time independent variance and if the covariance between successive terms in time independent. Error Correction Model for co-integrated economic variables are commonly interpreted as reflecting partial adjustment of one variable to another. We show that error correction models may also arise because one variable forecasts another.
The model is specified as:

$$\Delta LOGRGDPt=\Theta_0 + \sum_{t=1}^{n}\theta_{1t}\ \Delta LOGTEM + \sum_{t=1}^{n}\theta_{2t}\ \Delta LOGCAE + \sum_{t=1}^{n}+\theta 3t\Delta LOGRAF+ \lambda ECM_{t-1} + \varepsilon_t \quad (8)$$

$$\Delta LOGAGOt = \Theta_0 + \sum_{t=1}^{n}\theta_{1t}\ \Delta LOGTEM + \sum_{t=1}^{n}\theta_{2t}\ \Delta\ LOGCAE +\sum_{t=1}^{n}+\theta 3t\Delta LOGRAF+\lambda ECM_{t-1}+\varepsilon_t \quad (9)$$

Where:
Δ is the first difference operator
λ is the error correction coefficient and the remaining variables are defined below.

The diagnostic test include test for heteroscedasticity.
It tests whether the variance of the errors from the regression is dependent on the values of the independent variables (TEM, CAE, RAF and AGO). Granger causality was used to estimate the

causal relationship between dependent and independent variables. To implement the Granger test, the following causality models were estimated as stated below.

Causality between TEM and RGDP:

$$TEMt = \alpha_1 + \sum_{i}^{p} \gamma_i TEM_{t-1} + \sum_{i=1}^{p} \delta_i RGDP_{t-1} + \varepsilon_{1t} \quad (10a)$$

$$RGDP_t = \alpha_2 + \sum_{i=1}^{p} \theta_1 RGDP_{t-1} + \sum_{i=1}^{p} \pi_i TEM_{t-1} + \varepsilon_{1t} \quad (10b)$$

Causality between TEM and AGO:

$$TEM_t = \alpha_{1+} \sum_{i=1}^{p} \gamma_i TEMt_{-1} + \sum_{i=1}^{p} \delta_i AGOt_{-1} + \varepsilon_{1t} \quad (11a)$$

$$AGO_t = \alpha_2 + \sum_{i=1}^{p} \theta_1 AGO\ t_{-1} + \sum_{i=1}^{p} \pi_i TEMt_{-1} + \varepsilon_{1t} \quad (11b)$$

Causality between CAE and RGDP:

$$CAE_t = \alpha_1 + \sum_{i=1}^{p} \gamma i CAE_{t-1} + \sum_{i=1}^{p} \delta_i RGDP_{t-1} + \varepsilon_{1t} \quad (12a)$$

$$RGDP_t = \alpha_2 + \sum_{i=1}^{p} \theta_1 RGDPt_{-1} + \sum_{i=1}^{p} \pi_i CAEt_{-1} + \varepsilon_{1t} \quad (12b)$$

Causality between CAE and AGO:

$$CAE_t = \alpha_1 + \sum_{i=1}^{p} \gamma_i CAE_{t-1} + \sum_{i=1}^{p} \delta_i AGO_{t-1} + \varepsilon_{1t} \quad (13a)$$

$$AGO_t = \alpha_2 + \sum_{i=1}^{p} \theta_1 AGO\ _{t-1} + \sum_{i=1}^{p} \pi i CAEt_{-1} + \varepsilon_{1t} \quad (13b)$$

Causality between RAF and RGDP:

$$RAF = \alpha_1 + \sum_{i=1}^{p} \gamma_i RAF_{t-1} + \sum_{i=1}^{p} \delta_i RGDP_{t-1} + \varepsilon_{1t} \quad (14a)$$

$$RGDP = \alpha_2 + \sum_{i=1}^{p} \theta_1\ RGDP_{t-1} + \sum_{i=1}^{p} \pi_i RAF_{t-1} + \varepsilon_{1t} \quad (14b)$$

Causality between RAF and AGO:

$$RAF = \alpha_1 + \sum_{i=1}^{p} \gamma_i RAF_{t-1} + \sum_{i=1}^{p} \delta i AGO_{t-1} + \varepsilon_{1t} \quad (15a)$$

$$AGO = \alpha_2 + \sum_{i=1}^{p} \theta i AGO + \sum_{i=1}^{p} \pi_I RAF_{t-1} + \varepsilon_{1t} \quad (15b)$$

Sources of data

This study made use of secondary data obtained from Central Bank of Nigeria (CBN) bulletin and Nigerian Meteorological Agency (NIMET) for the period of 1981-2016. The agricultural output and gross domestic product data were derived from CBN while Climatic variables data which include annual temperature, rainfall, carbon-dioxide were culled from NIMET, Oshodi, Lagos.

Results

Unit Root Test

Table 1 shows the results of the Augmented Dickey- Fuller Test with assumption of intercept.

Table 1. Augmented Dickey-Fuller Test of Stationarity

Variables	1st difference	order of integration
LOGRGDP	-3.229356 (0.0268)	I (1)
LOGRAF	-7.588183 (0.0000)	I (1)
LOGCAE	-6.736845 (0.0000)	I (1)
LOGAGO	-3.359031 (0.0198)	I (1)
LOGTEM	-8.057082 (0.0000)	I (1)

Source: Researchers' Computation (2021)

It indicates that all variables were non-stationary at level, but all the variables were integrated of order one that is, the series were stationary at first difference I (1). The data for all variables were transformed into

log forms in order to normalize them (table 1).

Lag Selection

Table 2 contained the result of the lag length selection analysis for economic growth model (Model One) and agricultural output (Model Two). The lowest value AIC, SC and HQ are -22.24, -21.35 and -21.93. Based on this finding, the study therefore estimated Johansen Co-Integration Test with 1 lag.

Table 2. Lag Selection

	Model One		Model Two	
	Lag 0	Lag 1	Lag 0	Lag 1
LogL	275.71	409.13	357.1886	489.5046
LR	NA	228.73*	NA	226.8274*
FPE	2.12e-12	2.61e-15*	2.02e-14	2.64e-17*
AIC	-15.53	-22.24*	-20.1822	-26.82883*
SC	-15.35	-21.35*	-20.00445	-25.94006*
HQ	-15.46	-21.93*	-20.12084	-26.52203*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Researchers' Computation (2021)

Co-Integration Test

Table 3 contains the cointegration test. For Model One, the result shows that the null hypothesis (no co-integration) is rejected. The Maximum Eigen Value and Trace statistic further shows that the null hypothesis of no co-integrating equation, among the variables was rejected. Both the Maximum Eigen Value and Trace Statistic indicate that there is co-integrating equation respectively. This means that there is a long run relationship variable. That is, the linear combinations of these variables do not cancel out the stochastic trend in the series. In this case, ECM was used to prevent the non-meaningful regression results.

Table 3. Co-integration Test

	Model One	Model Two
None	0.994108* [195.6862] {47.85613} (0.0000)	0.994031* [194.5337] {47.85613} (0.0000)
At most 1	0.359223* [21.12403] {29.79707} (0.3500)	0.352564* [20.41602] {29.79707} (0.3951)

At most 2	0.146411* [5.991507] {15.49471} (0.6965)	0.139688* [5.635025] {15.49471} (0.7382)
At most 3	0.017756* [0.609140] {3.841466} (0.4351)	0.015159* [0.519366] {3.841466} (0.4711)
* Eigenvalue []Trace Statistic {}0.05 Critical Value ()MacKinnon-Haug-Michelis (1999) p-values		

Source: Researchers' Computation (2021)

Similarly, for Model Two, the result shows that the null hypothesis (no co-integration) is rejected. The Maximum Eigen Value and Trace statistic further shows that the null hypothesis of no co-integrating equation, among the variables was rejected. Both the Maximum Eigen Value and Trace Statistic indicate that there is co-integrating equation respectively. This means that there is a long run relationship variable. That is, the linear combination of these variables do not cancel out the stochastic trend in the series. In this case, ECM was used to prevent the generation from spurious results (i.e., non-meaningful) regression results. This is simply because spurious data begets spurious result.

Error Correction Model Results

Table 4 shows the ECM result for model one and model two. The purpose of ECM is to indicate the speed of adjustment from the short run to the long run equilibrium state.
For Model one: The coefficient value of LOGRAF lag (-1) which was 930.1179 showed a positive relationship between economic growth but it is statistically significant. However, the result implies that a percentage increase in LOGRAF would lead to 930% increase in RGDP. The coefficient value of LOGCAE lag (-1) indicating (-21.56165) shows a negative relationship but significance at 1%. The result implies that a percentage increase in LOGCAE would lead to decrease in RGDP. The coefficient value of LOGTEM (-1638.568) is negatively related to RGDP and it is statistically significance. The result implies that a percentage increase in LOGTEM would lead to 1639% decrease in RGDP.

The result of ECM shows that about 89% of disequilibrium between short run and long run dynamics would be corrected each year in the variables of interest (LOGRAF, LOGCAE & LOGTEM) and is significance at 1%. The R-Squared value of 0.886663 shows that 89% of total variation in the RGDP is being explained by the explanatory variables (LOGRAF, LOGCAE and LOGTEM). The F-Statistic value of 56.7185 with the probability value of 0.0000 is significant which shows the fitness of the model.

Table 4. ECM Results

Description	Model One	Model Two
Dependent Variable	LOGRGDP	LOGAGO
C	-549.9292 [70.69157] {-7.779276} (0.0000)	-51.33653 [6.876762] {-7.465219} (0.0000)
LOGRAF(-1)	930.1179 [119.9628] {7.753383} (0.0000)	89.07975 [11.67014] {7.633134} (0.0000)
LOGCAE(-1)	-21.56165 [2.726695] {-7.907614} (0.0000)	-2.065508 [0.265242] {-7.787267} (0.0000)
LOGTEM(-1)	-1638.568 [213.9323] {-7.659284} (0.0000)	-156.9090 [20.81205] {-7.539333} (0.0000)
ECM(-1)	0.893623 [0.095845] {9.323651} (0.0000)	0.890736 [0.095711] {9.306488} (0.0000)
R-squared Adjusted R-squared F-statistic Prob(F-statistic) Durbin-Watson	0.886663 0.871031 56.71875 0.000000 1.908219	0.885403 0.869596 56.01508 0.000000 1.912162
[] Std. Error {} t-Statistic () Prob.		

Source: Researchers' Computation (2021)

The Durbin Watson Statistic always has a value between zero and 4.0. A value of 2.0 means that there is no autocorrelation detected in the model. Values from zero to 2.0 indicate positive autocorrelation and values from 2.0 to 4.0 indicate negative autocorrelation. In the regression conducted, the value of the Durbin Watson was 1.908219 indicated that there was a positive autocorrelation in the model because the value is below 2.0.

For Model Two: The coefficient value of LOGRAF lag (-1) (89.07975) is positively related to AGO and it is statistically significant. The result implies that a percentage increase in LOGRAF would lead to 89.01% increase in AGO. The coefficient value of LOGCAE lag (-1) (-2.065508) shows a negative relationship between Agricultural output but significant at 1%. However, the result implies that a percentage increase in LOGCAE would lead to 2.066% decrease in AGO. The coefficient value of LOGTEM (-156.9090) is negatively related to AGO but it is statistically significant. The result indicates that a percentage increase in LOGTEM would lead to 157% decrease in AGO. The result of ECM shows that about 89% of

disequilibrium between short run and long run dynamics would be corrected each year in the variables of interest (LOGRAF, LOGCAE & LOGTEM) and is significant at 1%. The R-Squared value is 0.885403 shows that 89% of total variation in the AGO is being explained by the explanatory variables (LOGRAF, LOGCAE and LOGTEM). The F-Statistic value of 56.01508 with the probability value of 0.000000 is significant which shows the fitness of the model. In the regression conducted, the value of the Durbin Watson was 1.912162 indicated that there was a positive autocorrelation in the model because the value is below 2.0 (Table 4).

Diagnostic Analysis

Table 5 contains post estimation test for model one and two. For model one, since the probabilities are not significant and greater than 5% level of significance. The null hypothesis is therefore accepted which implies that the model is free of any heteroscedasticity problem

Table 5. Diagnostic Analysis Results

Description	Model One	Model Two
F-statistic	0.284907 (0.8854)	0.290801 (0.8815)
Obs*R-squared	1.285595 (0.8638)	1.311166 (0.8595)
Scaled explained SS	2.387471 (0.6649)	2.516550 (0.6417)
Test: Breusch-Pagan-Godfrey Heteroskedasticity Test Null Hypothesis Ho: There is no heteroskedasticity in the model. Alt. Hypothesis H_1: There is heteroskedasticity in the model. () Probability		

Source: Researchers' Computation (2021)

For model two, since the probabilities are not significant and greater than 5% level of significance. The null hypothesis is therefore accepted which implies that the model is free of any heteroscedasticity problem.

Granger Causality

The results of the Granger causality test are contained in Table 6. The result for model one revealed that LOGRGDP granger caused LOGRAF with F-statistic value of 5.63908and a probability value of 0.0237. This implies that there is one-way causation between LOGRGDP and LOGRAF at 5% level of significance. LOGRGDP granger caused LOGCAE with F-statistic value of 4.84575 and a probability value of 0.0350. There is one-way causation between LOGRGDP and LOGCAE at 5% level of significance. This fact is in line with the economic theory of Kuznet Curve who posited that as economic growth increases due to industrialization, environment will worsen due to pollution until a certain point where the country reaches a specific average income. Then money is invested back into the environment, and the ecosystem is restored. LOGRGDP granger caused LOGTEM with F-statistic value of 6.11166 and a probability value 0.0189, there is one-way causation between LOGRGDP and LOGTEM at 5% level of significance.

Table 6. Granger Causality Tests

Model	Hypotheses	F-Statistics (Prob.)
Model One	LOGRAF does not Granger Cause LOGRGDP LOGRGDP does not Granger Cause LOGRAF	0.03678(0.8491) 5.63908(0.0237)*
Model One	LOGCAE does not Granger Cause LOGRGDP LOGRGDP does not Granger Cause LOGCAE	0.53768(0.4687) 4.84575(0.0350)*
Model One	LOGTEM does not Granger Cause LOGRGDP LOGRGDP does not Granger Cause LOGTEM	0.00268(0.9591) 6.11166(0.0189)*
Model Two	LOGRAF does not Granger Cause LOGAGO LOGAGO does not Granger Cause LOGRAF	0.00184 (0.9660) 5.39369 (0.0267)*
Model Two	LOGCAE does not Granger Cause LOGAGO LOGAGO does not Granger Cause LOGCAE	0.33353(0.5676) 4.62437(0.0392)*
Model Two	LOGTEM does not Granger Cause LOGAGO LOGAGO does not Granger Cause LOGTEM	0.03932(0.8441) 5.85447(0.0214)*
() Probability		

Source: Researchers' Computation (2021)

For model two, the result revealed that LOGAGO granger caused LOGRAF with F-statistic value of 5.39369 and a probability value of 0.0267. This also implies that that is one-way causation between LOGAGO and LOGRAF which is significant at 5%. LOGAGO granger caused LOGCAE with F-statistic value of 4.62437 and a probability value of 0.0392, there is one-way causation between LOGAGO and LOGCAE at 5% level of significance. LOGAGO granger caused LOGTEM with F-statistic value of 5.85447 with a probability value of 0.0214, which shows there is one-way causation between LOGAGO and LOGTEM at 5% level of significance. Hence, we accept the null hypothesis and state there is one-way causation between all the variables.

Discussion

The findings on this study showed the relationship between climate change, agricultural output and economic growth in Nigeria concluded that LOGRAF, LOGCAE and LOGTEM are the significance factors that contributed to Agricultural output and economic growth in Nigeria during the period under review.

The coefficient value of LOGRAF lag (-1) which was 930.1179 showed a positive relationship between economic growth but it is statistically significant. However, the result implies that a percentage increase in LOGRAF would lead to 930% increase in RGDP. This result is in conformity with the work of Snaeil *et al* (2019) who found out that rainfall changes have a positive effect on yield in grain production in Iran while temperature has a negative impact. These results are in conformity with Opaluwa *et al*. (2020) who examined the impact of climate change on crop farming and livestock keeping in Nigeria using data between 1970 and 2016 and confirmed long term adverse impact and threat to food production in Nigeria. Similarly, the result of Valentine *et al*. (*2018*) also corroborated the study empirical findings with their research output which examined the impacts of climate change on

agricultural operations in Nigeria and found that rainfall has significant effects on agricultural productivity in the country.

The coefficient value of LOGCAE lag (-1) indicating (-21.56165) a negative relationship but significance at 1%. The result implies that a percentage increase in LOGCAE would lead to decrease in RGDP. The coefficient value of LOGTEM (-1638.568) is negatively related to RGDP and it is statistically significant. The result implies that a percentage increase in LOGTEM would lead to 1639% decrease in RGDP (proxy for economic growth). Surprisingly, this results also corroborate the findings of various authors with respect to the negative effect of climate change (Bozzola *et al.,* 2018; Hossaina *et al.,* 2019). According to Ebele and Emodi (2016), in their study of variability in timing and amount of rainfall. It was anticipated that adverse impacts on the agricultural sector will exacerbate the incidence of rural poverty and has the potential to affect African agriculture in a range of ways leading to an overall reduction of productivity which could result to a loss in GDP. Odjugo (2005) also studied the effects of climate change on the socio-economic development of Nigeria, and finds that climate change and existing climatic variability will have harsh effects on the low-income and marginalized poor people in Nigeria and will, in addition, make the process of eradicating poverty more difficult because of the negative effects of climate change on economic growth, poor people's livelihoods and assets and the level of risks to which the people are exposed.

The result indicates that a percentage increase in LOGTEM would lead to 157% decrease in AGO. The result of ECM shows that about 89% of disequilibrium between short run and long run dynamics would be corrected each year in the variables of interest (LOGRAF, LOGCAE & LOGTEM) and is significant at 1%. The R-Squared value is 0.885403 shows that 89% of total variation in the AGO is being explained by the explanatory variables (LOGRAF, LOGCAE and LOGTEM). The facts of this findings are in line with the economic theory and particularly as stated in the *apriori* expectation coupled with the results of previous studies like Ojemade *et al*. (2020) and Gbenga *et al*. (2020) who examined the impact of climate change crop farming and livestock keeping in Nigeria using data between 1970 and 2016. The authors confirmed long term adverse impact and threat to food production in Nigeria.

Onuoha (2009) examined the threats posed by climate change across the globe with particular reference to developing countries including Nigeria, where agriculture is a dominant sector and in turn depends on weather and climate. The study concluded that the challenges of climate change to economic growth and sustainable development in Nigeria require creative thinking, holistic ideas, innovative solutions and the involvement of all stakeholders. Contrary to the above submissions and surprisingly, in an empirical study by Akomolafe *et al*. (2018), the authors examined impact of climate change on agricultural output in Nigeria using rainfall, temperature, and CO_2 emission as proxy for climate change. The results however revealed that climate change has no significant impacts on agricultural output in the short run.

Conclusion

The study empirically investigates climate change, agricultural output and economic growth in Nigeria for the period of 1981-2016. The results of unit root test indicate that

real GDP, rainfall, temperature, carbon emission and agricultural output were integrated order one (1). That is, they were found to be stationary at their first difference. The optimal lag selection criteria suggested by the Akaike Information Criterion (AIC) was period of (1 lag).

The Johansen Co-Integration Test of model one showed three co-integrating equations at 1% level of significance. Model two showed one co-integrating equation and model one showed three co-integrating equations at 1% level of significance. It indicated the existence of long run relationship among the variables (LOGRAF, LOGCAE. LOGTEM and LOGAGO).

The Error Correction Model (ECM) of the models one and two surprisingly showed that about 89% of disequilibrium would be corrected each year by changes in the variables of climate change. Result also showed that, (LOGRAF, LOGCAE &LOGTEM) are the significant climate change variables that contributed to the economic growth of Nigeria. Moreso, the R-Squared shows 89% of total variation in RGDP is being explained by the explanatory variables.

This study therefore concluded that LOGRAF, LOGCAE & LOGTEM are the significance variables that contributed to Agricultural output and economic growth in Nigeria during the period under review. The result also concluded that there was causality between LOGTEM, LOGCAE and LOGRAF and Agricultural output and economic growth.

In view of the above findings, the study recommends that Nigerian Government and all the stakeholders involved in the global phenomenon need to increase public awareness, promote research that will handle issues related to climate change. The Federal, State and Local Government, International agencies and other development partners are advised to fund climate change projects in Nigeria for sustainable economic growth, probably, through agricultural and research institutions to commence research into crops that are resistance to drought and heat.

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Short Communication

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Sensory Evaluation of Meat Derived from Heritage Turkey Hens Administered *Moringa oleifera* Leaf and Seed Extracts

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Abstract

A lot of organic substances are now regularly administered to poultry while raising them with the aim of boosting their productivity without commensurate check on the acceptability of these meats to consumers. This study therefore assessed the organoleptic properties of thigh meat derived from heritage turkey hens that were administered aqueous *Moringa oleifera* leaf and seed extracts. Meat samples were obtained from turkeys that were given *Moringa* extracts as follows: Treatment one (T_1) was from turkeys that had no leaf and seed extract thus served as control. Meat Treatment two (T_2) was from turkeys that had 1% *Moringa* seed weight in volume (w/v). Meat Treatment three (T_3) was from turkeys with 0.5 % seed and 0.5% leaf extract w/v. Meat Treatment four (T_4) was from turkeys given 1% leaf extract w/v. 50g of the thigh muscle from these turkeys were cooked and subjected to 9-point hedonic scale where it was scored for colour, texture, taste and general acceptability. There were significant differences for all the parameters measured among the treatments. The meat colour, taste, texture, flavour and general acceptability were improved with the administration of *Moringa* leaf and seed extracts. Meat samples from treatment four (T_4) (1% leaf extract) were best in terms of colour, taste, flavour as well as general acceptability. Sensory evaluation, being an important aspect of meat marketing to consumers, was not negatively affected by *Moringa*; rather the leaf extract improved the turkey meat quality.

Keywords: Turkey, *Moringa oleifera*, meat, sensory, extract**.**

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Introduction

Eating wholesome food is key to good health. The need to raise poultry birds organically can never be overemphasised, especially now that it has been discovered that administration of antibiotics to poultry can lead to antibiotic toxicity in man. This is because the chemical composition of poultry meat is strongly influenced by the birds' feeding (Kiczorowska *et al*., 2015). Modifications of the chemical compositions of the meat are connected to the assimilability of nutrients from feed (Winiarska-Mieczan e*t al.*, 2016). Famers now rely on using plant materials with pharmaceutical and therapeutic properties to ensure that their animal products are not detrimental to human health. These nutrients either improve or deteriorate meat quality (Yogesh *et al*., 2015). The use of plant materials as additives to animal feed has yielded so many positive results. The *Moringa* leaf extracts have been used by Abakpa *et al.* (2017) to improve the white blood cell count in Alloxian-induced diabetic dogs showing its therapeutic attributes. Abdulkarim *et al.* (2015) had observed the influence of *Moringa oleifera* seed meal on haematology and serum biochemistry of broiler chicken. This study therefore assessed the possible effect of administering aqueous *Moringa oleifera* leaf and seed extracts on the organoleptic traits of heritage turkey meat to human consumption.

Materials and Methods

Meat samples were obtained from turkeys that were given *Moring*a extracts as thus; Sample one (T1) was from turkeys that had no leaf and seed extract thus served as control. Meat sample two (T2) were from turkeys that had 1% *Moringa* seed weight in volume (w/v). The meat sample three (T3) were from turkeys with 0.5 % seed and 0.5% leaf extract w/v. Meat sample four (T4) were from turkeys given 1% leaf extract w/v. 50g of the thigh meat from these turkeys were cooked and subjected to a nine-point hedonic scale where the samples were scored for colour, texture, taste and general acceptability. A nine-point Hedonic scale ranging from 9 = like extremely to 1 = dislike extremely was used to evaluate the samples for colour, flavour, taste, texture and overall acceptability as described by Ihekoronye and Ngoddy (1985).

Table 1. A nine-point Hedonic evaluation of the samples was conducted using ten panelists.

Scores	Description
9	Like extremely
8	Like very much
7	like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Source: Ihekoronye and Ngoddy (1985).
Table water was used for mouth rinsing intermittently.

The meat samples were marked with the aid of tooth picks (varying numbers based on treatment number) and boiled in the same pot without condiments and taste enhancer. This

was done to avoid bias and complications in the evaluation of the meat samples. A Ten-man unbiased panelist was used in the assessment processes using a questionnaire. Each meat sample was tasted and scored for colour, flavour, texture, juiciness, tenderness and general acceptability.

Statistical analysis

The experimental design adopted was Completely randomization design (CRD). The data generated were subjected to analysis of variance (ANOVA) using the Statistical Product for Service Solutions (SPSS) version 2020. Means were separated using the Duncan's Multiple Range Test and significance was accepted at p = 0.05 (Steel and Torrie, 1980).

Results and Discussion

Table 2 shows the mean values of sensory evaluation of meat collected from local turkeys administered *Moringa* leaf and seed extracts. The colour, taste, texture, flavour and general acceptability of the meat were significantly ($p<0.05$) different among the treatments. The meat colour, taste, texture, flavour and general acceptability improved with the administration of *Moringa* leaf and seed extracts. The meat colour was better among the *Moringa*-treated group than the control meat with meat on Treatment 4 (1% leaf w/v) having the most liked colour. The taste, texture, general acceptability and flavour improved with the administration of *Moringa oleifera.* T4 (1% leaf w/v) was best in terms of taste (8.29 ± 0.22), flavour (7.86 ± 0.27), general acceptability (7.68 ± 0.16) when compared to T3 (0.5% seed and 0.5% leaf w/v) and T2 (1% seed w/v). The texture was best in T3 (0.5% seed and 0.5% leaf w/v) scoring 8.00 ± 0.23 when compared with other *Moringa* administered groups T4 (7.64 ± 0.35), T2 (6.93 ± 0.22) than T1 6.43 ± 0.34). The treatment groups on leaves extracts were best in terms of colour, taste, flavour as well as general acceptability. This was in line with the findings of Abd El-Rahman *et al*. (2019) on luncheon meat acceptability that was dressed with *Moringa oleifera* leaf extract. The study corroborated with the findings of Rahman *et al*. (2020) on goat meat nuggets that was treated with Moringa leaf extracts.

Table 2. Mean values of Sensory Evaluation of female Turkey Meat

Parameters	T_1	T_2	T_3	T_4
Colour	6.57 ± 0.29^{c}	6.93 ± 0.32^{bc}	7.79 ± 0.03^{ab}	8.21 ± 0.30^{a}
Taste	7.07 ± 0.37^{b}	7.36 ± 0.37^{ab}	7.79 ± 0.04^{ab}	8.29 ± 0.22^{a}
Texture	6.43 ± 0.34^{c}	6.93 ± 0.22^{bc}	8.00 ± 0.23^{a}	7.64 ± 0.35^{ab}
Flavour	6.50 ± 0.34^{b}	7.29 ± 0.28^{ab}	7.43 ± 0.48^{ab}	7.86 ± 0.27^{a}
General Acceptability	6.93 ± 0.32^{b}	7.43 ± 0.34^{ab}	8.0 ± 0.30^{a}	7.68 ± 0.16^{a}

Means with different letters on the same row are significantly ($P<0.05$) different according to Duncan's Multiple Range Test.

T1 = Turkeys without leaf and seed extract (control); T2 = Turkeys treated with 1% *Moringa* seed weight in volume (w/v); T3 = Turkeys treated with 0.5 % seed and 0.5% leaf extract; T4 = Turkeys treated with 1% leaf extract w/v.

Conclusion

Sensory evaluation being an important aspect of meat acceptability to consumers, was not negatively affected by the taste of *Moringa*, rather the leaves extracts improved the turkey meat quality most.

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Microgravity Research in Biology and Biochemistry of Plants: A Review

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Abstract

Microgravity science is the study of the physical occurrence whereby the earth's gravity is significantly decreased. Microgravity research encompasses a wide range of disciplines including biological systems. Spaceflight microgravity experiments are rare and quite expensive; this led to the development of simulated microgravity equipment such as the Clinostat. Biological samples provide a means for investigating the physiological responses to spaceflight. One of these biological samples is plant. Growing plants for food in space and on other planets will be necessary for exploration of our universe. Gravity has constantly influenced both physical and biological phenomena through earth's history. A justification for microgravity research in the biological sciences is the anticipation that new knowledge will be accumulated. This review provides an overview of the possible effects of microgravity conditions on plant's growth and physiology; while experiments of microgravity effects on morphology, phenotype and genetics are recommended. The results of real and simulated microgravity research showed that the environment of space has significant scientific, technological and marketing/commercial prospects on plants (e.g. vegetables, cereals, legumes), this is inclusive of some African nations that have equipment such as Clinostat that can simulate microgravity.

Keywords: Microgravity, Biology, Biochemistry, Plant.

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Introduction

Man has always explored, exploited, colonized and controlled their environment by expanding their field of activity. From the very first hominids, technological progress has exposed our species to extreme situations and hostile environments. But although mankind's expansion into space seems irreversible, it is still a major challenge for humans. Indeed, gravity has shaped the plant and animal world over millions of years, and man spend much of his live resisting it (Oluwafemi, 2017).

Gravity has supplied a constant input throughout the evolution of life on earth, providing a directional cue by which plants organize cells, tissues, and organs; and they elaborate their body plans. The various means by which the force of acceleration due to gravity is perceived, transduced, and transmitted throughout the body of the plant remains an active and important research enterprise, drawing upon the latest tools in cell biology, biochemistry, molecular genetics, signal transduction, and physiology to advance our understanding of this complex response (Oluwafemi, 2017; Afolayan *et al*., 2019). In addition, the development of an international effort to explore space has provided opportunities to investigate plant growth responses in the microgravity environment of low-earth orbit aboard Spacelab, Mir, the International Space Station (ISS), U.S. Space Shuttle missions, and various satellite-based lab environments.

Plants evolved in the presence of gravity, and they developed molecular and cellular mechanisms to adjust growth according to physical forces in a 1g world (Afolayan *et al*., 2019). Through this force the growth of plant organs is coordinated, enabling plants to conquer and explore the space below and above the surface of the earth. Gravity guides the growth direction of germinating seedlings allowing downwards growing primary roots to explore the soil for water and minerals and upwards growing shoots to synthesize sugars by photosynthesis in the light. This directional growth along the gravity vector, known as gravitropism, allows plants to control and adjust the optimal orientation, but the molecular mechanisms and underlying signaling networks are far from being understood. It was shown that relocalization of statoliths (starch-filled plastids located in columella cells) and changes in auxin distribution play important roles in gravity signal transduction.

Therefore, microgravity science involves the study of physical phenomena in which the normal force of gravity present on earth is greatly reduced. Microgravity research involves a broad range of disciplines, including materials, fluid dynamics, combustion, and biological systems. However, access to microgravity, for example by the International Space Station (ISS), is rare and costly. Besides, substitutes to replace the orbital microgravity access using sub-orbital microgravity, for example drop-towers, parabolic-flights, and suborbital-rockets unfortunately permit brief investigational time gaps. Ground simulations and models such as bed-rest, random positioning machines, magnetic levitation and immersion are better prolonged means. The use of microgravity simulators and models allow the assessment of microgravity induced deconditioning effects, and reveal gravitational mechanisms in the body's physiological systems, as well as mechanisms involved in adaptation of the body to microgravity. In particular, they allow researchers to develop and test measures to counter the deleterious effects of weightlessness. Immersion is one of the models, because it creates conditions that

closely resemble the gravity-free environment (Tomilovskaya *et al*., 2019).
2-D (one-axis) (Figure 1) Clinostat appears as an ideal approach to study aspects of gravity perception and signal transduction as it provides the possibility to simulate microgravity on ground and can be used to prepare or to validate microgravity experiments. 2-D Clinostats allow rotating objects along a horizontal axis perpendicular to the gravitational vector to generate high quality of reduced gravity conditions (Oluwafemi *et al*., 2018; Oluwafemi and Olubiyi, 2019). Several experiments conducted worldwide using clinororation and involving various model plants have improved the understanding of the mechanisms governing plant response to simulated microgravity (Brykov and Kordyum, 2015).

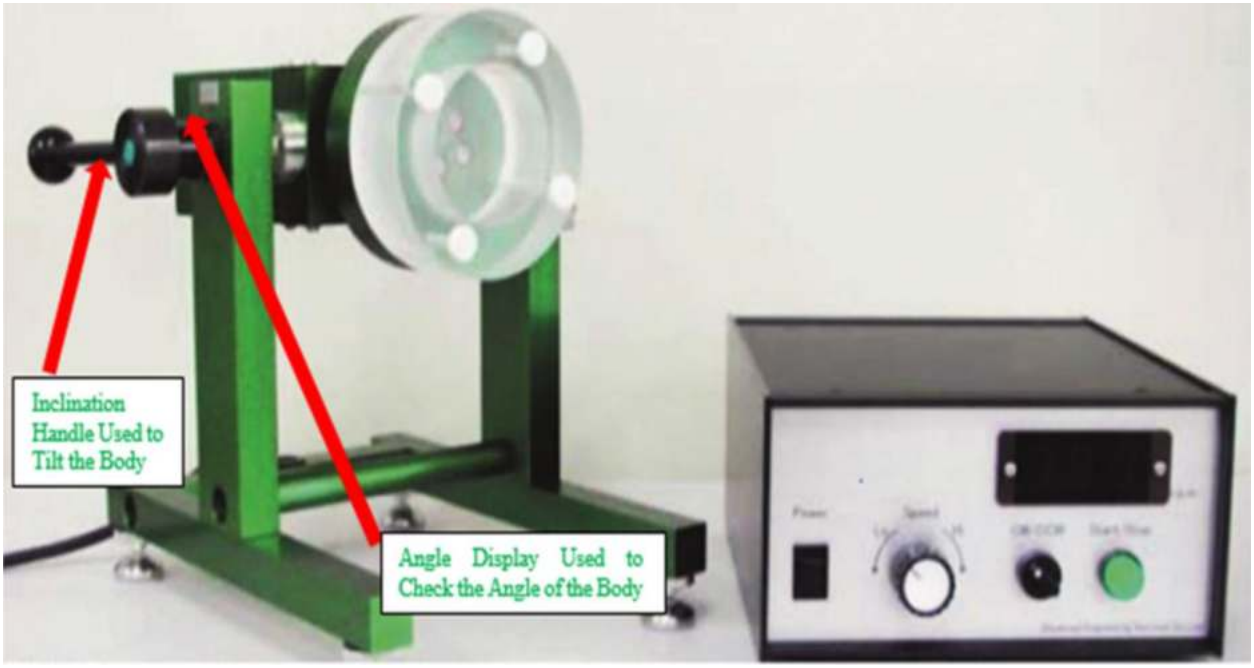


Figure 1. One-axis Clinostat with Adjustable Rotational Axis Angle

In research on microgravity, there is competition or trade-off in quality and cost between space experiments and alternative methods on the ground. This means that space is not the only available means of carrying out microgravity experiments. Sometimes, achievements in space may be enhanced by combination with the results obtained by experiments on the ground. For example, in order to prepare the best possible samples for space research, it is important to retain competition between experiments in space and on the ground to raise the level of research through creative ingenuity and hard work (Oluwafemi and Neduncheran, 2022).

This study is a review of possible microgravity research in the biology and biochemistry of plants. The collection in this review provides a valuable resource.

Life Sciences and Microgravity

The scientific communities working on Life Sciences in the microgravity environment have access to a number of different existing space and ground-based facilities to conduct experiments as discussed earlier. Investigational prospects during real spaceflight are restricted, therefore ground-

based models are essential. Weightlessness results in numerous changes, that affects several systems of an organism (Oluwafemi and Neduncheran, 2022).

Biological samples provide a means for investigating the physiological responses to spaceflight. One of these biological samples is plant. Growing plants for food in space and on other planets will be necessary for exploration of our universe. Biology and Biochemistry research are classified under biological sciences; as biology is a branch of science dealing with living organisms and their vital processes, while biochemistry is a branch of science that deals with the chemical and physico-chemical processes and the substances which occur in living organisms. Gravity has constantly influenced both physical and biological phenomena through earth's history. A justification for microgravity research in the biological sciences is the anticipation that new knowledge will be accumulated by the optimized production of small amounts of microgravity-derive biomaterials such as purified proteins or protein crystals (Enemali *et al*., 2020).

Spacecraft as Biology and Biochemistry Laboratory

The last 25 to 30 years of spaceflight research has allowed scientists to begin to recognize the research potential of carrying out experiments where the gravity vector has been removed. Many of these experiments have given interesting phenomenological observations, which still await clarification at the biochemical and genetic levels but spaceflight research has been technologically limited in terms of carrying out the best experiments in space biology. These limitations are apparent even today in the experiments designed for Space Simulation Facility (SSF). National Astronautics and Space Administration (NASA) designated several areas for investigation in space, and they reflect the need for developing simple growth parameter conditions before more sophisticated research projects can be undertaken. These studies include, for example, optimization of plant nutrient and water supplies and plant holding facilities; the ability to grow multiple generations of organisms; determining the effects of microgravity on gas exchange; the control of development at organ and cellular level in microgravity and other experiments to establish baselines of capabilities. All were included to determine the limitations of basic growth and development processes in microgravity, and all reflect our inability to carry out even the simplest biochemical and molecular biological experiments. Thus, given the very short time frame to the launch of SSF, the research programs to be included in the SSF agenda must be selected in the immediate future to ensure that the most modern, highest quality science is conducted. Microgravity research can provide unique new approaches to further basic understanding of development and metabolic processes of cells and organisms, and to further the application (Oluwafemi, 2018).

Microgravity Science and Research on Plant

Microgravity science is the knowledge or study of matter, material or a body under microgravity environment. In microgravity science and research, one is concerned with how, in various circumstances, the relationships or balances among various fundamental phenomena depend on the presence or absence of gravity and, hence, how certain processes of practical significance are subject to gravity level. Some occurrence can consequently be secluded for study if gravity is removed (Oluwafemi *et al*., 2019).

The work of gravity in plant growth and development on the earth is very much important. What is less well understood is how plants respond when gravity is removed. This is why research is done in this field on plants. Gravity effects on plants growth and development has been the topic of systematic study for more than one hundred years with the initial work of Charles Darwin on roots gravitropic response. The spaceflight environment effect on plants has been investigated in the time of BioSatellite experiments,1960s. Therefore, continuous experimentation of plant responses in the real space environment have made the knowledge of the mechanisms of how plant respond to gravity to be elucidated.

The microgravity environment has also been instrumental in understanding how the unique aspects of the spaceflight (microgravity, lack of convective currents) will affect biological life support systems for long-duration space missions. Microgravity experiments which for a very long time could only be done in the space amenities (e.g. space shuttle, space station, and satellite) are crucial for the advancement of microgravity science and space life sciences. The recoverable satellite is a useful and efficient tool for space experiments in the microgravity environment, and such in research on microgravity.

Microgravity Research in Biology

Animal and plant life have been intertwined for hundreds of millions of years. Plants have oxygenated the atmosphere, and the fact that our planet can sustain such a large number of people today is almost entirely due to genetic mutations in wild wheat that occurred at the end of the last Ice Age. Charles Darwin not only alerted the world to the origin of species, he investigated and described the behaviour of plants in response to their environment; an environment that includes gravity. In a strange and interesting form of life, plants pose a conundrum: in the presence of gravity their roots grow downward and away from sunlight, while their stems and shoots grow upward and toward sunlight. How, then, do plants sense gravity? At a very basic level, every plant must have a mechanism that responds to gravitational force by transforming physical stimulus into a biological process. The study of these effects on living organisms is called gravitational biology. Not a new area of research but numerous investigations have produced a variety of results, some expected, some unexpected, but always fascinating. A historical review of these data reveals different pieces of the larger puzzle. The remarkable adaptability of plants to a condition never encountered in evolution is the near-weightlessness of microgravity (Thomas *et al*., 2000).

More than 25 years ago when Dieter Volkmann, Anders Johnsson and František Baluška began research, access to the real environment of microgravity in space was limited. So, their research began in laboratories with equipment that simulates the absence of gravity: Clinostats and centrifuges, random positioning machines and magnetic levitation. Later they were able to use sounding-rockets, providing up to six minutes of microgravity. They as well set out to investigate hypergravity which are greater forces than those on earth. Afterwards, they were able to get out of the labs and into space. For experiments in microgravity, they used cress and lentil plants because both germinate quickly. In cress seedlings cultivated during flight on the centrifuge under earth's gravitational conditions, the plant roots showed lower sensitivity to gravitational force compared with those cultivated in microgravity chambers. These findings

suggested that an organism grown in microgravity conditions adapts its biological processes in such a way that the organism's sensitivity to gravity is affected (Afolayan *et al*., 2019).

Further experiments performed by three European research groups demonstrated that roots from cress and lentil plants are in general highly sensitive to gravitational force. Three plant samples were used: one on the ground, one in orbit in a centrifuge that varied its speed (its acceleration force can mimic the effects of gravity) between earth's gravity and one thousandth of earth's gravity, and the third, also in orbit, under microgravity conditions. Results from the plants in the centrifuge were the most surprising, indicating that the initial effects can be seen at values between one thousandth and one hundredth of the earth's gravity (10^{-2} and 10^{-3}g, earth = 1g). Their root growth not only showed the weakest response to gravity but it also mirrored the type of growth seen in water. The results from the centrifuge were what one would expect from a plant in the neutral buoyancy of water (where a body's weight decreases by the amount of water it displaces). At some point in distant history, this was probably exactly how plant evolution began (UNOOSA, 2019).

Microgravity Research in Biochemistry

Due to inability to carry out even the simplest biochemical and molecular biological experiments, basic growth and development processes in microgravity are usually done (Oluwafemi *et al*., 2020). Many of the biochemistry experiments done under microgravity still await clarification at the biochemical and genetic levels. Biological properties change as gravitational force is diminished, underscoring the relationship between physical force and biological function (Bizzarri *et al*., 2015). Consequentially, the changes in enzymatic, genetic, and epigenetic pathways may lead to several modifications of cells and tissues shape, function, and behavioural traits. However, researches on microgravity have improved the knowledge on biochemistry, to providing valuable data and models in understanding some human diseases (Bizzarri *et al.*, 2015). Thus, microgravity-related researches have fostered the growth of three dimensional (3-D) environments, that facilitate mandatory unrestricted cell interactions to define the biology of microenvironment, formation and progression. In the real and simulated microgravity, the 3-D culture allows precise role for biophysical constraints in shaping cell phenotypes and functions, to aid tissue-engineering techniques. Hence, space-based research continually played an important role to reformulating theoretical framework in biology, to serve as a paradigm for novel innovation.

Microgravity Research in Biology and Biochemistry of Plants (Specified Differences in Biological Sciences of Plant Under Gravity and Microgravity)

The growth of germinated roots under microgravity or under simulated microgravity is usually not stimulated in any direction (Figure 2). There is usually root length enhancement (Oluwafemi *et al*., 2020) which have physiological basis from the following, that: the root cortical cells proliferate at a higher rate than under gravity influence; there was an accelerated cell cycle (mitosis) which would have been aided by plant growth hormones such as auxins (it can be said that simulated microgravity enhances and speeds up the work of growth hormones); and microgravity environment disrupts normal carbohydrate metabolism affecting the root cell structure.

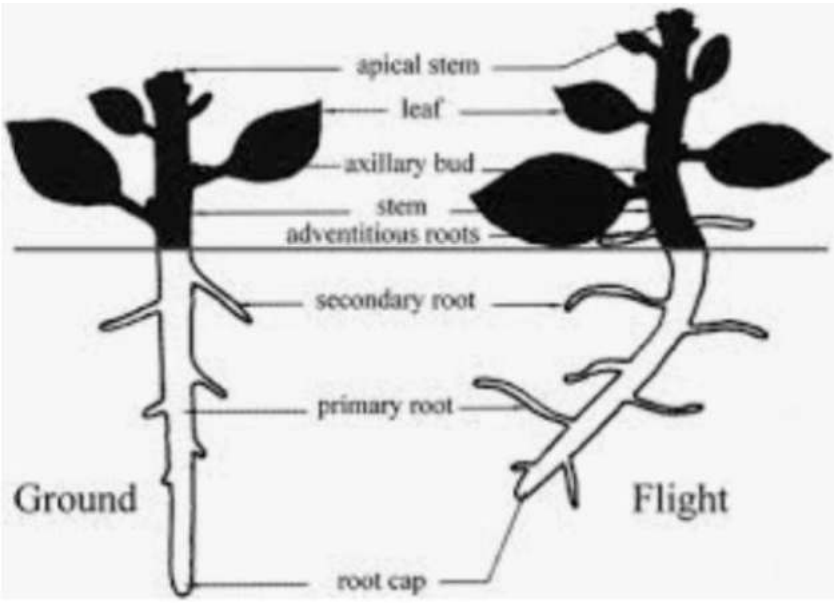


Figure 2: Ground and Spaceflight Seedlings (Anna-Lisa and Robert, 2015).

The effect of microgravity on chromosome behavior, gene expression, and on plant photosynthesis, respiration and transpiration are also useful to be determined. All these involve the flow of information and communications within the underlying cells. The biochemical and genetical characterizations that can be carried out include but not limited to metabolomics proximate analysis, proteins, enzymes, hormones and genes associated with the two experimental samples (microgravity/simulated microgravity and earth's gravity). These samples could be from any portion of the plant according to the discretion of the experimenter. For the proximate, it includes the nutritional facts of the moisture content, crude protein, crude fat, crude fibre, ash content and carbohydrate; while the amino acids concentrations in the protein can also be determined. Experiments of microgravity effects on the morphology and phenotype are also recommended. Microscopic parameters of the root xylem and phloem are determinable through Transmission Electron Microscope (TEM), and the stomata size and number that will be determined from the stomata printing viewed under microscope are part of the morphology experiments recommended to be able to differentiate between the form and the structures of plant grown under space condition or simulated space condition and those grown under normal earth's gravity (Brungs *et al*., 2016).

The interaction of light, as it is a chemical energy for plant activities or metabolism can also be deduced, as the light dependent reactions in the thylakoid membrane that uses light energy to make ATP and NADPH could be speed-up to enhance root elongation. NADPH is used as a reducing agent in the Calvin Cycle (set of chemical reactions that take place in chloroplasts during photosynthesis) to reduce atmospheric carbon dioxide (CO_2) generating monosaccharides for the use of plant for energy and for structure (Yahia *et al*., 2019). This can be said as one of the reasons for growth enhancement under microgravity than under gravity influence.

The fresh and dry weight of the roots parameters and the shoot parameters of the plants can be evaluated in furtherance to verify the influence of microgravity simulations technique on the biomass accumulation. At the long run, it is proposed that the microgravity simulated seedling can be transplanted unto the field to access their propensity for nutritional qualities, productivity, environmental stresses resistance and phenotype to compare with those grown under gravity influence (Oluwafemi *et al*., 2020).

Benefits of Microgravity Research to Plant Agriculture

Space farming is the cultivation of food crops and other materials in space or on off-earth celestial objects equivalent to agriculture on earth. The supply of food to the space laboratories and the proposed interplanetary spaceships are expensive. Furthermore, the unimaginable resupplying of food to interplanetary missions makes the growing of food inflight a great idea. Moreso, space farm allows a sustainable environment, as plants can be used to recycle wastewater; generate oxygen; purify the air continuously; and recycle faeces. The space farm therefore turns the spaceship into an artificial ecosystem of hydrological cycle and nutrient recycling. It can therefore be said that plants can assist the life support system since they can be used to purify water and recycle carbonIVoxide into oxygen. When grown on a large-enough scale, plants therefore can hugely impact how spacecraft and colonies are designed (Oluwafemi, 2022).

Agriculture is the heart of the supply of food to the world. Soil condition, water availability, weather extremes and climate change can represent challenges both to farmers and the overall food security of the population (Oluwafemi, 2022). Food security is being able to access enough food that is safe, nutritious and culturally acceptable at all times that allows for healthy living. The issues of food shortages are complex ones, with the most common factors being projected as global population growth, limited production resources and global climate change.

There is an urgent need to produce more food while reducing the impact on environment and ecosystem, but space-based technologies are solutions to these challenges including food security. For the benefit of the earth, space farming therefore increases our knowledge of agriculture. From outer space to the wide open spaces of farmland, the benefits originating from International Space Station research and technology stretch far and wide (Afolayan *et al*., 2019).

Space technologies has led to the emergence of what is called precision agriculture. These technologies have allowed farmers to find novel and efficient ways of dealing with economic, environmental and societal challenges of food production by producing better products (Afolayan *et al*., 2019), for example through biotechnology to insert the novel genes of plants obtained from the microgravity environment into the normal earth crops to transform them to have enhanced characteristics such as adaptation to extreme conditions, having more nutrient etc. The space technologies are of importance to agronomists, farmers, food manufacturers and agricultural policy makers as it enhances products and increases profit. The observation of crop growth for fertility and disease variances are done on space farming and earth crop farming. Space farmers use cameras aboard the International Space Station to come up with new and more efficient ways of maintaining their crops.

Researchers plan to transfer what they have learnt growing food in the harsh outer space environment to the hostile climates on earth. Detailed information of plants growth is collected and it is hoped that this information helps. Goals include to have better quality crops, better crop yields and better agricultural systems and greenhouses.

Space technologies have helped increase crop yield and reduce environmental waste of commonly overused chemicals. A number of technologies used in the space sector have returned to earth over the years as space spin-offs and have found their way into the market. Examples of these spin-offs include: use of sensors that send text messages to farmers when the plants need water; Bio-KES that slows decaying process of plants, purifies air, eliminate pathogens and preserves products; aeroponic and hydroponic methods that helps plants grow faster and healthier; chlorophyll meters that aid plant nutrient management; control robotics for harvesting; GPS auto-steering tractor that helps farmers reduce fuel costs, decrease driver fatigue and eliminate overlap on fields; LED systems that target plant growth in greenhouses to allow maximum efficiency in light absorption; the use of simulated microgravity equipment to pre-space stress seedlings before transplanting to the field to have better crop yield and better crop quality. Therefore, space farming increases the knowledge of agriculture on the earth, making it a necessity (Oluwafemi, 2022).

Clinostat availability as a microgravity simulating instrument has made a world of all possibilities to research into space. Microgravity experiments can be done using Clinostat (Thomas *et al*., 2000). Types of Clinostat include the one-dimensional (1D), 2D and the 3D. Samples such as plants, cells, micro-organisms, small samples from material sciences etc. can be mounted on the Clinostat to see what their orientation will be under simulated microgravity. For plants growth on the Clinostat, there are experimental variable which include: humidity, temperature, light conditions, rotation-speed of Clinostat (fast or slow), rotational-axis angle of Clinostat and rotation-direction (clockwise or anti-clockwise). Then observations will be done for some hours or days after which the root-morphology of the plants seedlings grown under normal earth gravity (control) and that grown under simulated microgravity (using Clinostat) will be studied using unaided eyes, specialized software such as ImageJ, microscope and other further analysis on the roots can be done. Observations can also be done on the shoots. Some results obtained from previous work shows that for most of the plants experimented upon, there is better growth rate of the clinorotated sample than that of the normal earth gravity sample. From these results, it has shown that there are advantages to the agricultural sector of planting under microgravity/simulated microgravity.

However, nations engaged in space are actively assessing, both qualitatively and quantitatively, the productivity and effectiveness of these endeavors, given the intense competition for resources and funding for alternate pursuits.

Conclusion

This review discussed the essence of microgravity relating to biology and biochemistry as well as the typical life sciences. It evaluates the use of biological samples to investigate the physiological and biochemistry responses to spaceflight or simulated microgravity. Microgravity researches have thus, developed and increased the knowledge on biological,

physiology and biochemistry, with new innovative and technological data, experimental models and solutions. Inclusive in this review is also the benefits of microgravity research to the plant agricultural sector.

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Competing interests

There are no competing interests among authors.

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