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Aims and Scope

Journal of VOWDA [ISSN:2795-3130 (ONLINE); ISSN:2795-3149 (PRINT)] is a peer reviewed open-access research journal publishing high quality manuscripts in different areas of Agricultural Sciences, Biotechnology in relation to plant or animal sciences, Food safety and Nutrition, Biomedicine and Social Sciences related to agriculture. Journal of VOWDA publishes twice in a year in electronic form. The journal provides an avenue for academics, researchers, professionals and students to showcase their research findings such as original articles, reviews, technical reports, short communications and case studies, all written in **English**. We invite authors to kindly submit their articles as attachment in MS-Word format to secretariat@vowda.org

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Abstract

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Shodehinde, S.A. (2022). Impact of African yam beans (*Sphenostylis stenocarpa*) flour incorporation in wheat flour for composite noodles production. *Journal of Voice of Women in the Development of Agriculture* 1(1):14-28.
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Kareem, K.T., Oyedele, A.O., Oduwaye, O.F. and Ugwu, J.A. (2022). Effects of land preparation methods and cropping systems on maize (*Zea mays* L.) viral diseases. *Journal of Voice of Women in the Development of Agriculture* 1(1):27-37.
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Original Article

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Original Article

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Roles of Small-holder Farmers in Mitigating Food Insecurity

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Abstract

The world population is estimated to grow by more than one-third by the year 2050 amidst several fears of food insecurity. This study focuses on the role of small-scale farmers in ensuring food security in the African region. Online questionnaires (n = 185) were randomly distributed. Socio-demographic characteristics revealed 45.9% male and 54.1% female with at least first-degree level of education. 170 (91.9%) respondents were from West Africa, 10(5.4%) from South Africa and 5(2.7%) from Central Africa. The farm characteristics revealed that 45.9% owned a farm while 51.4% do not. Crop production ranged from rice, maize, tubers, legumes, livestock, palm oil, and cassava. Occupation and responsibility of the farmers revealed that 81.1% have been involved in farming processes. A 56.8% lack of fund as a major barrier faced by women was recorded. Also, a total of 58.8% agreed, 21.6% strongly agreed, 8.1% disagreed and 10.8% strongly disagreed with the effectiveness of women's participation in the current challenge. 56.8% of the respondents perceived that it was not easy for women to gain leadership opportunity and experience. The results also indicated that 56.8% of women do not face any discrimination in rural markets and 18.9% of their male counterpart faced discrimination. Similarly, it was observed that about 89.2% of the respondents do not have processing machines and about 73.0% of them were making effort towards acquiring them. This study observed women's active participation in food production needs to be further intensified through a responsive agropreneurship incentives.

Keywords: Agropreneurship, gender diversity, food production, sustainable developments.

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Introduction

The world population is expected to grow by more than one-third, that is, 2.3 billion people, between the years 2009 and 2050. This growth is slower than the one seen in the past four decades, where the population grew by more than 90% (3.3 billion people). Nearly all the predicted growth is to take place in the developing world, predominantly in Africa. The fastest growth (+114%) is forecasted for sub-Saharan Africa and the slowest growth (+13%) for East and Southeast Asia (Desa, 2015). Food security exists when all people in a society have adequate food for an active, healthy life at all times (Labadarios *et al.,* 2011, Rabbitt *et al.,* 2016 and Coleman-Jensen *et al.,* 2014). As a broad term, 'food security' is defined as the availability of safe and nutritious food and or a guaranteed capability to procure and acquire food of good quality in a socially acceptable way. Food insecurity on the other hand occurs when basic healthy food is not easily accessible, and poor households struggle to secure enough food for their nutritional needs (Bosc *et al.,* 2013). Food insecurity has been identified as a global crisis (Laborde *et al.,* 2020, and Hwalla *et al.,* 2021). Food insecurity is a major challenge in African countries where the rate at which the population grows far exceeds both the quantity and quality of food required to sustain the population. It is reported that 204 million of the 814 million undernourished people in the world live in sub-Saharan Africa (Bosc *et al.,* 2013). The root causes of hunger are poverty and poor food distribution. The majority of poor households in sub-Saharan Africa are struggling to access high national and healthy food. Food insecurity and hunger in sub-Saharan Africa are caused by agricultural policy uncertain such as land reform and expropriation land without compensation. Increased food requirements from a growing world population will only escalate existing food security problems. The United Nations estimates that by 2050, 86% of the world's population living in extreme poverty will be concentrated in sub-Saharan Africa (Giller, 2020). And in order to ensure food security in the future, current food production levels will need to be increased by at least 70%(Eigenbrod and Gruda, 2015, Hlophe-Ginindza and Mpandeli, 2020).

Projected climate change and unexpected extreme weather events will worsen the fragile agricultural systems, negatively affecting the natural resource base, particularly in places prone to soil degradation, water scarcity and desertification (Field *et al.,* 2018). The sub-Saharan Africa is well known for relying heavy on rainfed agriculture, however, due to threats posed by extreme climatic events, high climate variability and change, the majority of the climate sensitive sectors are struggling to cope and adapt to challenges posed this natural vagary. The general effect of climate change on agriculture will differ between different geographic regions, and it will still be difficult for farmers to plan and manage production while preventing crop losses or outbreaks of pests and diseases (Hlophe-Ginindza and Mpandeli, 2020).

Most of the poor population in Africa depends on agriculture, particularly small-scale farming, as the primary source of their livelihoods. Ensuring food security and poverty reduction in many African countries depends largely on the on the growth and development of the agricultural sector (Agriculture and Department, 2005, Gassner *et al.,* 2019). Agriculture in Africa is dominated by small-scale famers who rely on family labor; with 33 million farms that are less than 2 ha, small-scale farms represent 80% of all farms (Bachewe *et al.,* 2018). The role of small-scale farmers in ensuring food, nutrition security and sustainable rural development in Africa is becoming more crucial as the world faces increasing climate change challenges. Africa needs ecologically sound and climate-resilient farming systems to provide nutritionally balanced food and ensure food security for the most vulnerable (Hlophe-Ginindza and Mpandeli, 2020).

Small-scale agriculture presents an opportunity to improve the livelihoods of the rural poor and ensure food security; however, many of the rural farmers, who had previously managed to successfully cultivate crops for subsistence use and to supplement their income, now experience poor yields or have ceased production. This can be attributed to increased urbanization, poor productivity and competition from commercial agriculture, which is producing food more effectively and at lower prices (Muyombano and Espling, 2020, Hadebe *et al.,* 2017). It is, therefore, imperative that small-scale farmers adopt new technologies to increase production and, consequently, ensure food security. Improved productivity of these small farmers is the key to providing practical, sustainable solutions able to address the growing problem of food security on a global scale.

The main objective of the current study is to investigate the roles of small holder farmers (women) in mitigating food insecurity in selected African states. Specific objectives are to determine the demographic and farm characteristics of women in the study area, occupation and farm responsibility, perception and skills of leadership and effectiveness of women participation in addressing food scarcity and insecurity in the affected regions.

Methodology

A cross-sectional data was carried out and a Snowball sampling technique was used targeting farmers in selected African states. Using the Google form, an online questionnaire was developed. The questionnaire was distributed through electronic means, and this was easily shared on social media including WhatsApp, Twitter, LinkedIn, which is a smartphone/desktop enabled social media platform with over several users. Information regarding the demographic and farm characteristics, occupation and responsibilities, skills and leadership, and effective participation in food production in selected Africa states were obtained by a random distribution of Questionnaires as previously described by Odeyemi et al. (2018) (n = 185). The participants who were the first point of contact were encouraged to disseminate the link of the survey to other contacts. Data collected through the Google form commenced from April 1st – 26th, 2021. Participation in the data was voluntary and participants could withdraw at any time after providing consent to participate. On receiving and clicking the link, participants were auto directed to the synopsis that explained the purpose of the data, and only the participants that consented were included in the data. Participants were directed to complete the demographic details then a set of several questions followed which the participants were to answer. No personal or private data was collected and similarly, the data collection procedure followed the provisions of the Declaration of Helsinki. It was online data therefore participants with no access to the internet could not participate. The authors were able to collect data from selected states of Africa. The data obtained were analysed using descriptive statistics to describe the socio-demographic information, while analysis of variance (ANOVA) was used with a statistical package for social sciences –IBM SPSS v 25 (Alyami *et al.,* 2020).

Results and Discussion

Table 1. Demographic characteristics of the respondents (N = 185)

Demographic Details		**Frequency (%)**
Gender	Male	85 (45.9)
	Female	100 (54.1)
Level of Education	Tertiary	185 (100)
Location in Africa	West Africa	170 (91.9)
	South Africa	10 (5.4)
	Central Africa	5 (2.7)
Age Group	20-30 years	50 (27.0)
	31-40 years	70 (37.8)
	41-50 years	55 (29.7)
	Above 50 years	10 (5.4)
Marital Status	Married	125 (67.6)
	Divorced/Separated	5 (2.7)
	Single	55 (29.7)

Source: Field data, 2021

The result of socio-demographic characteristics of the respondents were presented in the above table (Table 1). It was gathered that 85(45.9%) were male while 100(54.1%) were female. Similarly, all the sample respondents had at least first-degree level of education as indicated by 185(100.0%). Equally, majority were from West Africa as indicated by 170(91.9%) followed by South Africa 10(5.4%) and the by Central Africa as indicated by 5(2.7%). In terms of the age group, majority of the respondents were between the ages of 31-40 years of age. In addition, findings also indicated that about 67.6% were married and about 2.7% were divorced while 29.7% were single. These outcomes are similar to the reports of Adepoju et al. (2015)on the roles played by women farmers in South-West Nigeria. Olumakaiye and Ajayi (2006) conducted a study investigating the association between educational status of women and provision of food for household members for food security in Nigeria. The results showed that educational level attained by the respondents has a fairly high degree of association with the varieties of food provided. They concluded that women with higher education are likely to provide varieties of food thereby increasing the household food security.

The bottom line therefore is that improving women's human capital and capabilities, especially education, will not only empower them to exercise their choice but also ensure food security for household members. In a study by Doocy and Burnham (2006) measures of socioeconomic status were compared with a measure of physical well-being, Mid-Upper Arm Circumference (MUAC) in the food insecure regions of Ethiopia. Evidence shows that income, housing conditions and education had the greatest correlation to MUAC and significant differences in these measures were observed between malnourished and adequately nourished individuals. On the choice of MUAC as a measure of food insecurity measure, they argue that MUAC was chosen as the anthropometric measure because it is commonly used for nutrition screening in emergency situations and because it is recommended for assessing acute adult malnutrition and prevalence of under-nutrition at the population level (Cogill, 2003). This implies that women with higher education are likely to provide varieties of food security. Similarly, Smith and Haddad (2000) in a cross-country analysis to explain factors responsible for child malnutrition in the developing world between 1970 and 1995 provide evidence that increase in women's education accounted for 43% of the total reduction in child malnutrition by far the largest contribution.

Table 2. Farm characteristics of sample

Farm Characteristics	Response (N = 185)							
Do you Own a farm	Nil	Yes	No					
Frequency (%)	5 (2.7)	85 (45.9)	95 (51.4)					
Do you intend to own a farm	Nil	Yes	No					
Frequency (F)	5 (2.7)	160 (86.5)	20 (10.8)					
What is your role on the farm	Nil	Director	Volunteer	Others				
Frequency (F)	30 (16.2)	90 (48.6)	40 (21.6)	25 (13.5)				
Is your farm owned or rented	Nil	Owned	Rented					
Frequency (F)	25 (13.5)	120 (64.9)	40 (21.6)					
How will you describe the farm you live and/or work	Nil	Commercial	Subsistence					
Frequency (F)	5 (2.7)	75 (40.5)	105 (56.8)					
What commodities are produced on the farm	Nil	Rice	Maize	Tuber	Legume	L/Stock	P/Oil	Cassava
Frequency (F)	5 (2.7)	5 (2.7)	35 (18.9)	25 (13.5)	20 (10.8)	70 (37.8)	10 (5.4)	15 (8.1)

respondents

Source: Field Data, 2021.

Table 2 above presents the descriptive statistics based on farm characteristics. According to the descriptive statistics, it was revealed that 45.9% owned a farm, 51.4% do not while 2.7% were neutral. Findings also gathered that 86.5% intend to own a farm, 10.8 % do not while 2.7% were indifferent. in terms of the roles on the farms, the majority was the director of their farm as indicated by 48.6%, followed by a volunteer as indicated by 21.6% then by others as indicated by 13.5% while only 16.2% were indifferent. Similarly, findings also showed that 120(64.9%) of the respondents owned the farm they operated while only 40(21.6%) were on rented land. In addition, it was also gathered that about 40.5% of the respondents opined that they operate on the commercial level while 56.8% claimed they operate under subsistence agriculture. Consequently, the commodities that are produced on the farm range from rice, maize, tubers, legumes, livestock, palm oil, and cassava as indicated by 2.7%, 18.9%, 13.5% 10.8%, 37.8%, 5.4%, and 8.1% respectively. Increasing the productivity of small-scale farmers requires significant investment and ongoing support in agricultural extension services.

Agricultural extension services can provide farmers with the vital tools and critical knowledge needed to adopt and implement new, more sustainable farming methods. Small-scale farmers face a number of risks, which require a more interactive extension system. The adoption of new technologies will serve to increase product yields, improve local food security and livelihoods, as well as build resilience against severe climate changes. The traditional extension system, which uses a top-down approach in transferring technology, is rapidly becoming outdated in the market-oriented and more competitive climate of today's agricultural scene. In order to ensure continued and increased contribution of small-scale farmers to food security in Africa, there needs to be renewed emphasis on, as well as new approaches to, agricultural extension. The role of extension officers should not be limited to providing and transferring knowledge for increased productivity, but should also focus on new roles, including linking small-scale farmers to high value and export markets, ensuring sustainable production and mitigating the effect of climate change (Adepoju *et al.,* 2015).

Table 3. Descriptive statistics showing occupation and responsibility of farmers

Occupation and responsibility	**Response (N = 185)**							
How many years have you been involved in the farm	Nil	0.5years	**6-10 years**	**Above 10 years**				
Frequency (%)	5 (2.7)	150 (81.1)	5 (2.7)	25 (13.5)				
Day to day responsibility on the farm and within the farm household	Nil	Livestock mgt.	Admin/Marketing	Land Preparation.	Family Care	Transport/Logistic	Others	Literacy/Technology
Frequency (%)	5 (2.7)	100 (54.1)	15 (8.1)	10 (5.4)	15 (8.1)	5 (2.7)	35 (18.9)	
What are the barriers to women in advancing their role on the farm/as a land manager	Nil	Funding	Cultural	Access to land	Climate change	Access to Market	Lack of Government Intervention	Education/Technology
Frequency (F)	5 (2.7)	105 (56.8)	20 (10.8)	15 (8.1)	5 (2.7)	5 (2.7)	10 (5.4)	20 (10.8)

Source: Field Data, 2021

Based on the occupation and responsibility of farmers as presented in table 3, findings revealed that the majority of the farmers have been involved in farming between 0-5 years as indicated by 81.1%, this was followed by above 10 years as indicated by 13.5%. In terms of barriers faced by women in advancing their role on the farm as land managers, it was deduced that they were faced with the barriers of funding, culture, access to land, lack of government intervention, education/literacy level, technology as indicated by 56.8%, 10.8%, 8.1%, 5.4%, 5.4%, and 5.4% respectively. Equally, on the day-to-day responsibilities on the farm and within the farm household, farmers were majorly responsible for the management of the farm cum livestock, marketing, family care, and land preparation as indicated by 54.1%, 8.1%, 8.1%, and 5.4% respectively. Béné *et al.,* (2016) noted that there is normally an overlap between poverty and food security due to inadequate income and wealth and hence, their inadequate access to available food. In addition, income growth, however, helps improve food demand and hence, food security. Food demand and supply trends are known to influence prices as well as the composition in their diets and other factors related to food security. Although food insecurity is usually associated with rural households and urban poor who are more vulnerable to high food price and limited access to food as a result of how income, there are differences between household food security within the urban and rural areas. While real wage and employment are the main determinants of food security in the urban areas, the level of domestic food production dictated by the extent and ease of access to production inputs and services is a primary determinant of food security in rural areas (Béné *et al.,* 2016).

Women comprise about 43 percent of the global agricultural labor force and of that in developing countries, but this figure masks considerable variation across regions and within countries according age and social class. Women comprise half or more of the agricultural labor force in many African and Asian countries, but the share is much less in some. Time use surveys, which provide a more comprehensive assessment of how men and women spend their time, further emphasize the heterogeneity among countries and within countries in women's contribution to agriculture. The labor burden of rural women exceeds that of men, and includes a higher proportion of unpaid household responsibilities related to preparing food and collecting fuel and water. The contribution of women to agricultural and food production is clearly significant (Adepoju *et al.,* 2015 and Chandrakar, 2020).

However, it is impossible to verify empirically the share produced by women because agriculture is usually a venture among household members and involves a range of resources and inputs that cannot be readily assigned by gender. Women's participation in rural labor markets show much heterogeneity at the regional level, but women are over represented in unpaid, seasonal and part-time work, and the available evidence suggests that women are often paid less than men, for the same work. We conclude that accurate, current, regionally specific information and analysis is necessary for good gender-aware agricultural policy making (Ejike *et al.,* 2018). Data collection has improved substantially over the last decades, as has our understanding of the complexity of women's roles and the need to collect data not only on primary activities but on all women's activities. Data are needed to better understand gender roles in agriculture and how they change over time and in response to new opportunities. We have shown that women's roles are diverse and that they vary across regions and countries. These roles cannot be understood properly, and interventions targeting cannot be designed effectively, without also understanding their differential access to land, capital, assets, human capital, and other productive resources (Briones, 2019).

Table 4. Descriptive statistics showing the perception of farmer's skills and leadership

Skills and leadership	**Response (N = 185)**					
What skill are you currently contributing to farm business development	Nil	Marketing	Language	Team Building	Financial	analytical
Frequency (%)	5 (2.7)	40 (21.6)	10 (5.4)	60 (32.4)	25 (13.5)	45 (24.3)
How easy do you think is for women to gain leadership opportunities and experience in farming	Nil	Not easy	Indecisive	Easy		
Frequency (%)	5 (2.7)	105 (56.8)	25 (13.5)	50 (27.0)		
Do you face discrimination in the rural market	Nil	Yes	No			
Frequency (%)	5 (2.7)	75 (40.5)	105 (56.8)			
By who do you face discrimination	Nil	Male	Customers	Government Agency	Others	
Frequency (%)	90 (48.6)	35 (18.9)	25 (13.5)	15 (8.1)	20 (10.8)	
Do you have processing facilities for farm produce	Nil	Yes	No			
Frequency (%)	10 (5.4)	10 (5.4)	165 (89.2)			
Are you making effort to get the required one?	Nil	Yes	No			
Frequency (%)	20 (10.8)	135 (73)	30 (16.2)			
How many workers do you have in your organization	Nil	0.5	6-10			
Frequency (%)	5 (2.7)	165 (89.2)	15 (8.1)			

Source: Field Data, 2021

Table 4 presents the descriptive statistics showing the skills and leadership traits possessed by the farmers. It was gathered that farmers were majorly contributing team-building skills, analytical and marketing skills to farm business development as indicated by 32.4%, 24.3%, and 21.6% respectively. Similarly, respondents perceived that it is not easy for women to gain leadership opportunities and experience in farming as indicated by 56.8% not only that, but it was also recorded by the majority of the women do not face any discrimination in the rural market as indicated by 56.8%, and those that face discrimination were majorly from their male counterparts as indicated by 18.9%. Similarly, it was gathered that about 89.2% of the respondents do not have a processing machine and about 73.0% of them were making effort towards acquiring one. In terms of no of workers, findings indicated that about 89.2% opined that they have below 6 workers working with them on the farmland.

As previously discussed by Adepoju *et al.,* (2015) the major problem faced by the women is lack of equipment for processing activities, insufficient food items and lack of electricity. Logit analysis shows that year of education, household size and total monthly expenditure a proxy for income are significant in ensuring food security of the respondents. While women continue to face occupational segregation and discrimination in rural labor markets, some new forms of organization in supply chains for export-oriented crops and agro-processing have created better-paying employment opportunities for women in many countries than existed before. Wages are typically higher and working conditions better than in traditional agricultural employment. The large-scale incorporation of women in the packing stage of non-traditional agro-export production may be one of the most important developments for female employment over the last few decades (Raney *et al.,* 2011).

Women are clearly an important part of the agricultural labor force, but agriculture and agricultural value chains are equally important to women as a source of employment. Commercial value chains for high-value products such as fresh fruit, vegetables, flowers and livestock products are growing rapidly to supply urban supermarkets and export markets. The growth of modern value chains and the broader structural transformation of the agricultural sector in many developing countries have major implications for women's employment, but the impact of these trends for women has received relatively little analytical attention (Maertens and Swinnen, 2009a).

Women dominate employment in many of the high-value agricultural commodity chains in sub-Saharan Africa and Latin America (Table 5). New jobs in export-oriented agro-industries may not employ men and women on equal terms, however they often provide better opportunities for women than exist within the confines of traditional agriculture and can also be instruments of change with significant implications for women and rural development (Raney *et al.,* 2011, Maertens and Swinnen, 2009b).

Table 5. Descriptive statistics showing the effectiveness of small holders' participation in addressing food scarcity and insecurity

Women effectiveness	**Response (N = 185)**				
African youth are now involved in Agriculture	Nil	Agree	Strongly Agree	Disagree	Strongly Disagree
Frequency (%)	5 (2.7)	105 (56.8)	40 (21.6)	15 (8.1)	20 (10.8)
Are there an avenue for training woman farmers in your community	Nil	Yes	Maybe	No	
Frequency (%)	5 (2.7)	60 (32.4)	30 (16.2)	90 (48.6)	
There are more women farmers in Africa than men	Undecided	Strongly disagree	Disagree	Agree	Strongly agree
Frequency (%)	20 (10.8)	15 (8.1)	70 (37.8)	40 (21.6)	40 (21.6)
Do think women in Africa contribute to food Insecurity	Undecided	Strongly disagree	Disagree	Agree	Strongly agree
Frequency (%)	5 (2.7)	5 (2.7)	10 (5.4)	95 (51.4)	70 (37.8)

Source: Field Data, 2021

The result presented in Table 5 presents the descriptive statistics showing the effectiveness of women participation in addressing food scarcity and insecurity in Africa. Findings revealed that African youth are involved in agriculture as 58.8% agree and 21.6% strongly agree only 8.1% disagree and 10.8% strongly disagree. More, findings revealed that there is no avenue for training women farmers as indicated by 48.6%. in addition, on the question that states that there are more women farmers in Africa than men, it was gathered that 10.2% were undecided, 8.1% strongly disagree, 37.8% disagree, 21.6% agree while 21.6% strongly agree. This stressed that men farmers are more than women's farmers in Africa at this accounted for the reason why women contribute to food insecurity as indicated by 99.2%. This is because women are more men in terms of population growth.

Economic development has and will continue to transform the agricultural sector in many developing countries. The process includes greater commercialization, urbanization and integration into the global economy. These trends and changes bring with them challenges and opportunities, some with a distinct gender dimension. Economic development and rising incomes lead to greater demand for high-value commodities, processed products, and pre-prepared foods. In turn, food supply chains become increasingly vertically integrated, linking input suppliers, producers, processors, distributors and retailers. Supermarkets are part of this vertical chain because they are convenient, meet diversifying tastes, and set standards for quality and safety. The penetration of supermarkets is most pronounced in Latin America and parts of Asia, but is increasing in parts of Africa as well (Balsevich *et al.,* 2006 and Rimal, 2013).

Small-holder production systems in rapidly growing areas are facing increasing pressure to commercialize, diversify and expand. Increasing scales of production are being observed particularly in the livestock sector, which attempts to supply rapidly growing markets for meat, milk and eggs. Small-scale producers face particular pressures as size and private health and safety standards set by large retailers and wholesale buyers become increasingly important (De Haen *et al.,* 2003). Studies cited in Berdegue *et al.,* (2006) show that, in general, farmers who produce for supermarkets are larger, more educated, have more access to information, are able to hire-in labor, have greater access to irrigation and are closer to transport infrastructure. It is frequently assumed that small farmers will be marginalized by these trends, and that women farmers will be more severely penalized because of their smaller scale, lower education levels and limited access to resources. However, a number of studies suggest that this may not always be the case. In Eastern Europe and Central Asia, Dries *et al.,* (2004) finds that transaction costs and investment constraints are important and that companies prefer to work with few, large and modern suppliers, but they also find that small farms play a much larger role in actual supermarket contracting than would be expected. Zhang *et al.,* (2005) find that in Sichuan, China, small farms continue to supply fresh produce.

Conclusion and Recommendations

Going by the findings of this study, it is generally revealed that small-holder farmers particularly women play a significant role in ensuring household food security. Ensuring national food self-sufficiency does not necessarily translate into household food security. The need to ensure household food security is not only a function of food supplies but also of demand of purchasing power. It was revealed that women empowerment will serve as a critical ingredient in ensuring both national and household food security. Based on the findings of this study, it is therefore recommended that small-holder farmers should be supported with produce processing equipment and other incentives to boast production and sales. The adoption of new agricultural practices is more important now than it was in the past. When small-scale farmers adopt and plant improved crop varieties, they increase their agricultural income and escape poverty, thereby increasing local food security. The adoption of the National Development Plans as proposed by some countries in Africa such as Nigeria on Agriculture and Food Security when fully implemented would reduce food insecurity and ultimately increase food production.

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Effects of Aqueous and Ethanolic Extracts of *Laganaria breviflorus* (Christmas melon) leaves on Aflatoxigenic Fungi Isolated from Polished Rice Sold in Major Markets in Abeokuta, Nigeria

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Abstract

The inhibitory effects of *Laganaria breviflorus* leaf extracts on aflatoxigenic fungi isolated from rice was studied. Polished rice obtained from major markets in Abeokuta was cleaned and plated on Potato Dextrose Agar (PDA) and Methyl Red Desiccated Coconut Agar (MRDCA) to isolate aflatoxigenic fungi. Aqueous and ethanolic leaf extracts were used on isolated organisms and zones of inhibition was measured. Isolated mycoflora from the rice included *Aspergillus niger, A. flavus, A. parasiticus, A. fumigatus, A. terreus, A. nidulans*, *Penicillium chrysogenum, Fusarium* spp., *Mucor* spp., *Rhizopus* spp. and *Alternaria* spp. *Aspergillus, Fusarium and Alternaria* genera produced toxins and were subjected to the leaf extracts. Ethanolic extracts showed wider zones of inhibition that ranged between 19 - 22 mm, with *Aspergillus flavus* (19 mm) showing the least susceptibility and *A. niger* (22 mm) showing the highest susceptibility. The zones of inhibition of the aqueous extracts ranged from 10 - 15mm, *A. parasiticus* and *A. niger* exhibited zones of inhibition of 10 mm and 15 mm respectively. The study has revealed the potentials of ethanolic and aqueous extracts of the *Laganaria breviflorus* leaves as a possible ameliorating agent against aflatoxigenic organisms and consequently as an aid in the reduction of food contamination resulting from mycoflora and their toxins.

Keywords: Aflatoxins, Aqueous extracts, Ethanolic extracts, *Laganaria breviflorus,* Leaves, Mycoflora, Mitigation.

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Introduction

Food safety and security are among the major problems in the current climate of increasing population. These are mainly determined by three key aspects, enough food availability, access to safe food and utilization of the food in terms of quality, nutritional and cultural purposes for a healthy life (Ferdenades *et al*., 2017). The failure of any of these aspects leads to food insecurity and malnutrition that further influences human health, in addition to the socio-economic aspect of society. In addition, food and feed contamination by mycotoxins are one of the key factors responsible for creating food insecurity (Medina *et al*., 2014). As per the Food and Agriculture Organization (FAO), one-fourth of the world's crop is affected by mycotoxins (Wu, 2015; Pestka, 2017).

Aflatoxins are mycotoxins that contaminate crops and it is a global threat that compromises the safety of food, feed, and also influences the agricultural economy and crop-dependent small scale industries. Crops can be contaminated during the process of harvesting, storing, and transporting by the fungi specifically moulds and can lead to the productions of several mycotoxins (Murphy *et al.,* 2006).

The presence of these moulds does not always indicate that harmful levels of aflatoxins are present, but does indicate a significant risk. The moulds can colonize and contaminate food before harvest or during storage, especially following prolonged exposure to high- humidity environment, or to stressful conditions such as drought (Shahbazi, 2017).

In terms of cultivation and consumption, rice (*Oryza sativa*) is the world's most extensively cultivated crop after wheat and a staple food of above 50% of the total world population (FAO, 2002). Globally, about 593 million tonnes (Mt) is produced annually (FAO, 2002) and Nigeria is one of the nine major rice-importing countries. Others include Cote d'Ivoire, Philippines, Iran, Saudi Arabia, Brazil, Senegal, Japan, and Indonesia (Hynes, 2005).Nigeria produces 3.13 million tonnes on the average annually and of this quantity Niger State, one of the thirty six states of the federation contributes about 0.474 (15.14%) million tonnes yearly (ADP, 2004).

Rice is also one of the important cereals which under favourable conditions favours the growth of fungi and production of mycotoxins. Daily high intake of rice with a low level of contamination is of health concern. Thus, it is necessary to implement effective strategies to prevent contamination and fungal growth. Numerous attempts at decontaminating mycotoxigenic fungi in staple foods have been carried out, although some were positive but the decontaminating agents such as Aluminosilicates and Bentonite clay are not readily available or cheap.

Medicinal plants have been used from centuries for the treatment of various diseases. There are about 53,000 medicinal plants around the world (Hamilton, 2004). In developing countries, according to World Health Organization, about 70–95% people used medicinal plants as primary health care for the treatment of diseases (WHO, 2011). In current scenario, 70% of synthetic medicines are derived from plants (Anjorin,2013). Medicinal plants have antifungal, antimicrobial, anthelmintic, antibiotic, antiviral, anti-inflammatory, antiarthritic, antirheumatic, and antihemorrhoidal properties.

Laganaria breviflorus (Christmas melon) is a rough-skinned variety of Muskmelon (*Cucumis melo L.*), belonging to the Cucurbitaceae family. It is of great economic importance and it is largely cultivated in Africa and Europe mostly used as one of the phytogenic plant in curing Newcastle disease in indigenous chicken (Filomena *et al*., 2019). Because it's potential to inhibit mycotoxigenic fungi have not been researched, it is therefore the aim of this study to determine the antifungal capability of extracts from leaves of *Laganaria breviflorus.*

Materials and Methods

Collection of rice samples

Polished rice was purchased from Lafenwa and Kuto markets in Abeokuta, Ogun State, Nigeria. *Laganaria breviflorus* leaves were collected from the farm and transported to the laboratory in a zip lock bag.

Isolation and characterization of fungal isolate

Rice samples, unwashed, washed and cooked with distilled water were crushed in a sterile mortar and pestle separately and cultured on PDA plates and incubated at room temperature for 72 hours. Distinct colonies were isolated and subcultured until pure colonies were obtained. The pure cultures were stored on PDA slants for characterization and identification. Isolates were identified macroscopically through: color, texture, pigment and microscopically by mounting on slides with lactophenol cotton blue.

Toxigenicity test of fungal isolates

The isolates were cultured on Methyl Red Desiccated Coconut Agar Medium and incubated in a dark cupboard at room temperature for three days, after incubation, the growth on the plates was exposed to ultraviolet light for 3 hours at 360nm to observe production of fluorescence. The isolate that fluorescence was considered toxigenic.

Extraction procedure of *Laganaria breviflorus* (Tagiri) leaves

Extracts were collected from *Laganaria breviflorus* (tagiri) using aqueous and ethanolic extraction method according to (Owolabi *et al*., 2007). Aqueous extract from leaves of *Laganaria breviflorus* was obtained by sun drying and crushing with sterile mortar and pestle and then 1g of the crushed sample was weighed and dissolved in 10ml of sterile water in a sterile conical flask and covered with cotton wool and wrapped with aluminium foil and shaken vigorously. While the ethanolic extracts was obtained with the same procedure but with 3ml of ethyl alcohol. The mixture was also be left to stand for 72 hours at room temperature and then filtered with Whatman No.4 filter paper.

Inhibitory process of *Laganaria breviflorus* (Tagiri) leaves

The toxigenic strains were inoculated on Yeast Extract Broth. The isolates in the Yeast Extract Agar were cultured on freshly prepared and sterilized PDA medium using pour plate method and allowed to solidify. After solidification, the plates were punctured using sterile metal cork-borer and ethanolic and aqueous leaf extracts of *Laganaria breviflorus* were introduced into the holes and labeled appropriately. Control plates were maintained without addition of the extracts.

All the plates were incubated at room temperature for 72 hours under sterile conditions. The zones of inhibition were measured around each well.

Data Analysis

Data were expressed as mean ± standard deviation. One-way analysis of variance was used to analyze the mean and the post hoc treatment was performed using Duncan multiple range tests. Significant difference was accepted at $P \leq 0.05$.

Results

Isolation and characterization of fungal isolates from polished rice

A total of 12 fungal species were isolated from polished rice obtained from Abeokuta markets, they include *Aspergillus niger, Aspergillus flavus, Aspergillus parasiticus, Aspergillus fumigatus, Aspergillus terreus, Aspergillus nidulans, Penicillium chrysogenum, Neurospora crassa, Mucor, Fusarium and Saccharomyces* species (Table 1). Microscopic characterization of the fungi species revealed globus to sub-globulus spherical conidia to circular multilateral budding (Table 2).

Determination of toxigenic fungal isolates from polished rice

Aspergillus niger, Aspergillus flavus, Aspergillus parasiticus, Aspergillus fumigatus, Aspergillus terreus, Aspergillus nidulans all showed toxigenicity and this was determined by blue-green fluorescence when placed under ultraviolet light for 3 hours (Table 3).

Table 1. Cultural characteristics of fungal isolates

Isolate	Surface color	Reverse side	Elevation	Growth rate
Aspergillus niger	Dark brown to black	White to yellow	Umbonate	Rapid
Aspergillus flavus	Yellow/greyish green	Colourless to yellow	Umbonate	Moderate to rapid
Aspergillus parasiticus	Dark green	Orange yellow	Convex	Fast
Aspergillus fumigatus	Blue green	White to tan	Umbonate	Rapid
Aspergillus terreus	Pinkish cinnamon to deeper with age	Pale to bright yellow to deep brown	Umbonate	Moderate to rapid
Aspergillus nidulans	Dark cress green	Purplish red, brownish dark with age	Umbonate	Slow to moderate
Penicillium chrysogenum	Dark lemon green	Yellow white	Flat	Moderate
Neurospora crassa	Royal orange	Light brown	Raised	Fast
Mucor sp.	Pale brown	Brown	Curled, Raised	Fast
Fusarium sp.	Magenta pink	Magenta red turning violet	Raised	Moderate
Saccharomyces sp.	Creamy to white	White to light yellow	Flat, smooth, moist, dull	Moderate

Table 2. Microscopic characteristics of fungal isolates

Isolates	Colour of spore	Type of spore	Septation	Conidia shape
Aspergillus niger	Deep brown-black	Conidiospore	Septate	Globules to subglobulus and very rough
Aspergillus flavus	Greenish yellow	Conidiospore	Septate	Spherical
Aspergillus parasiticus	Pink	Conidiospore	Septate	Rough, thick wall and spherical
Aspergillus fumigatus	Blue-green	Conidiospore	Septate	Flask-shaped vesicles
Aspergillus terreus	Tan to brown	Conidiospore	Septate	Biseriate, compact and densely columnar conidial heads
Aspergillus nidulans	Dark green	Conidiospore	Septate	Conidial head are Columnar,vesicles are hemispherical Conidia are globose and rough
Penicillium chrysogenum	Blue to blue green	Conidiospore	Septate	Flask shaped
Neurospora crassa	Pinkish orange	Ascospore	Septate	Longitudinal striations resembling nerve axons
Mucor sp.	White to greenish brown	Sporangiospore	Non septate	Globose shaped
Fusarium sp.	Brown	Chlamydiospore	Septate	Circular
Saccharomyces sp.				Multilateral budding, blastoconidia are unicellular, globose and ellipsoid

Table 3. Presence of toxigenic fungi isolated from polished rice

Isolate	Toxigenicity
Aspergillus niger	Positive
Aspergillus flavus	Positive
Aspergillus parasiticus	Positive
Aspergillus fumigatus	Positive
Aspergillus nidulans	Positive
Penicillium chrysogenum	Positive
Neurospora crassa	Negative
Mucor sp.	Negative
Fusarium sp.	Positive

Effect of the aqueous and ethanolic extract of leaves of *Laganaria breviflorus*

Table 4 shows the effects of the extracts on the toxigenic fungi, zone of inhibition of growth of toxigenic fungi isolated from polished rice. Ethanolic extracts showed wider zones of inhibition that ranged between 19 and 22 mm, with *Aspergillus flavus* (19 mm) showing the least susceptibility and *A. niger* (22 mm) showing the highest susceptibility. The zone of inhibition of the aqueous extracts ranges from 10-15mm. The percentage inhibition zones as exhibited by the aqueous and ethanolic extracts are shown in Figs 1 and 2 respectively.

TABLE 4. Zone of inhibition of growth of toxigenic fungal isolates

Toxigenic isolates	Aqueous extract (mm)	Ethanolic extract (mm)
Aspergillus niger	14 .80 ± 0.41[a]	22.00 ± 1.51[ab]
Aspergillus flavus	12.66 ± 0.88[abc]	19.83 ± 0.44[bc]
Aspergillus parasiticus	10.00 ± 0.36[ab]	23.00 ± 0.57[a]
Aspergillus fumigatus	10.73 ± 0.89[cd]	19.33 ± 0.66[bc]
Aspergillus nidulans	13.66 ± 1.33[ab]	19.43 ± 1.55[bc]
Penicillium chrysogenum	8 .33 ± 1.66[d]	21.43 ± 0.43[ab]
Mucor sp.	14.66 ± 0.33[a]	18.63 ± 0.31[c]
Fusarium sp.	11.20 ± 0.61[bc]	23 .00 ± 1.00[a]
Aspergillus terreus	10.00 ± 0.00[cd]	20.66 ± .0.43[abc]

Suceptible: ≥19mm, Intermediate: 15-18mm and Resistant: ≤ 14

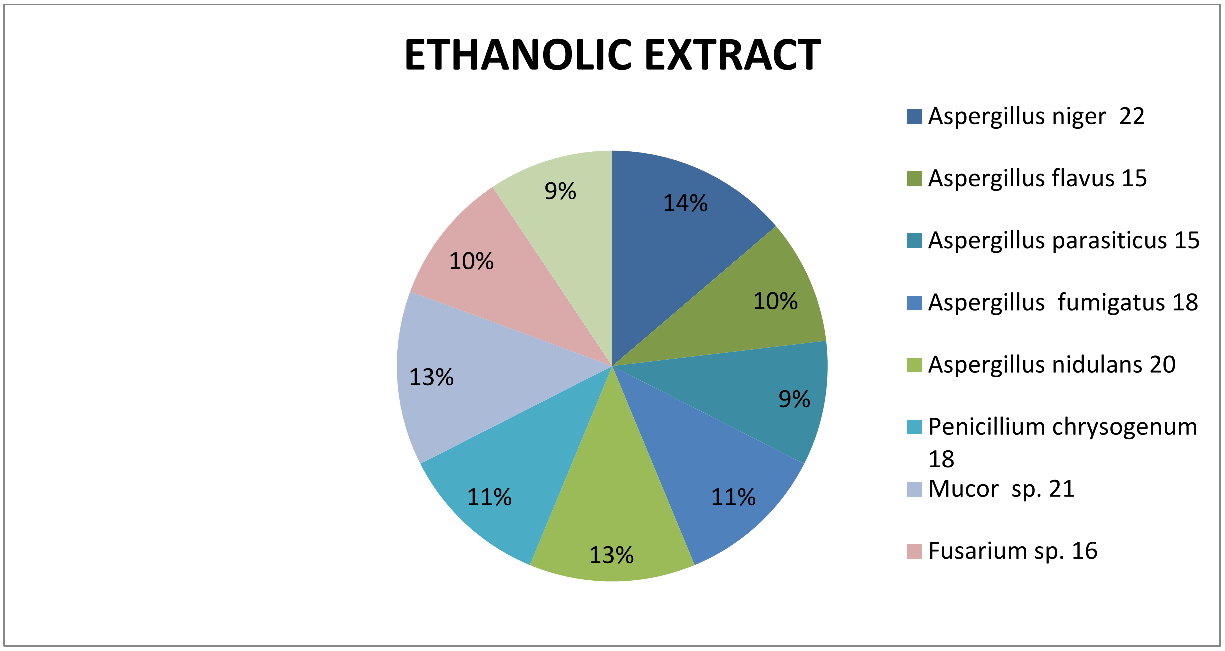

Figure 1. Zone of inhibition of ethanolic extract on toxigenic isolates

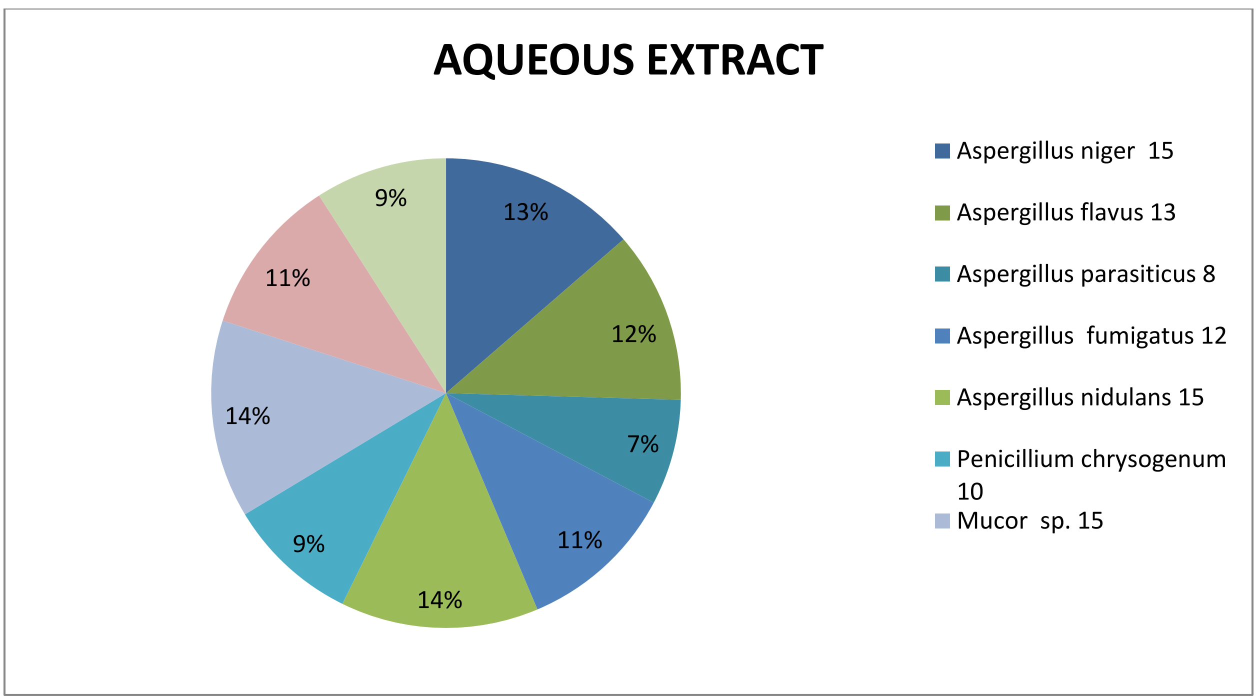

Figure 2. Zone of inhibition of aqueous extracts on toxigenic isolates

Discussion

The study revealed the occurrence of mixed fungal isolates in polished rice samples in Abeokuta market. The presence of fungal isolates in rice could be attributed to the ubiquitous nature of microorganisms. These result is in accordance with the study of (Sawane and Sawane, 2014), that reported 96 fungal isolates belonging to 16 genera of *Aspergillus, Penicillium* and *Fusarium* and other fungi genera from 36 samples of stored rice in India. The most dominant genera were the *Aspergillus* group, which is expected because of the dogged nature of the organisms and the ability to withstand the atmospheric condition in the tropics (Bryden, 2012).

The toxin production potentials of some of the *Aspergillus* species in the study suggests the risk human and animals can be in due to the consumption of staple foods such as rice that have been compromised. Shaker *et al. (*2013) reported the production of toxins by fungi that were isolated from rice in Iraqi markets. The abundance of these toxin producing fungi in rice might be due to the poor storage facilities especially in developing countries. Bainton *et al*., (1980) reported the proliferation of fungi in storage that results in the production of mycotoxins.

The use of bioactive compounds from natural sources as functional foods to promote human health and treat various diseases has been increasingly attracting considerable attention. This study also tested the ability of the aqueous and ethanolic leave extract of *Laganaria breviflorus* in the inhibition of toxigenic fungi isolated from polished rice, the positive result is an indication that the plant can serve as not only an antiviral agent but also an antifungal agent. The ethanolic extracts inhibited more toxic isolates than the aqueous extracts; this might be due to the strength with which the ethanol extracts the active component from the leaves. This is in conformity with the report of Dieu-Hien *et al*. (2019**)** who observed higher inhibiton with ethanolic and methanolic extracts of *Limophila aromatic* leaves against some disease causing microorganisms. Although the ethanolic extracts works best for the fungi, the aqueous extracts also inhibited the toxigenic fungi to in a significant manner. Since no study has reveals the use of *Laganaria breviflorus* as an antifungal agent in solving the problem of toxins in staple foods such as polished rice this is the first of its kind, further studies on its active component would give a broader picture on its effectiveness.

Conclusion

This study has shown the ability of *Laganaria breviflorus* leaf extract to inhibit aflatoxigenic moulds. These are cheap, non-toxic, biodegradable and sustainable materials. This could serve as alternatives to synthetic fungicides for controlling mycotoxigenic fungi in stored food.

Competing interests

The authors declare no competing of interest.

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Original Article

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Orange-fleshed Sweet Potato (*Ipomoea batatas* Lam.) Composite Biscuit: A Super Snack for Alleviating Food Insecurity and Micronutrient Deficiency in Africa

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Abstract

Sweet potato tuber categorized as "poor man's food" is globally gaining recognition as one of the most valued food crops which can be used in alleviating food insecurity and micronutrient deficiency due to its great nutritional potentials. Orange-fleshed sweet potato (OFSP) is an emerging bio-fortified variety of sweet potatoes in the tropical and sub-tropical regions; it has a great chance for being acceptable as staple food in the food chain to tackle food insecurity and micronutrient deficiency in Africa. OFSP is rich in β-carotene (a precursor of vitamin A) and other micronutrients of great nutritional values but low in protein. This study was carried out to produce biscuit from blends of OFSP, soy concentrate (source of protein), sweet potato starch and date palm. The biscuit was evaluated for proximate, mineral, anti-nutrient and consumer acceptability. The results showed that protein values ranged from 6.46 to 19.42%, ash contents ranged between 2.63 and 3.81%. Calcium values ranged from 101.75 to 301.45 mg/100g, potassium ranged from 186.37 to 451.03 mg/100g, Magnesium values ranged between 15.37 and 30.19 mg/100g, Phosphorous values ranged between 101.04 and 620.21 mg/100g, Sodium-potassium ratio (Na/K) was less than (<) 1. It was observed that all the anti-nutritional factors considered were within the acceptable limit / standard. The OFSP composite biscuit compared favourably with control sample. Thus, OFSP composite biscuit will be a suitable food approach to combat food insecurity and micronutrient deficiency in Africa.

Keywords: Orange-fleshed sweet potato composite biscuit, proximate composition, minerals composition, anti-nutrient, micronutrient

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Introduction

Biscuits are baked products desirable for all ages due to its qualities such as low purchasing power, low manufacturing cost, long shelf-life, convenience and it is a ready-to-eat snack (Obafaye and Omoba, 2018). It is generally produced from imported wheat flour which is of great disadvantage to our economy, non-wheat flour such as sweet potato and its varieties can be used to produce biscuits as a complementary food (Adeyeye and Akingbala, 2015; Adeola and Ohizua, 2018; Ayensu *et al.,* 2019; Oloniyo *et al.,* 2020). Sweet potato (*Ipomoea batatas* Lam.) is a dicotyledonous seasonal tuber crop, grown in the tropical and subtropical regions for consumption (Alam *et al.,* 2016; Kwon *et al.,* 2019; Shen *et al.,* 2019). It plays a major role worldwide as a staple and important crop in developing countries (Mollinari *et al*., 2020). It is one of the world's most important, versatile and under-exploited tuber crops (Olatunde *et al.,* 2016). Sweet potato is ranked seventh most important food crop of the world after the order of rice, maize, wheat, potato, barley and cassava (Jan *et al.*, 2017). For the past two decades, sweet potato has gained prominence due to its short growing cycle (four to five months) which tolerates flexible cultivation, harvesting system, also it permits quick production and processing thereby reducing “food shortage period” (Devaux *et al.,* 2014; FAOSTAT, 2018). Sweet potato has higher advantage over other root and tuber crops (yam and cassava) which have a longer cropping cycle, they are vital for annual cycle of food availability. Sweet potato is cheap and nutritionally rich staple food that contributes to minerals, vitamins and dietary fiber when consumed (Ayensu *et al.,* 2019). Researchers have reported that Nigeria is the leading producer of sweet potato in Africa with 3.93 Metric tons (MT) and second to China in the global production (Truong *et al.,* 2018; FAOSTAT, 2018; Ma 2019; Abioye *et al.,* 2019; Zhu and Sun, 2019). Nigeria is followed by Tanzania, Indonesia and Uganda in Africa (FAOSTAT, 2018). Sweet potato is majorly cultivated in the northern part of Nigeria in States like Kaduna, Kano, Zamfara and Sokoto (FAOSTAT, 2018). The varieties of sweet potato have a wide range of colour in both the skin and flesh (Adebisi *et al.,* 2015). Sweet potato with either slight or deep orange colour is known as orange fleshed sweet potato (OFSP), which is a biofortied sweet potato high in β-carotenoid known as a precursor of vitamin A (Nzamwita *et al.,* 2017).

OFSP have substantial health benefits as it promotes a healthy living (Aywa *et al*., 2013; Shikuku *et al.,* 2019). OFSP has significant antioxidant activity and potentially improves vitamin A status in children (Hotz *et al.,* 2012; Faber *et al.,* 2013; Tumuhimbise *et al.,* 2019; Nyathi *et al.,* 2019; Oloniyo *et al.,* 2021). It is a rich source of fiber, minerals (calcium, potassium, phosphorous, magnesium), vitamins (A, E, C and B complex) and carotenes (Stathers *et al*., 2013) but it is low in protein (Tumuhimbise *et al.,* 2019; Haile and Getahun, 2018). OFSP have been utilized as food in some part of Africa such as Nigeria, Kenya and Uganda (Edun *et al.,* 2019; Tumuhimbise *et al.,* 2019; Parker *et al.,* 2019) and researchers have given innumerable report on different food products developed from OFSP (Truong and Avula, 2010; Stathers *et al.,* 2013; Dooshima 2014; Abidin *et al.,* 2015; Andrade *et al.,* 2016; Olagunju *et al.,* 2020; Oloniyo *et al.,* 2021) but there is dearth of information on the biscuit produced from blends of OFSP, soy concentrate, date palm and potato starch.

Therefore, this study, seeks to provide information on Orange-fleshed sweet potato composite biscuit as a super snack for alleviating food insecurity and micronutrient deficiency in Africa.

Materials and methods

Sources of materials

Mother's delight (UMUSP002), King J (UMUSP001) and cream fleshed sweet potato used in this study were cultivated and harvested at five months of maturity stage from a local farm at Oba Ile, Akure, Ondo State, Nigeria. TGX923-1E variety of soy beans were obtained from Niger State, Nigeria. Date palm fruits and other ingredients (yeast and margarine) were obtained from *Shasha* market in Akure, Nigeria.

Sample preparation

Preparation of sweet potato flour

The tubers were processed into flour by the method described by Oloniyo *et al.* (2020). Two hundred kilograms (200 kg) of the tubers were properly cleaned, peeled and cut into smaller pieces using sharp table knife; the small pieces of tubers were dried at 60°C for 48 h in an oven. The dried pieces of tubers were milled and screened via 250 µm mesh size to uniform finer flour. The flour was stored at 4°C in an airtight polyethylene bag prior to use.

Preparation of soy concentrate flour

Soy concentrate flour was obtained from Soy bean as described by Oloniyo *et al.* (2020). Soybeans (3.0 kg) were saturated in water (10 L) for 20 h at 40 ^{o}C. The saturated soy beans were drained and wet-milled, water was added at a ratio of 6:1 to form slurry and the slurry was filtered to separate its residue from the milk. Soymilk was then heated for 5 min to reach a boiling point then, 15 ml of lemon juice (coagulants) was added to one (1) liter of boiling soy milk to concentrate the milk; the concentrated milk was gently removed into a clean muslin cloth and pressed for 6 h. The pressed soy concentrate was oven dried for 24 h at 40 °C, thereafter; it was milled, cooled and sieved via 250 µm mesh size. The soy concentrate flour was stored at 4 °C in an airtight container prior to analysis

Preparation of date palm flour

Date palm fruits were processed into flour by a method described by Sadiq *et al.* (2013). Date palms were cleaned and oven dried for 24 h at 50 ^{o}C. The dried date palm were chopped into smaller units with pestle and mortar, afterward it was milled into fine flour, sieved via 150-mesh size and stored in an airtight container at 4 °C prior to analysis.

Preparation of potato starch flour

Tuber of sweet potato were processed into starch by a method described by Riley *et al.* (2006) and modified by Awolu and Olofinlae (2016). The tubers were peeled, washed and wet milled to form slurry; the slurry was filtered using a muslin cloth to remove its residue. The granules were allowed to settle and water decanted followed by centrifugation at 3,000 x g for 10 min. Starch slurry was allowed to air dry in an oven at 50 °C for 24 h. The dried starch was milled and packaged in a polyethylene bag at 4 °C for further analyses

Experimental design for the flour blends

In this study, Response Surface Methodology (Design Expert, 8.0.3.1 trial version) was used to design the experiment. Orange fleshed sweet potato

flour (OFSP), soy concentrates flour (SCF), sweet potato starch and date palm flour were the independent variables while protein and carotenoid contents were the dependent variable.
The independent variables were OFSP (56–70 g/100g); SCF (06–20 g/100g); potato starch flour (14 g/100g) and date palm flour (10 g/100g). Each of the sweet potato variety generates thirteen samples which in total gave the total sum of thirty-nine samples as shown in Table 1. Samples with the best response variables were used for biscuit production.

Table 1. Experimental design for the optimization of sweet potato composite blends

RUNS	SP (g)	SC (g)	DP (g)	PS (g)
1	70.00	6.00	10.00	14.00
2	56.00	20.00	10.00	14.00
3	70.00	6.00	10.00	14.00
4	59.50	16.50	10.00	14.00
5	70.00	6.00	10.00	14.00
6	56.00	20.00	10.00	14.00
7	56.00	20.00	10.00	14.00
8	66.50	9.50	10.00	14.00
9	63.00	13.00	10.00	14.00
10	70.00	6.00	10.00	14.00
11	56.00	20.00	10.00	14.00
12	60.67	15.33	10.00	14.00
13	65.33	10.67	10.00	14.00

SP-Sweet potato flour, SC- Soy concentrate, DS- Date palm, PS – Potato Starch

Production of Biscuit

Biscuits samples were processed from dough according to the preparation method described by Omoba *et al*. (2015) with slight modification. The formula used was as follows: 250 g flour blends, 50 g margarine, 2 g sodium chloride and 50 to 55 mL water. The margarine was creamed in a mixer grinder (Model: speedo) with a flat beater for 5 min at 61 rpm (speed 1). Sodium chloride was added to the sieved flour; it was later added to the cream in the mixer and then mixed for 3 min at 60 rpm. The dough pieces were cut into circular shape and baked at 200 ^{o}C for 8-10 min. After baking, the biscuits were left to cool at room temperature and were kept at 4 ^{o}C in an air tight sealed polyethylene porch prior to analysis.

Sample analysis

Determination of carotenoid content

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The carotenoid content of the composite flour was determined as described by Rodriguez-Amaya and Kimura (2004)

Proximate composition of the composite OFSP biscuit

The proximate (moisture, crude fat, crude fibers, crude protein, and crude ash) composition of composite biscuit was determined according to the method described by AOAC (2010). Carbohydrates were calculated by difference and the caloric value was calculated by Atwater factor method as described by Osborne and Voogt (1978).

Mineral contents of the composite OFSP biscuit

The contents of minerals such as Calcium (Ca), Potassium (K), Magnesium (Mg), Zinc (Zn), Iron (Fe), Phosphorous (P) and Sodium (Na) in the composite biscuit were determined as described by AOAC (2010). The single official AOAC multi-element method (AOAC 968.08) and the atomic absorption spectroscopy method were used to determine Ca, Fe, and Zn. AOAC official method 964.04 was used to determine P while Na and K were determined using a flame photometer.

Anti-nutritional composition of the composite OFSP biscuit

The phytate content of the composite biscuit was determined with the use of indirect colorimetric method as described by Wheeler and Ferrel, (1971), the oxalate, alkaloid and trypsin inhibitor content of the biscuit was determined as described by AOAC (2010) method, the tannin content of the biscuit was determined as described by Joslyn (1970).

Phytate-mineral molar ratio of the composite OFSP biscuit

The moles of phytate and minerals were obtained by dividing the weight of phytate with the minerals of each of the mineral molecular weight as described by Norhaizan and Nor Faizadatul (2009). The phytate-mineral molar ratio was obtained by dividing the moles of phytate with the moles of each mineral as mathematically shown below:

$$\text{Molar ratio (Mr)} = \frac{\text{Pa/MwPa}}{\text{Min/Mwin}} \qquad \text{Eq. (1)}$$

Eq. (1) was used to calculate the molar ratio.

Where: Pa = Calculated phytate content

Mwpa = Molecular weight of Pa = 660

Min = Mineral content obtained for each minerals (i.e Zn, Ca and Fe)

Mwin = Mineral molecular weight (Zn = 65, Fe = 56, Ca = 40 g/mol).

Evaluation of the sensory qualities of orange fleshed sweet potatoes composite biscuit

Sensory evaluation of the biscuit was carried out as described by Oloniyo *et al.* (2020). Sixty (60) undergraduate students (fourth-two (42) male and eighteen (18) female) from Federal University of Technology, Akure, Nigeria were used as the semi-trained panelists. The School of Agriculture and Agricultural Technology (SAAT) of the Federal University of Technology, Akure (FUTA), Nigeria approved the sensory evaluation protocols used in this study. A training session of about thirty (30) min was conducted to enlighten the panelist on the assessment of the samples. The sensory evaluation of the composite biscuit was carried out two (2) h after baking. The panelists rated the given biscuit products separately using a nine point hedonic scales with the ratings measure of: 9- for Like extremely, 8- for Like very much, 7- for Like moderately, 6- for Like slightly, 5- for Neither like nor dislike, 4- for Dislike slightly, 3- for Dislike moderately, 2- for Dislike very much and 1- for Dislike extremely for all the quality attributes and acceptance tests. The attributes evaluated in the biscuit samples were aroma, taste, appearance, crispness, and overall acceptability.

Statistical analyses

Data were generated in triplicate; one-way analysis of variance (ANOVA) was used to analyze the result obtained using Statistical Package for Social Sciences (SPSS) version 21. Its means were separated using Duncan's new multiple range test (DNMRT). Statistical significance was accepted at $p \leq 0.05$.

Results and Discussion

Protein and carotenoid content of sweet potato based composite flour

The protein and carotenoid content of sweet potato based composite flour are shown in Fig 1. High protein contents were observed in samples OFSPM2, OFSPM6, OFSPK2, OFSPK3, OFSPK6, CFSP2 and CFSP6 with 19.60, 17.50, 21.10, 15.40, 18.60, 18.30 and 16.80 % respectively. High percentage of protein observed in this sample might be as a result of the incorporation of soy concentrate flour into OFSP flour. This result was in agreement with the report of Kumar *et al.* (2022) that Soy proteins are good sources of plant protein for a healthy living.

High carotenoid content were observed in sample OFSPM1, OFSPM4, OFSPM5 and OFSPM7 with 26.18, 23.71, 17.40 and 20.13 mg/100g respectively. Carotenoids are dietary form of vitamin A, it is a complex compound found in foods but when it is been consumed, it is then converted into rhodopsin and retinal which is a visual pigment and antecedent of retinoic acid, which controls body growth and visual development (Le *et al.,* 2017). In this study it was observed that all the samples with the high carotenoid content were found to have mothers delight orange fleshed sweet potato base and this agrees with the report of Alam *et al.* (2016) that orange flesh sweet potato is a good source of beta carotene which is a precursor of vitamin A and it also agreed with the report of Oloniyo *et al.* (2021) that mothers delight orange fleshed sweet potato is a good source of beta carotene among other varieties considered.

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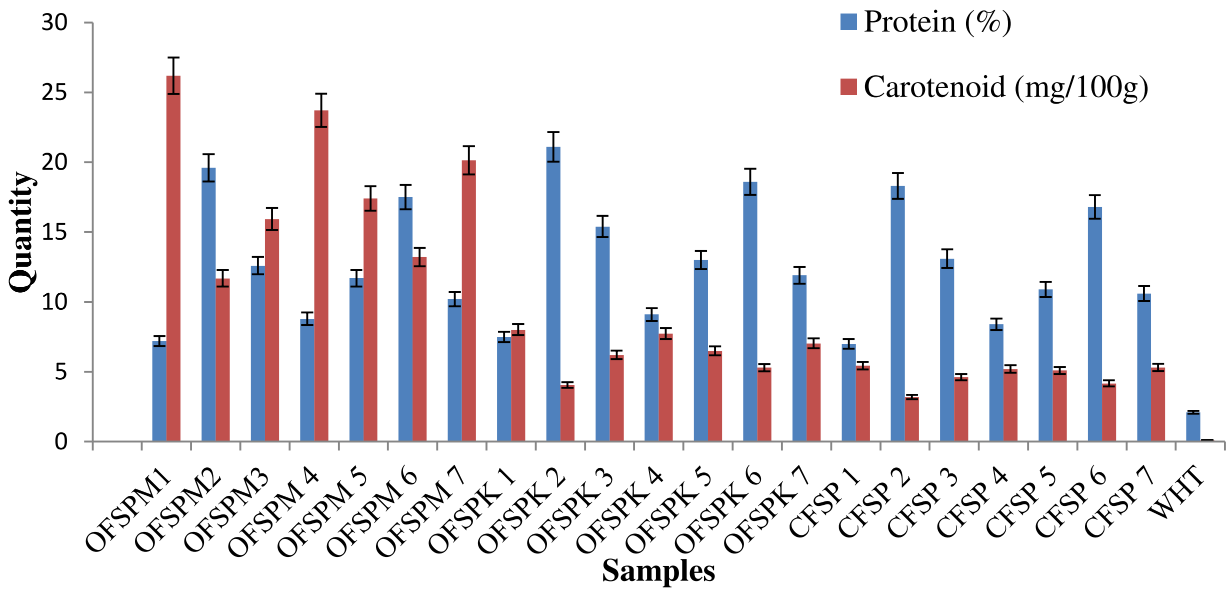

Figure 1. Protein and carotenoid content of OFSP composite flour

WHT- control. OFSPM- mother's delight orange-fleshed sweet potato, OFSPK- king J orange - fleshed sweet potato, CFSP- cream-fleshed sweet potato. OFSPM- mother's delight orange fleshed sweet potato, OFSPK- king J orange fleshed sweet potato, CFSP- cream-fleshed sweet potato.

Proximate Composition of Sweet Potato Composite Biscuits

The Proximate compositions of sweet potato composite biscuit were presented in Table 2. The moisture content of the biscuit ranged from 5.53 to 9.30%. WHT (9.30%) had the highest moisture content while OFSPM4 (5.53%) had the lowest moisture content. The obtained results agrees with the report of Laukova´ *et al.* (2019) who reported the moisture content of 6.21% for sweet potato powder-enriched cereal products but the moisture content was lower compared to the report of Edun *et al.* (2019). The obtained moisture content of composition of sweet potato biscuit was considered a food quality characteristic where storage is considered; since microbiological deterioration is hasten with the presence of water thereby subjecting it to spoilage. The obtained moisture content obtained in this study was lower compared to the report of Zhu and Sun (2019) who reported that of steamed biscuit fortified with purple sweet potato flour was 13%. The moisture content is the quantity of water contained in a food sample.

Ash content ranged from 2.63 to 3.81%. CFSP6 (2.63%) biscuit had the least ash content while OFSPM2 (3.81%) had the highest ash content. High ash contents observed in the biscuit samples shows that sweet potato are good sources of minerals (Tiruneh *et al.,* 2018). The high ash value observed in the biscuit might be as a result of inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food (Ismail, 2017). It is called total ash because it is a residue that remains after heating which removes water and organic material such as fat and protein.

Protein content in the Sweet potato biscuit ranged from 6.46 to 19.42%. WHT (6.46%) biscuit had the least protein content of while OFSPK2 (19.42%) had the highest protein content. It was observed that the protein value of the biscuit samples was sufficient to combat Protein energy malnutrition in our country when compared to the standard (FAO, 2010). Foods high in protein content are of great nutritional benefits in developing countries (Nigeria) where protein malnutrition is prevalent (Okpala and Okoli, 2011). Protein is one of the classes of food required by children for their growth, tissue repair, and the maintenance of the body cells. It also acts as an enzyme and hormone in the body. Protein maintains body fluid, electrolyte and acid–base balance, and strong immune system. Proteins act as carriers for other nutrients such as lipids, vitamin A, iron, sodium, and potassium (Adeola and Ohizua, 2018).

Crude fat content of the biscuit ranged from 5.22 to 15.69%. WHT (5.22%) had the least fat content while OFSPM2 (15.69%) had the highest fat content. The high fat content observed might be as a result of the addition of margarine during the production of the biscuit. High fat content in a sample can leads to rancidity (Adefegha *et al.*, 2018).The fat contents of the biscuit samples were similar to the report of other researchers who used composite flours for biscuit productions (Giwa and Abiodun, 2010; Silky and Tiwari, 2014). The variations observed in the fat contents of the biscuit samples, despite the same quantity of margarine (fat) used in the recipe, may be due to variations in their moisture contents observed in this study. The fat content of the biscuits was within the standard value as reported by Manley (2001) to range from 15 to 20%. Similar values of fat content ranging from 15.1% to 18.1% were reported by other researcher (Asif-Ul-Alam *et al.,* 2014; Silky and Tiwari, 2014).

Fibre content of the biscuit ranged from 3.49 to 6.03%. WHT (3.49%) had the least fibre content while OFSPM1 had the highest fibre content of 6.03% each. Fiber was known to aid the rate of food in the digestive system. It had been reported that sweet potatoes are good sources of fiber (Adeola and Ohizua, 2018).).

Carbohydrate contents of the biscuit ranged from 49.32% to 72.62%. OFSPM2 (49.32%) had the least carbohydrate content while WHT (72.62%) had the highest carbohydrate content of 72.62%. The calculated energy value of the biscuit ranged from 363.30 to 416.28 Kcal. WHT (363.30 Kcal) had the least carbohydrate content while OFSPK6 and CFSP6 had the highest energy value with 416.28 and 416.19 Kcal respectively. Energy value (EV) is the amount of calorie available in a given food sample. It is a function of the fat, total protein and carbohydrates present in a food. The EV of the biscuit samples obtained in this research agrees with the report of Adeyeye and Akingbala (2015) who reported that the calculated energy value of biscuit falls within the ranged of 397 and 457 Kcal/g.

Table 2. Proximate (%) and calculated energy (Kcal) composition of sweet potato composite biscuits (*dry matter basis*)

Sample	Moisture	Total Ash	Crude Protein	Crude Fat	Crude Fibre	Carbohydrate	Energy Value
OFSPM1	8.21±0.1[b]	3.19±0.7[c]	6.62±0.4[k]	8.33±0.1[k]	6.03±0.1[a]	67.62±0.7[b]	371.93±0.2[j]
OFSPM2	7.77±0.3[c]	3.81±0.1[b]	18.22±0.1[c]	15.69±1.2[a]	5.19±0.6[c]	49.32±0.1[k]	411.37±0.5[e]
OFSPM4	5.53±0.1[l]	2.71±0.7[k]	8.8±0.3[j]	10.93±0.1[j]	4.4±0.1[f]	67.63±0.7[b]	404.09±0.1[i]
OFSPM5	5.9±0.2[k]	2.81±0.2[i]	11.7±0.2[h]	12.11±0.1[h]	4.38±0.1[g]	63.1±0.5[d]	408.19±0.3[g]
OFSPM6	7.21±0.7[f]	3.00±0.2[f]	17.5±0.2[e]	13.28±0.4[f]	4.64±0.1[e]	54.37±0.1[g]	407.00±0.1[h]
OFSPM7	5.95±0.1[j]	2.74±0.1[j]	10.2±0.1[i]	11.94±0.1[i]	4.19±0.1[i]	64.98±0.9[c]	408.18±0.2[g]
OFSPK2	7.41±0.7[d]	3.02±1.9[e]	19.42±1.3[a]	15.02±0.2[c]	5.09±0.3[d]	50.04±0.1[j]	413.02±0.4[c]
OFSPK3	6.38±0.1[i]	2.98±0.1[g]	15.4±0.5[g]	12.54±0.2[g]	4.17±0.1[j]	58.53±0.3[e]	408.58±0.1[f]
OFSPK6	6.56±0.7[h]	3.92±0.9[a]	18.6±1.0[b]	15.16±0.9[b]	4.4±0.1[f]	51.36±0.2[h]	416.28±0.9[a]
CFSP2	7.33±0.5[e]	3.14±0.7[d]	18.11±0.6[d]	15.01±0.2[d]	5.22±1.1[b]	51.19±0.2[i]	412.29±0.4[d]
CFSP6	7.1±0.0[g]	2.63±0.1[l]	16.8±0.1[f]	14.39±0.5[e]	4.21±0.1[h]	54.87±0.1[f]	416.19±0.9[b]
WHT	9.3±0.9[a]	2.91±0.1[h]	6.46±0.4[l]	5.22±0.8[l]	3.49±0.3[k]	72.62±0.4[a]	363.3±0.5[k]

Values are averages of triplicate readings (mean ±standard deviation). Means within a column followed by different superscripts letter(s) are significantly differences ($p \leq 0.05$). WHT- control. OFSPM- mother's delight orange-fleshed sweet potato, OFSPK- king J orange - fleshed sweet potato, CFSP- cream-fleshed sweet potato.

Mineral Composition of the Sweet Potato Composite Biscuit

The mineral compositions of sweet potato composite biscuit were presented in Table 3. Calcium (Ca) values ranged from 101.75 to 301.45.0mg/100g, potassium (K) values ranged from 186.37 to 451.03 mg/100g, magnesium (Mg) values ranged from 15.37 to 30.19 mg/100g, zinc (Zn) values ranged from 20.62 to 42.53 mg/100g, iron (Fe) values ranged from 4.61 to 10.63 mg/100g, phosphorous (P) values ranged from 101.04 to 620.21 mg/100g, sodium (Na) values ranged from 7.26 to 8.01 mg/100g. Toxic minerals such as cadmium (Cd), lead (Pb), and chromium (Cr) were not detected in all the samples (biscuit) which implies that the biscuit produced are safe for consumption. In the composite biscuit, phosphorous was observed as the most abundant mineral while sodium was the least mineral. The ratio of sodium to potassium ranged from 0.01 to 0.04, Na and K are important cations used in the regulation of plasma volume, acid-base balance, and nerve and muscle contraction. Diets rich in K are known to reduce the risk of kidney stone because the naturally occurring K salts in plant foods neutralizes acidity in the blood stream. The minerals in the composite biscuit was observed in the order of Phosphorous (P)> Potassium (K) > Calcium (Ca) > Magnesium (Mg) > Iron (Fe) > Zinc (Zn) > Sodium (Na). Consumption of foods high in calcium helps in the development and formation of teeth and bones in the body; it also prevents osteoporosis (Tai *et al.,* 2015; Duan *et al.,* 2018; Oloniyo *et al.,* 2021). Potassium helps to regulate fluid balance, muscle contractions and nerve signals (McDonough and Nguyen, 2015), high-potassium diet may help reduce blood pressure, water retention, protect against stroke, it prevents osteoporosis and kidney stones (Krupp *et al.,* 2018). Magnesium is a cofactor in enzyme systems that help to regulate biochemical (protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation) reactions in the body (Gröber *et al.,* 2015; Rude 2010). It helps in the production of energy, oxidative phosphorylation, and glycolysis (Morais *et al.,* 2017; Rosanoff *et al.,* 2012). Zinc is used for body defense (immune) system and proper functioning of human body (Djoko *et al.,* 2015). It plays a role in cell division, wound healing, cell growth, breakdown of carbohydrates and proper functioning of smell and taste organs (Bonaventura *et al.,* 2015). Iron is an important component of hemoglobin; it is a substance in red blood cells that carries oxygen from the lungs to other parts of the body (Whitfield *et al.,* 2015). Lack of red blood cells is called iron deficiency anemia. Iron (Fe) was an essential nutrient for plants, required for vital processes like respiration and photosynthesis, and playing a fundamental role in electron transfer and reversible redox reactions (Balk and Schaedler, 2014). Phosphorus helps in the formation of strong bones and teeth. It plays an important role in the utilization of carbohydrates, protein and fats in the body. Sodium is an essential electrolyte in the body that helps to maintain and regulate water in cells, stabilize blood pressure levels (Zocchi *et al.,* 2017; Bu *et al.,* 2018). Insufficient sodium in the blood is also known as hyponatremia. High sodium and low potassium intake can increase the risk for heart disease and stroke. (Okayama *et al.,* 2016); low sodium and high potassium could help to control or maintain hypertension and lower the risk of cardiovascular disease and even death (Steffensen *et al.,* 2018).

Table 3. Mineral composition (mg/100g) of the composite sweet potato biscuit

Sample	Ca	K	Mg	Zn	Fe	P	Na	Na/k	Cd	Pb	Cr
OFSPM1	209.55±0.5^{d}	393.05±2.5^{d}	19.93±0.5^{f}	37.03±0.7^{b}	9.99±0.3^{b}	421.04±0.1^{c}	6.83±0.4^{e}	0.02	BDL	BDL	BDL
OFSPM2	238.02±0.8^{c}	451.03±1.4^{a}	30.19±0.3^{a}	42.53±0.6^{aa}	10.63±0.7^{a}	518.12±0.3^{b}	7.19±0.4^{d}	0.02	BDL	BDL	BDL
OFSPM4	164.23±0.5^{i}	312.93±0.5^{g}	13.05±2.5^{l}	26.83±0.4^{g}	5.92±0.3^{j}	324.01±0.7^{h}	6.04±0.1^{g}	0.02	BDL	BDL	BDL
OFSPM5	169.19±0.5^{g}	309.42±0.5^{h}	15.27±2.5^{j}	23.26±0.4^{i}	7.15±0.3^{h}	317.03±0.7^{i}	5.22±0.1^{j}	0.02	BDL	BDL	BDL
OFSPM6	244.36±0.5^{b}	319.18±0.5^{e}	13.13±2.5^{k}	26.11±0.4^{h}	8.33±0.3^{g}	330.88±0.7^{f}	5.84±0.1^{i}	0.02	BDL	BDL	BDL
OFSPM7	169.11±0.5^{h}	289.02±0.5^{i}	16.84±2.5^{h}	28.20±0.4^{e}	4.61±0.3^{l}	338.35±0.7^{e}	5.91±0.1^{h}	0.02	BDL	BDL	BDL
OFSPK2	187.33±0.2^{e}	394.06±1.7^{c}	27.02±0.2^{b}	31.25±0.4^{d}	9.36±0.6^{e}	620.21±1.8^{a}	6.61±1.2^{f}	0.02	BDL	BDL	BDL
OFSPK3	170.61±0.5^{f}	313.19±0.5^{f}	23.15±2.5^{d}	22.01±0.4^{j}	8.44±0.3^{f}	329.23±0.7^{g}	4.48±0.1^{l}	0.01	BDL	BDL	BDL
OFSPK6	301.45±0.5^{a}	425.22±0.5^{b}	23.21±2.5^{c}	28.81±0.4^{d}	9.82±0.3^{c}	379.95±0.7^{d}	5.04±0.1^{k}	0.01	BDL	BDL	BDL
CFSP2	118.05±1.8^{j}	204.95±0.3^{k}	20.71±0.2^{e}	27.06±0.2^{f}	6.74±0.8^{i}	313.18±0.4^{j}	7.83±0.4^{b}	0.04	BDL	BDL	BDL
CFSP6	109.64±0.5^{k}	219.62±0.5^{j}	18.42±2.5^{g}	15.24±0.4^{l}	5.67±0.3^{k}	217.73±0.7^{k}	8.±01.1^{a}	0.04	BDL	BDL	BDL
WHT	101.75±1.6^{l}	186.37±1.6^{l}	15.37±0.1^{i}	20.62±0.4^{k}	9.55±0.8^{d}	101.04±1.2^{l}	7.26±0.9^{c}	0.04	BDL	BDL	BDL
FAO and USDA Limits (mg/day)	19-881	19-502	4.5-452	0.23-2.1	1-5.6		30-134	<1			

Values are averages of triplicate readings (mean ±standard deviation). Means within a column followed by different superscripts letter(s) are significantly differences ($p \leq 0.05$). WHT- control. OFSPM- mother's delight orange-fleshed sweet potato, OFSPK- king J orange - fleshed sweet potato, CFSP- cream-fleshed sweet potato.

Antinutritional properties of sweet potato composite biscuit

The antinutritional properties of sweet potato composite biscuit are presented in Table 4. Phytate content of the composite sweet potato biscuit ranged from 0.42 to 0.93 mg/100g, the highest phytate value was observed in OFSPM2 (0.93 mg/100g) while WHT (0.42 mg/100g) had the least value of phytate. Phytate forms complexes with protein at low and high pH and causes indigestion of food and flatulence (Adeola and Ohizua, 2018). The results agrees with the report of Okpala and Okoli (2011) who reported low phytic acid for cookies produced from pigeon pea, cocoyam, and sorghum flour blends to fall between the range of 0.56 and 0.70 mg/100g.

The oxalate content of the composite sweet potato biscuit ranged from 0.61 to 2.36 mg/100g, the highest oxalate value was observed in OFSPM2 (2.36 mg/100g) while WHT (0.61 mg/100g) had the least value of oxalate. The low values of oxalate obtained in the study may be of great health benefits as reported by Kaushal *et al.* (2012) that low values of oxalate have been linked to reduction in blood cholesterol. Oxalate was also known to form complexes with most essential trace elements including calcium thereby making them unavailable for enzymatic activities and other metabolic activities (Prashanth *et al.,* 2015). Consumption of large dose of oxalic acid has being linked to gastroenteritis, shock, convulsion, kidney stones and renal damage (Sinha and Khare, 2017). Oxalates cannot be seen, tasted or smelled in a food (Sinha and Khare, 2017).

The tannin content of the composite sweet potato biscuit ranged from 0.19 to 1.70 mg/100g, the highest tannin value was observed in OFSPM5 (1.70 mg/100g) while CFSP6 (0.19 mg/100g) had the least value of tannin. The low tannin content is desirable as tannin forms insoluble complexes with proteins to decrease the digestibility of proteins (Uzoechina, 2007). Tannins aggravate the astringent taste in the mouth and decrease food palatability, cause damage to intestinal tract and enhance carcinogenesis (Roland *et al.,* 2017).

The saponin content of the composite sweet potato biscuit ranged from 0.46 to 1.44 mg/100g, the highest saponin value was observed in OFSPM5 (1.44 mg/100g) while CFSP6 (0.46 mg/100g) had the least value of saponin. Sinha and Khare (2017) define saponin as water-soluble plant constituents, which can form soapy foam even at low concentrations. They are glycosides with a non-sugar aglycone portion which was termed a sapogenin. Saponins are distinguished by their bitter taste and ability to haemolyse red blood cells.

The alkaloids content of the composite sweet potato biscuit ranged from 1.20 to1.74 mg/100g. The highest alkaloids value was observed in both OFSPK6 and OFSPK6 with 1.7 mg/100g while WHT (1.20 mg/100g) had the least value of alkaloid. Alkaloids are the bitter components of plants found widely in nature and frequently have pharmacological properties (Banerjee *et al.,* 2018). It acts as plant metabolites often basic nitrogen–containing compounds able to form salts with acid (Stevenson *et al.,* 2017). Solanine is an alkaloid present in small amounts in potatoes. It is considered to be anti-nutrients because of their action on the nervous system, disrupting or inappropriately augmenting electrochemical transmission. Alkaloids such as glycoalkaloids, solanine and chaconine present in potato and *Solanum* spp. (Umemoto *et al.*, 2016) are haemolytically active and toxic to fungi and humans. Some plant alkaloids are reported to cause infertility (Olayemi, 2010).

The trypsin inhibitor content of the composite sweet potato biscuit ranged from 6.32 to 21.09 mg/100g. The highest trypsin inhibitor value was observed in OFSPK2 (21.09 mg/100g) while OFSPM6 (6.32 mg/100g) had the least value of trypsin inhibitor. The high values of trypsin observed could be as a result of the addition of soy concentrate flour into composite flour for the biscuit production This was in agreement with the report of Silky and Tiwari, (2014) that legumes are rich in trypsin inhibitors. It was generally observed in this study that the antinutritional content of the biscuits was not too high and it falls within the tolerable levels.

There was a significant ($p \leq 0.05$) difference in the phytate, oxalate, tannin, Saponin, alkaloids and trypsin inhibitor contents of the biscuit samples. Inyang and Ekop (2015) reported that tannins are

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antioxidant (polyhydric phenols) which are present in virtually all parts of plants and have been found to inhibit trypsin, chymotrypsin, amylase, and lipase activities. Antinutrients are substances that reduce the nutritional values of food by reducing the bioavailability, digestibility and utilization of nutrients (Tadele, 2015).

Table 4. Antinutritional properties (mg/100g) of sweet potato composite biscuit

SAMPLES	Phytate	Oxalate	Tannin	Saponin	Alkaloids	Trypsin Inhibitor (mg/g)
OFSPM1	0.77±0.5^{d}	2.09 ± 0.3^{h}	1.63±0.4^{b}	1.22±0.6^{e}	1.24±0.3^{g}	15.31±0.1^{g}
OFSPM2	0.93±0.1^{a}	2.36± 0.1^{b}	1.52±0.1^{e}	1.18±0.2^{f}	1.60±0.9^{c}	20.16±0.3^{b}
OFSPM4	0.52±0.1^{i}	1.33±0.1^{a}	1.55±0.1^{d}	1.32±0.1^{c}	1.27±0.1^{f}	11.62±0.1^{i}
OFSPM5	0.61±0.1^{g}	2.49±0.1^{a}	1.70±0.1^{a}	1.44±0.1^{a}	0.83±0.1^{k}	10.84±0.1^{j}
OFSPM6	0.64±0.1^{f}	2.26±0.1^{j}	1.63±0.1^{b}	0.93±0.1^{h}	1.00±0.1^{j}	6.32±0.1^{l}
OFSPM7	0.78±0.5^{d}	2.21±0.1^{f}	1.56±0.1^{c}	1.29±0.1^{d}	1.05±0.1^{i}	7.94±0.1^{k}
OFSPK2	0.79±0.7^{c}	2.30 ± 0.9^{c}	0.34±0.2^{g}	0.93±0.8^{k}	1.71±0.4^{b}	21.09±0.1^{a}
OFSPK3	0.77±0.5^{d}	1.62±0.1^{i}	0.29±0.1^{i}	1.4±0.1^{b}	1.74±0.1^{a}	15.63±0.1^{f}
OFSPK6	0.84±0.1^{b}	2.11±0.1^{g}	0.31±0.1^{h}	0.89±0.1^{i}	1.74±0.1^{a}	20.09±0.1^{c}
CFSP2	0.73±0.2^{e}	2.29 ± 0.6^{d}	0.21±0.6^{j}	0.68±0.7^{j}	1.30±0.4^{e}	20.01±0.8^{d}
CFSP6	0.59±0.1^{h}	1.20±0.1^{k}	0.19±0.1^{k}	0.46±0.1^{k}	1.59±0.1^{d}	14.80±0.1^{h}
WHT	0.42±0.3^{j}	0.61 ± 0.3^{l}	0.64±0.1^{f}	0.99±0.8^{g}	1.20±0.5^{h}	15.72±0.3^{e}
Standard	≤ 450	≤50				

Values are averages of triplicate readings (mean ±standard deviation). Means within a column followed by different superscripts letter(s) are significantly differences ($p \leq 0.05$). WHT- control. OFSPM- mother's delight orange-fleshed sweet potato, OFSPK- king J orange - fleshed sweet potato, CFSP- cream-fleshed sweet potato.

Molar ratios composition of sweet potato composite biscuits

The molar ratio between phytate and divalent cations (Calcium (Ca), Iron (Fe) and Zinc (Zn)) of sweet potato composite biscuits were presented in Table 5. The phytate-calcium ratio (Phy: Ca) ranged from 0.0002 to 0.004, phytate-zinc ratio (Phy: Zn) ranged from 0.0019 to 0.0038 and phytate-iron ratio (Phy: Fe) ranged from 0.0037 to 0.0144. It was observed that the molar ratios of the biscuit samples were below the critical limits (Phy: Ca > 1.56, Phy: Fe > 14 and Phy: Zn > 10) as reported by Haile and Getahun (2018). This implies that the bioavailability of Ca, Fe and Zn are not inhibited by the concentration of phytate in the sweet potato composite biscuit. This is an indication that all the Ca, Fe and Zn in the varieties of sweet potato will be adequately metabolized by the body when digested. Bioavailability is the ability of the body to digest and absorb minerals in a food sample (Padhan *et al.,* 2018). Also, this indicates that absorption of Ca, Fe and Zn were not adversely affected by phytate in the sweet potato composite biscuit examined. The result obtained agrees with the report of Dako *et al.* (2016).

Phytic acid destroys the absorption of minerals (Zn, Ca and Fe) in the body and it can be reduced by food processing such as boiling, germination and fermentation. The molar ratio between phytate and divalent cations indicates the impact of phytate on the bioavailability of dietary minerals (Tiruneh *et al.,* 2018).

Table 5. Molar ratios composition of sweet potato composite biscuit

SAMPLES	Phytate : Ca	Phytate : Zn	Phytate : Fe
OFSPM1	0.0002	0.0020	0.0065
OFSPM2	0.0002	0.0022	0.0074
OFSPM4	0.0002	0.0019	0.0075
OFSPM5	0.0002	0.0026	0.0072
OFSPM6	0.0002	0.0024	0.0065
OFSPM7	0.0003	0.0027	0.0144
OFSPK2	0.0003	0.0025	0.0072
OFSPK3	0.0003	0.0034	0.0077
OFSPK6	0.0002	0.0029	0.0073
CFSP2	0.0004	0.0027	0.0092
CFSP6	0.0003	0.0038	0.0088
WHT	0.0003	0.0020	0.0037
CL	>1.56	>10	>14

OFSPM1-SP: SC: DP: PS- 70:06:10:14, OFSPM2- SP:SC:DP:PS- 56:20:10:14, OFSPM4-SP: SC: DP: PS- 67:10:10:14, OFSPM5-SP:SC:DP:PS- 63:13:10:14, OFSPM6-SP: SC: DP: PS- 61:15:10:14, OFSPM7- SP:SC:DP:PS- 65:11:10:14, OFSPK2- SP:SB:DP:PS-56:20:10:14, CFSP2 - SP:SB:DP:PS- 56:20:10:14, WHT- control. OFSPM- mother's delight orange-fleshed sweet potato, OFSPK- king J orange - fleshed sweet potato, CFSP- cream-fleshed sweet potato, CL- Critical limits, Ca- Calcium, Zn – Zinc, Fe - Iron

Sensory properties of sweet potato composite biscuit

The sensory attributes of the biscuit samples scored are presented in Table 6. The biscuit samples varied significantly ($p \leq 0.05$) in terms of aroma, appearance, crunchiness, taste and overall acceptability. Aroma scores ranged from 4.65 to 5.73, OFSPM1 (4.65) biscuit had the least aroma while WHT (5.73) has the highest value of aroma. The appearance of the biscuit ranged from 6.14 to 8.34, WHT (6.14) biscuit had the least appearance while OFSPM2 (8.34) has the highest value of appearance. Crunchiness scores ranged from 3.12 to 7.11, OFSPM5 (3.12) biscuit had the least Crunchiness while WHT (7.11) has the highest value of Crunchiness. Taste ranged from 3.47 to 8.35, WHT (3.47) biscuit had the least taste while CFSP2 (8.35) has the highest value of taste. The overall acceptance ranged from 3.70 to 7.50, OFSPM2 (3.70) biscuit had the least overall acceptance while OFSPK2 (7.50) has the highest value of overall acceptance. The obtained results agreed with the report of Adeola and Ohizua (2018). Taste was an important attribute in the acceptance of food product. This finding confirms the report by Preedy *et al*. (2011) that sweet potato flour adds natural sweetness (taste) to processed foods. KJP biscuit was compared favourably with the control sample.

Table 6. Sensory properties of sweet potato composite biscuit

Samples	Aroma	Appearance	Crunchiness	Taste	Overall acceptability
OFSPM1	4.65 ± 0.1^{j}	8.05 ± 0.8^{c}	4.95 ± 0.2^{g}	7.74 ± 0.1^{g}	4.00 ± 0.1^{g}
OFSPM2	5.63 ± 0.4^{c}	8.34 ± 0.3^{a}	4.15 ± 0.1^{h}	7.80 ± 0.1^{e}	3.70 ± 0.1^{i}
OFSPM4	5.24 ± 0.1^{e}	8.00 ± 0.1^{e}	3.86 ± 0.1^{j}	7.85 ± 0.1^{c}	4.05 ± 0.1^{f}
OFSPM5	5.61 ± 0.1^{d}	7.96 ± 0.1^{f}	3.12 ± 0.1^{l}	7.82 ± 0.1^{d}	3.97 ± 0.1^{h}
OFSPM6	4.95 ± 0.1^{i}	8.03 ± 0.1^{d}	4.00 ± 0.1^{i}	7.80 ± 0.1^{e}	4.00 ± 0.1^{g}
OFSPM7	5.03 ± 0.1^{g}	8.11 ± 0.1^{b}	3.46 ± 0.1^{k}	7.80 ± 0.1^{e}	4.00 ± 0.1^{g}
OFSPK2	5.00 ± 0.3^{h}	7.70 ± 0.8^{g}	6.60 ± 0.6^{d}	7.75 ± 0.1^{f}	7.50 ± 0.2^{a}
OFSPK3	5.03 ± 0.1^{g}	7.00 ± 0.1^{j}	6.39 ± 0.1^{e}	7.43 ± 0.1^{h}	7.25 ± 0.1^{c}
OFSPK6	5.69 ± 0.1^{b}	7.50 ± 0.1^{h}	6.00 ± 0.1^{f}	7.00 ± 0.1^{i}	7.30 ± 0.1^{b}
CFSP2	5.03 ± 0.1^{g}	7.70 ± 0.1^{g}	6.65 ± 0.1^{c}	8.35 ± 0.1^{a}	4.01 ± 0.1^{g}
CFSP6	5.11 ± 0.1^{f}	7.46 ± 0.1^{i}	6.78 ± 0.1^{b}	8.00 ± 0.1^{b}	4.32 ± 0.1^{e}
WHT	5.73 ± 0.9^{a}	6.14 ± 0.1^{k}	7.11 ± 0.1^{a}	3.47 ± 0.3^{j}	7.20 ± 0.4^{d}

Values are averages of triplicate readings (mean ±standard deviation). Means within a column followed by different superscripts letter(s) are significantly differences ($p \leq 0.05$). OFSPM1-SP: SC: DP: PS- 70:06:10:14, OFSPM2- SP:SC:DP:PS- 56:20:10:14, OFSPM4-SP: SC: DP: PS- 67:10:10:14, OFSPM5- SP:SC:DP:PS- 63:13:10:14, OFSPM6-SP: SC: DP: PS- 61:15:10:14, OFSPM7- SP:SC:DP:PS- 65:11:10:14, OFSPK2- SP:SB:DP:PS- 56:20:10:14, CFSP2 - SP:SB:DP:PS- 56:20:10:14, WHT- control. OFSPM- mother's delight orange-fleshed sweet potato, OFSPK- king J orange - fleshed sweet potato, CFSP- cream-fleshed sweet potato.

Conclusion

This study has shown that the nutritional composition of a biscuit developed from composite orange fleshed sweet potato is of great value in terms of proximate, minerals, carotenoid and antinutrient properties rich enough to be called a super snack rich in micronutrients to alleviate micronutrient deficiency. Biscuits developed from OFSPK2 composite flour had the highest carotenoid, protein, mineral content among other samples examined, hence it is a promising staple food to fight against micronutrient deficiency. Also, the sensory evaluation showed that OFSPK2 biscuits scored high value in the overall acceptability compared to the control sample.

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Measurement of Growth Rate of Rice (*Oryza sativa*) Seedlings under Gravity and Simulated Microgravity Conditions

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Abstract

Onboard spaceflight microgravity experiments are expensive and scarce. One of the simulated-microgravity instruments–Clinostat was used as ground-based research to investigate the shoot-morphology of rice seedlings. Plant shoot-morphology is important for gravi-responses. Rice seeds were soaked overnight and afterwards planted into different petri-dishes using plant-substrate called agar-agar in a wet-chamber in vertical-positions. The following conditions were maintained throughout the experiment: humidity between 85%, temperature of 25^{o}C and light of 100lx. After 3 days of germination under normal earth gravity, the petri-dishes were labeled "gravity-treated" and "microgravity-treated". The gravity-treated sample in vertical position was left under normal earth gravity to serve as the control experiment. The microgravity-treated sample was mounted on clinostat with the following additional conditions: fast rotation-speed of 90 rpm, rotational-axis angle of 90^{o} and rotation-direction was clockwise. The photos of the 2 samples were taken every one hour. These observations were made for 4 hours. After observations, the shoot-morphology of the seedlings were studied using specialized-software called ImageJ to measure the shoots-lengths from the two sets of pictures taken. The grand average shoot-lengths of the seeds per hour were calculated to give the growth-rates. The results showed an increased growth-rate per hour for the microgravity-treated than the gravity-treated control. The growth-rates of the gravity-treated were 0.09 cm/hr while the microgravity-treated was 0.13 cm/hr. These results serve as preparation for future-space experiments on rice and further research is needed as to ascertain the nutritional composition.

Keywords: Clinostat; Gravity; Growth rate; Microgravity; Rice.

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Introduction

Plants have been proposed as the basis for a biological life support system that could be used alone or in concert with physical/chemical life support systems to provide food, purification of the atmosphere and regeneration of water for crew members that are on long duration space flight missions (Hu *et al*., 2010). Microgravity is an experience in the outer-space where the gravitational pull is very low. It is a state of weightlessness, and it literally means very little gravity (Afolayan *et al*., 2019). Microgravity therefore is active in spaceflight. Microgravity, as a unique environment has been proved to affect the growth and development of plant (Sack, 1997; Medina, 2010). Therefore, it is of great interest to study the influence of microgravity on plant growth and development. Biological experiments under real microgravity conditions can be done in sounding rockets, parabolic flights or aboard spaceflight (Oluwafemi, 2022; Oluwafemi and Neduncheran, 2022), but the high costs of missions and the little opportunities available tend to slow down the pace at which result is achieved. In order to prepare and support space experiments on earth, simulation of microgravity in plant experiments is usually employed using clinorotation technique (Oluwafemi and Olubiyi, 2019). A clinostat is one of the instruments developed for this purpose. It is an experimental device used to eliminate the effect of gravity (Oluwafemi *et al*., 2018); a ground-based simulator of microgravity. Two-dimensional (2-D) and three-dimensional (3-D) clinostats are worthy tools to study gravity related processes where plants are rotated at low angular speeds, with the aim to disorient them similar to what happen under real microgravity (Kraft *et al*., 2000). For *in vitro* and seedling studies, clinorotation has been widely used (Paolicchi *et al*., 2002; Aronne *et al*., 2003).

There is usually growth enhancement under microgravity which have underlying mechanism in physiology that: shoot cortical cells replicate at a better rate than under normal earth's gravity; there could also be an enhanced cell cycle that might have helped plant growth hormones (e.g. auxins); and microgravity environ interrupts normal carbohydrate metabolism affecting the shoot cell structure and increasing plant cellular metabolism generally (Howard, 2010; Ferl and Paul, 2016).

In this relation as light is a chemical energy used in plant for metabolism; microgravity can speed-up light's use to make ATP and NADPH to enhance elongation. In the Calvin Cycle (chemical reactions that occur during photosynthesis, in the chloroplasts) NADPH is a reducing agent as it reduces atmospheric carbon dioxide to produce monosaccharides for the availability of energy for plant and for plant's structure (Yahia *et al*., 2019). This can be assumed as another reason for growth enhancement under microgravity than under gravity.

Due to the effect of microgravity on cells' structure, the growth direction of plants shoots and roots under microgravity are unregulated; this makes it important to study growth orientation of plants under microgravity (Takahashi, 2003).

Rice (*Oryza sativa*) is one of the commonest and important staple food in the world. It is cultivated in a wide range of environments and under varying climatic conditions. It has a fast growth which makes it good for clinorotation on the clinostat; as the seeds are small and easy to handle.

The aims of this study were to understand the impact of gravity on rice seedlings growth; and to determine what their growth orientation will be under microgravity.

Materials and methods

Experimental design

The proceduress necessary for preparing plant experiment using the Clinostat include: preparation of the plant agar-agar in petri dishes and planting of seeds into it (these are the experimental samples); cultivation of the samples inside a wet chamber; placement of the samples on the Clinostat (source of simulated microgravity) under possible experimental variables of humidity, temperature and light while on the Clinostat, rotation speed, rotational-axis angle and rotation-direction are the specific experimental variables. At the end, the application of the possible methods for getting results with a further analysis of observed graviresponses to compare the effect of simulated microgravity on grown seedling shoots of plants to those under gravity response; these can involve making observations during the experiments on the samples using observational and measurement tools (e.g. imageJ).

Methods

Rice seeds were obtained from a local market in Abuja, Nigeria and only one variety of this local seeds of rice were used in this experiment. Rice was used for this experiment because it is small, easy to handle and fast-growing with germination time of 3 days. The clinostat that was used for this research is a two dimensional (2-D) clinostat with a control box. It has a single rotational axis (i.e. one-axis desk-top type clinostat) which runs perpendicular to the direction of the gravity vector. It operates with respect to speed and direction of the rotation. This clinostat is manufactured by Advanced Engineering Services., Co. Ltd. Model UN-KTM2 REV. NC. 2012.11) (Figure 2). The rotational speed ranges from 0-90; rotational direction is either clockwise or anticlockwise; rotational axis angle could be set from 0° (parallel to the ground) to 90° (perpendicular to the ground); while the experimental conditions are that it has maximum diameter of a sample container of 10 cm and maximum weight of sample allowed to be 500 g.

The existence of thick seed coat hinders germination ability. Therefore, pre-soaking of the rice seeds in water was employed (Lumen, 2020) for seedlings to emerge. Rice seeds were soaked in tap water overnight (about 16 hours) to soften the seeds as the seeds have thick coats. Plant agar-agar was prepared into 2 petri-dishes following the standard preparation method by United Nations (2013); and Oluwafemi and Ibraheem (2021). Nine rice seeds were planted inside each petri-dish that contained the plant agar-agar (Fig. 1). Afterwards, the filled petri-dishes with agar-agar and rice were put inside a wet chamber in vertical position, since gravity acts vertically. The wet chamber used was prepared in a plastic box with a size of about 40 cm x 40 cm x 40 cm whereby 5 liters of water was put into it. Germination of the seeds was observed after 3 days and growth of short shoots after 7 days. The 2 petri-dishes were then taken and labeled “gravity-treated” and “microgravity-treated”. The gravity-treated sample was maintained in the vertical position in the wet chamber. The microgravity-treated sample was then placed at the center of the clinostat using double-sided tape (this was after 7 days) (Fig. 2). At an hour interval, the pictures of the 2 petri-dishes were taken.

Observation was done for 4 hours under the following conditions – humidity of 85%, temperature of 25ºC and light of 100 lux. In addition to these, the microgravity-treated sample had rotation speed of 90 rpm, sample stage was set to the horizontal position and the direction of rotation was clockwise. At the end of observation, analysis of growth rate was carried out, and the shoot emergence percentage and shoot emergence index were also determined.

The growth rate of the shoots was determined by measuring the length of the shoots and analysing the difference between the two cases. The length of the shoots was measured using the length measurement tool of the ImageJ software as applied on the images obtained. Shoot emergence index is a measure of the percentage and speed at which the shoots emerged under the two varying conditions of gravity and microgravity. The pictures of the two samples are shown in Fig. 3.

Figure 1. Petri-dishes with rice seeds and plant substrate (agar-agar)

Figure 2. Experimental set-up for clinostat use

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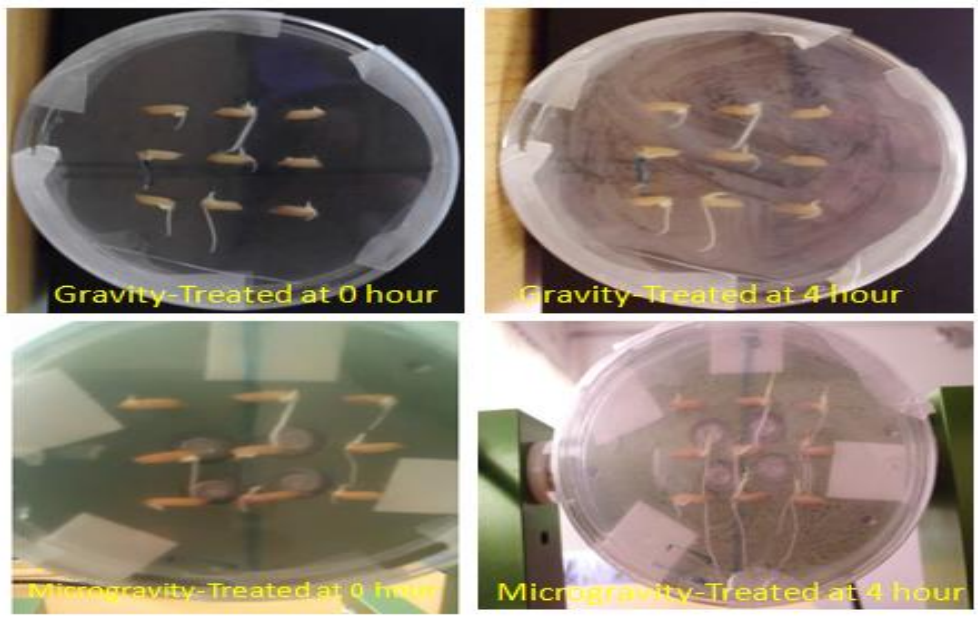

Figure 3. Gravity-treated and the microgravity-treated samples

Results

The pictures of the gravity-treated and microgravity-treated shoots were used for the data analysis. Fig. 4 shows lengths of the gravity-treated and microgravity-treated shoots versus the time. The graph was plotted using the average values of the length of the 9 seeds planted into each petri-dish. The average growth rate of the shoots was calculated in centimetres/hour [(cm/h) by dividing 0.3611 cm by 4 hours; and 0.5106cm by 4 hours i.e. the growth rate was calculated by dividing the grand average values by the observation time of 4 hours] for the gravity-treated and microgravity-treated shoots. The average growth rate of the shoots for the gravity-treated was 0.09 cm/h while that of the microgravity-treated was 0.13 cm/h. Tabulated for the gravity and microgravity experiments are also their shoot emergence percentage and shoot emergence index (Table 1).

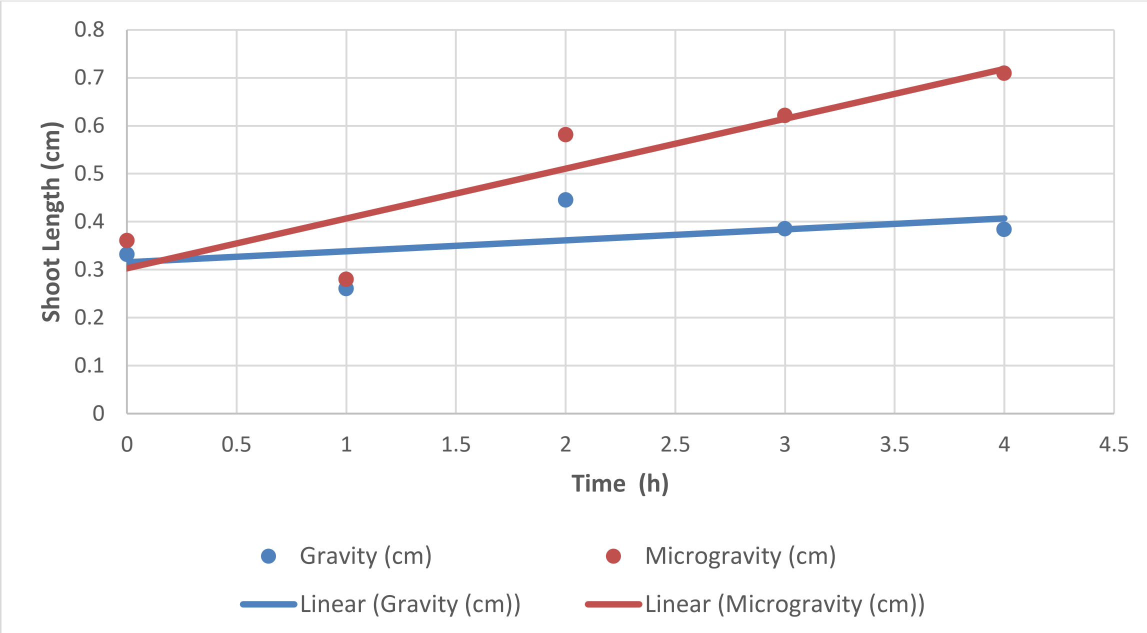

Figure 4. Graph of the shoot length against the observation time

Table 1. Shoot emergence percentage and shoot emergence index of the experimental samples

Sample	Shoot Emergence Percentage (%)	Shoot Emergence Index
Gravity-treated	70.78	19.45
Microgravity-treated	100.00	25.00

Discussion

The photos of the gravity-treated sample showed that the shoots continuously grew vertically as stimulated by the earth's gravity but nothing stimulated the direction of the microgravity-treated shoots growth (i.e. the growth direction under microgravity are unregulated); this is the expected growth orientation of the gravity-treated and the microgravity-treated shoots (Takahashi, 2003; United Nations, 2013).

The average growth rate of the shoots for the gravity-treated sample was 0.09 cm/h while that of the microgravity-treated sample was 0.13 cm/h, which means there was an increased growth rate of the rice seedling shoot under simulated-microgravity by 44.44%. More so, the shoot emergence index of the microgravity sample is also obviously higher than the gravity sample. This result is in-line with Howard (2010) suggesting that there are changes in plant cellular metabolism under microgravity that leads to increased proliferation and enhanced growth. According to Yahia *et al* (2019), there is the production of more monosaccharides under microgravity than under gravity; this further buttresses the better elongation of the shoot under microgravity than under gravity.

Conclusion

Microgravity environment has a great impact on plant growth and development, and this eventually affects plant yield. It is also evident that nutrient is essential for growth; as growth in this context, is an increase in size and mass. The better shoot growth rate under microgravity than under gravity that is observed in this experiment suggests possible increase in nutritional content. The nutritional content will be determined in the further work through proximate analysis. In the further work, the seedlings samples can be taken to the field (for vegetation) and grown till harvest time to determine if the better growth rate is sustained by the microgravity-treated sample. This may allow for the recommendation of pre-treatment of seedlings with microgravity before transplanting to the field to give a better result. This experiment also serves as a contributory role of space technology to agriculture. Therefore, the microgravity environment is an ideal environment to study specific mechanisms of gravity-dependent growth in the development of plants. These mechanisms include gravitropism and circmnutation of different species.

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Competing interests
There are no competing interests among authors.

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