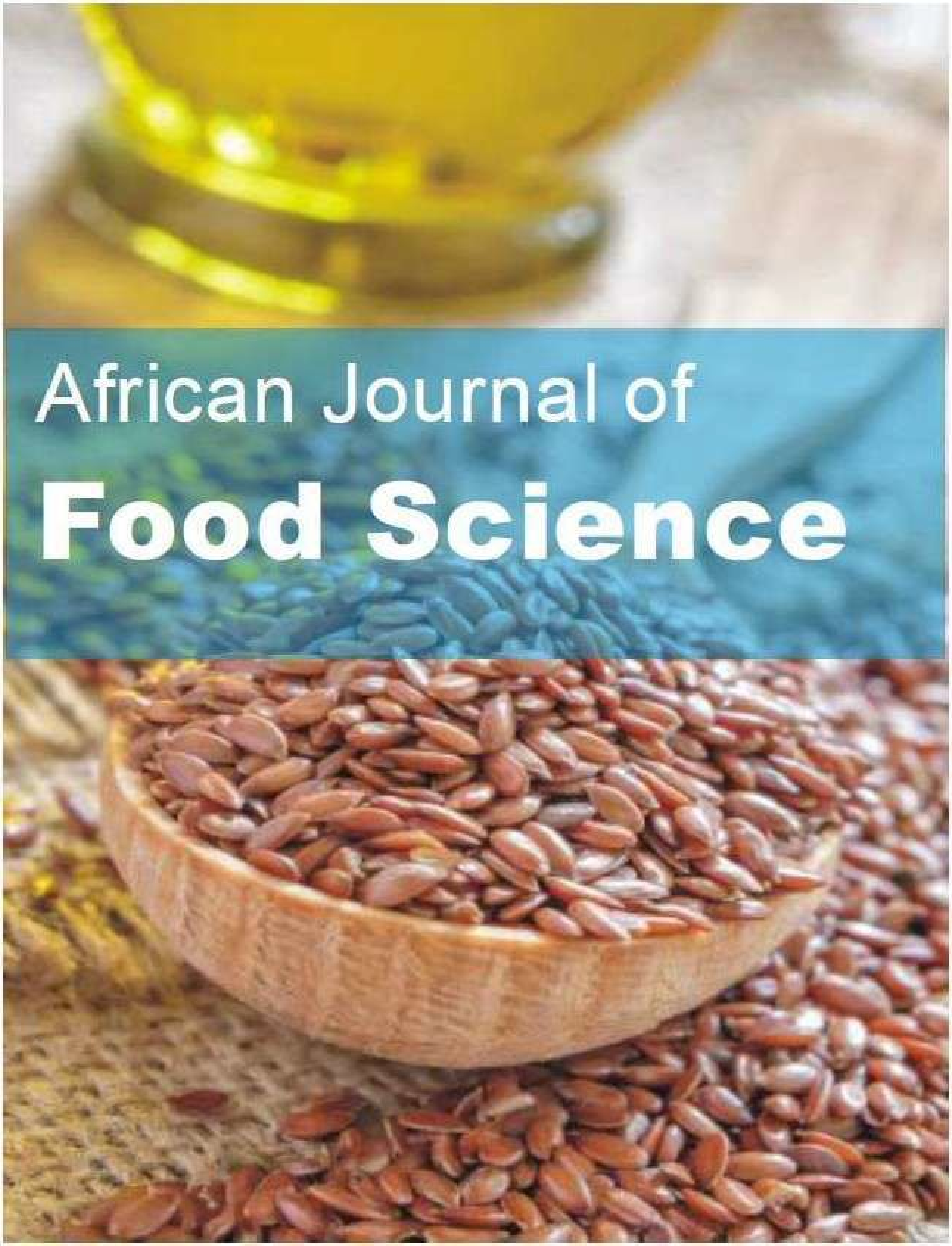
OPENACCISS



June 2023
ISSN 1996-0794
DOI: 10.5897/AJFS
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJFS

The African Journal of Food Science (AJFS) is a peer reviewed open access journal. The journal commenced publication in September 2007. The African Journal of Food Science welcomes for publication papers that investigate and review perspectives on food engineering, handling, processing, storage, preservation, contamination and packaging; sensory analysis. Other aspects covered include food safety, microbiology, nutraceuticals, chemistry, technology and nanotechnology in addition to quality and nutritional evaluation and genetic variation of food.

Indexing

Abstracts on Hygiene and Communicable Diseases, AgBiotechNet, Agricultural Economics Database, Agricultural Engineering Abstracts, Agroforestry Abstracts, Animal Breeding Abstracts, Animal Production Database, Animal Science, Biofuels Abstracts, Botanical Pesticides, CAB Abstracts, CABI's Global Health Database, Chemical Abstracts (CAS Source Index), CNKI Scholar Crop Physiology Abstracts, Crop Science Database, Dairy Science Abstracts, Environmental Impact Environmental Science Database, Field Crop Abstracts, Forest Science, Google Scholar, Grasslands and Forage Abstracts, Horticultural Science, Horticultural Science Abstracts, Irrigation and Drainage Abstracts, Maize Abstracts, Microsoft Academic, Nutrition Abstracts and Reviews Series A: Human and Experimental, Nutrition Abstracts and Reviews Series B: Livestock Feeds and Feeding, Nutrition and Food Sciences, Ornamental Horticulture, Parasitology Database, Plant Breeding Abstracts, Plant Genetic Resources Abstracts, Plant Genetics and Breeding Database Plant Growth Regulator Abstracts, Plant Protection Database, Potato Abstracts, Poultry Abstracts Rice Abstracts, Rural Development Abstracts, Seed Abstracts, Soil Science Database, Soils and Fertilizers Abstracts, Soybean Abstracts, Sugar Industry Abstracts, Tropical Diseases Bulletin Veterinary Bulletin, Veterinary Science Database, VetMed Resource, Weed Abstracts Wheat, Barley and Triticale Abstracts, World Agricultural Economics and Rural Sociology Abstracts

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Food Science is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Digital Archiving Policy

The African Journal of Food Science is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.

https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The African Journal of Food Science encourages metadata harvesting of all its content. The journal fully supports and implement the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF).
The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajfs@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJFS

Submit manuscript online http://ms.academicjournals.org

Academic Journals
73023 Victoria Island, Lagos, Nigeria
ICEA Building, 17th Floor,
Kenyatta Avenue, Nairobi, Kenya.

Editors

Editorial Board Members

Table of Content

Vol. 17(6) pp. 102-110, June 2023
DOI: 10.5897/AJFS2023.2247
Article Number: 5B428E970725
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

ACADEMIC JOURNALS
expand your knowledge

African Journal of Food Science

Full Length Research Paper

Higher amounts of proximate and minerals in composite biscuit made from African locust beans pulp

Jacob Setorglo[1]*, Matilda Lenia[2] and Christiana Nsiah-Asamoah[3]

[1]Department of Medical Biochemistry, School of Medical Sciences, College of Health and Allied Sciences, University of Cape Coast, Cape Coast, Ghana.
[2]Department of Vocational and Technical Education, School of Educational Foundations, College of Education Studies, University of Cape Coast, Cape Coast, Ghana.
[3]Department of Clinical Nutrition and Dietetics, School of Allied Health Sciences, College of Health and Allied Sciences, University of Cape Coast, Cape Coast, Ghana.

Received 18 January, 2023; Accepted 18 April, 2023

Food insecurity (FI) is still endemic in most parts of Low and Middle Income Countries (LMICs), including Ghana. This study was a quasi-experimental design carried out in the Wa Municipality. We assessed the proximate and minerals in African locust fruit pulp (*Parkia biglobosa*) and biscuits made from composite flours. We also did sensory evaluation on the formulated biscuits. We also assessed the acceptability of biscuits manufactured. We performed proximate analysis and used two treatments: control sample, wheat flour (WF) and ALFPF at 100, 75, 25, and 0%. A total of 100 respondents randomly selected, sensory evaluate the products based on appearance, texture, scent, taste, and acceptability, based on a nine-point hedonic scale questionnaire. Generally, the mineral and nutrient quantities were higher in the composite biscuit compared to the control except for fat and oil. Protein, fibre, carbohydrate content was statistically significantly (p < 0.001) higher for the sample with 25% flour and 75% ALFPF compared to the control and 50/50 and 75/25. Probably, this consumption can improve food insecurity and the consumption of this can improve food insecurity, hidden hunger levels among the population.

Key words: *Parkia biglobosa*, African locust bean, proximate, minerals, Wa municipality, Ghana.

INTRODUCTION

Hunger and malnutrition persist in many parts of Ghana, especially the zone of influence which is made up of the regions in the northern part. About 18% of the food insecure live in the Upper East region; in the Northern region it is 17%; and in the Ashanti region it was found to be 13%. Nationally, Upper East region records 49% food insecurity and this is the highest prevalence in the country (CFSVA Ghana, 2020). Stunting is endemic in the Northern egion (where approximately 33% of children are short-for-their-age) (GSS, GHS and ICF, 2015). There have been many calls for the use of biodiversity as a means to reduce FI and improve nutritional status (Burlingame et al., 2012; Charrondière et al., 2013; Chhikara et al., 2018). Although, the African locust bean tree (*Parkia biglobosa*) is perennial, it is is a rich source of plant protein (Quansah et al., 2019). This leguminosae

*Corresponding author. E-mail: Jacob.setorglo@ucc.edu.gh.

Table 1. Proportion of Dankote wheat flour to *Parkia biglobosa* flour (ALFPF) used to produce composite biscuits.

Treatment	Wheat flour (g)	Parkia biglobosa flour (g)
A	100	100
B	125	75
C	75	125
D (Control)	100	0

Source: Authors

is one of Northern Ghana's most popular trees (Zakari et al., 2015). And there is the need to use it in the use of low-cost local commodities (Awogbenja and Ndife, 2012). Essential eatable wild fruits improve health, food security, and income generation (Aworh, 2015; Bvenura and Sivakumar, 2017). Maroyi and Cheikhyoussef urged millions of people worldwide to take advantage of the local available edible fruits (Maroyi and Cheikhyoussef, 2017).

According to Ikhimalo(2019)., the fruits of African locust bean are mostly used as condiment, but it is a legume and its nutrients can be exploited. *P. biglobosa* fruit pulp exploitation is limited, aside from its application in cooking local delicacies (Adeloye and Agboola, 2022) with just a few uses for porridge and fresh meals (Amoa-Awua et al., 2014). The *tree* is available in Northern parts of Ghana (Alrayyes, 2018). The fruits are plucked when it is season and the yellow pulp is sucked and the seed which is high in minerals and nutrients is thrown away (Adeloye and Agboola, 2022). The avenue for exploiting the potential of the beans of the tree by making it part of a meal has not been exploited. Although Ghana is struggling to achieve the Sustainable Development Goal 2 of zero hunger. Although this wild fruit has been available in the Northern section of Ghana, food insecurity and malnutrition is highest there. It is important to harness the potential of this plant as a way of diversifying food consumption to reduce food insecurity and improve nutritional status (Ikhimalo, 2019). Cereal-based products are nutritious and can reduce food insecurity (Alrayyes, 2018). Wild fruits such as African locust beans have the potency of curing multiple disorders because of their rich fiber and antioxidant components (Ajayi et al., 2018; Alissa and Ferns, 2017; Shaheen et al. 2017). Cereal fortification with legumes (Singha and Muthukumarappan, 2018) has proven to be incredibly advantageous since both cereals and beans supplement each other in terms of unobtainable indispensable amino acids (Yu et al., 2016)..

The use of the flour from *P. biglobosa* as composite flour for preparing biscuits remains a warm area in the quest to reduce food security and improve nutritional status in Ghana. Previous studies advocated for increase use of the fruit without formulating any food product. This study determined the levels of proximate and minerals and consumer acceptance of biscuits formulated from African locust bean pulp powder composite through sensory evaluation.

MATERIALS AND METHODS

Study area

The study was conducted at Upper West Region of Ghana specifically, Wa Municipality at the time the fruit was in season. The Wa Municipality is bounded to the south by the Northern Region of Ghana and to the west by the Black Volta. The distance of Wa from the capital city of Ghana, Accra, is about 560 km.

Study design

The quasi-experimental research design is employed since this enables us to determine the physico-chemical characteristics of the study materials.

Sources of raw material

The local raw materials used for the development of the biscuits include ALBFP from dried fruits, fresh eggs, sugar, butter, and milk powder. The ALBFP for the biscuit formulation was obtained from the Upper West Region Wa. The other materials were bought from the super market in Wa.

Formulation of blends

The study adopted a completely randomized design with two treatments made up of commercially available flour made from wheat (Dankote brand) and the flour made from *P. biglobosa*. Table 1 shows the percentages of *P. biglobosa* flour used to replace Dankote brand flour at 100, 75, 25, and 0%. Composite biscuits were made from the formulations according to the method described in Vaclavik et al. (2021).

Preparation of *P. biglobosa* African locust bean fruit pulp flour

The fruit was harvested when it was in season in August-September. Maturity of the fruit was determined through its brownish colour and the sound it makes when the fruit is shaken. The method described by Vaclavik et al. (2021) was used in the formulation of *P. biglobosa* flour. The pods were de-husked manually followed by the removal of seeds from the yellow fruit pulp. The pulp was then desiccated for 9 h at 60°C (Genlab Widnes, Model T1211) to a moisture content of 10% at the research laboratory of School/Faculty of Agriculture and Natural Sciences, University of Cape Coast. The dried fruit was then milled with a hammer mill (Christy Hunt, England), thereafter, we sieved this with a 0.5 mm mesh. This flour was then wrapped in polythene bags and kept at room temperature at the same research laboratory (Stone and Sidel, 2004).

Preparation of the composite biscuit from *P. biglobosa*

This was made using the creaming method (Akubor et al., 2017; Awotedu et al., 2018) with components being margarine, *P. biglobosa* flour, sugar, salt, eggs and milk powder. All ingredients were weighed before use.

Preparation of the composite biscuit

The ingredients for the composite biscuit were mixed kneaded into stiff dough for 10 min. After this, though was careened out on a even surface to a sheet of even breadth of about 0.5 cm. Weighed amounts were then consigned on greased baking salvers, masked, left for about 15 minutes and heated for 20 min at 180°C in an oven. There after, the composite biscuits were then taken out of the oven packaged in an air-tight container after it was allowed to cool.

Sample size and sampling approach for sensory evaluation

As is consistent with the standards of the hedonic method of sensory evaluation, a total of 100 staff and students from the Home Science Department were randomly sampled in Wa Senior High Secondary School with sensory evaluation of the new products.

Proximate analysis of WF and ALBFP

Moisture, ash, protein, dry matter, fats/oils, and fibre contents were determined using AOAC recommended techniques (AOAC, 2019).

Mineral analysis of ALBFP and composite biscuits

The minerals were determined through methods that led to acid oxidation before a complete elemental analysis was carried out. A flame photometer was used to determine the amounts of potassium and sodium in the digested samples. The calculation of the amount of minerals was based on the method described (Ifesan et al., 2017). The calcium and magnesium were determined by the method that involves chelation of the cations with ethylene diaminetetra-acetic acid (EDTA). Amount of mineral was calculated using the procedure of Ifesan et al. (2017), phosphorus was assessed by applying the ascorbic acid procedure by D'souza et al. (2014).

Sensory evaluations

This assessment of the sampled biscuits was performed within 24 h of baking by 100 untrained people from Wa Technical Secondary Senior High School. Samples of the prepared biscuits with varying codes were arranged in a suitable area. Each biscuit was presented on its own plate. Before going on to the next coded biscuit, the assessors were provided with bread which they ate and rinse their mouths with water afterwards. The texture, appearance, acceptability and taste were accessed (Stone and Sidel, 2004). A nine-point hedonic scale was used to rate the parameters for the sensory evaluation. The items were scored as: 1 = liked extremely; 2 = liked very much; 3= liked moderately; 4= liked slightly; 5= liked or disliked, 6 = disliked slightly; 7= disliked very much; 8= disliked moderately; and 9= disliked extremely (Dahouenon-Ahoussi et al., 2012).

Statistical analysis

One way analysis of variance (ANOVA) was used to analyse the data generated from the study. Proportions and numbers were presented for the proximate, minerals and sensory results. The statistical significance between the means of the dependent variables were determined at 5%. Tukey post hoc test procedure was applied to determine where the differences in the averages of the estimates assessed exist.

Ethical consideration

Approval for the sensory evaluation study was provided granted by the Department of Vocational and Technical Education research committee, University of Cape Coast. Written consent was provided by all who took part in the study. Permission was also sought from the School of Agriculture and Natural Science where laboratory analysis was done. Institutional Review Board of the University of Cape Coast (UCCIRB/CES/2021/95) gave approval for the study.

RESULTS

Proximate constituents of wheat locust pulp flour and composite flour

Compared to the control (WF), locust pulp fruit had the highest amount of protein (12.06%), and fibre (6.2%). Among the composites, protein and fibre were highest in the blend of 25% wheat flour and 75% of locust pulp flour (25/75) proportion. Statistical significances observed were denoted with different letters at the 5% probability level (Table 2).

Mineral composition of wheat locust flour and composite flour

The locust pulp had the greater quantities of all five minerals determined in relation to the wheat flour (control). The proportions of the minerals were higher than blend of 25 parts of wheat flour and 75% of locust pulp flour. Means with similar variables are insignificant, while means with different variables are statistically significant at 5% probability level (Table 3).

Proximate composition proportions of composite biscuit

It was noticed that even after blending the proportion of the protein in the 25/75 was higher compared to all other mixtures and the control. Similar observation was made for the proportion of fibre, however, the fat/oil proportion was higher in the 75/25 proportion. Means with similar variables are insignificant, while means with different variables are significant at the 5% probability level (Table 4).

The amounts of phosphorus, potassium, sodium (µg/g), and the proportions of calcium and magnesium were

Table 2. Proximate constituents of wheat, locust pulp flour and composite flour.

Sample	Dry matter (%)	Moisture (%)	Ash (%)	Protein (%)	Fat/Oil (%)	Fibre (%)	Carbohydrate (%)
Wheat flour	89.21[a]	10.79[e]	0.57[a]	10.24[d]	0.99[e]	0.428[a]	85.95[e]
Locust Pulp	92.59[e]	7.41[a]	1.91[c]	12.06[b]	0.28[a]	6.202[e]	81.37[b]
50/50	90.93[c]	9.07[c]	2.66[d]	11.48[e]	0.39[b]	5.099[d]	78.06[a]
75/25	90.00[b]	10.00[d]	1.56[b]	8.21[c]	0.85[d]	3.238[b]	82.87[c]
25/75	91.57[d]	8.43[b]	3.59[e]	13.79[a]	0.65[c]	3.577[c]	83.98[d]
ANOVA							
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
l.s.d.	0.2937	0.2937	0.1279	0.2305	0.01568	0.2083	0.3172
Cv	0.2	1.8	3.4	1.1	1.4	3.1	0.2

50/50 = blend of 50% of locust pulp flour and 50% of wheat flour; 75/25 = blend of 75% of wheat flour and 25 parts of locust pulp flour; 25/75 = blend of 25% of wheat flour and 75% of locust pulp flour; in a row and column, the percentages denoted by the alphabets are not statistically different at P< 0.05.
Source: Authors

Table 3. Mineral composition of wheat locust flour and composite flour.

Sample	Phosphorus (µg/g)	Potassium (µg/g)	Sodium (µg/g)	Calcium (%)	Magnesium (%)
Wheat flour	136[a]	1058[a]	461.0[a]	0.78[a]	0.051[ab]
Locust Pulp	168[d]	6509[e]	974.6[d]	0.98[c]	0.054[b]
50/50	154[c]	4427[c]	958.6[cd]	0.86[b]	0.052[ab]
75/25	143[b]	2975[b]	908.7[b]	0.76[a]	0.050[a]
25/75	155[c]	5477[d]	933.2[bc]	0.85[b]	0.052[ab]
ANOVA					
p-value	<0.001	<0.001	<0.001	<0.001	0.043
l.s.d.	20.4	84.4	26.5	0.017	0.0024
cv (%)	0.7	1.1	1.7	1.1	2.5

50/50 = Blend of 50% of locust pulp flour and 50% of wheat flour , 75/25 = blend of 75% of wheat flour and 25 parts of locust pulp flour, 25/75 = blend of 25%of wheat flour and 75% of locust pulp flour. In rows and columns, the percentages denoted by the alphabets are not statistically different.
Source: Authors

higher in the 25/75 blend of composite biscuits. Generally, the values of these minerals increased above the level of non-biscuit levels. Means with similar variables are insignificant while means with different variables are significant at 5% probability level (Table 5).

Sensory analysis

Appearance

Biscuit prepared from wheat as well as composite biscuits was scored for appearance. More than half of the respondents (53.4%) satisfied with the appearance of biscuits prepared with 100% wheat, While 42.2 and 38.5% immensely liked the appearance of 50/50 and 25/75 biscuit samples, respectively (Figure 1).

Texture

The composite biscuit with locust wheat flour obtained the greatest texture score (47.9) (Figure 2). Among the composite biscuits, 25/75 had the highest score of 46% compared to 50/50 and 75/25 which had lower values of 34.2 and 31.5%, respectively.

Taste

The results showed 38.8% of panelists liked sample 25/75 very much, 45.2% liked sample 50/50 slightly, 20.4% neither liked nor disliked sample 25/75, 8.2 disliked sample 50/50 and 11 disliked the biscuit prepared form25/75 flour blend (Figure 3).

Table 4. Proximate estimates of composite biscuits.

Sample	Dry matter (%)	Moisture (%)	Ash (%)	Protein (%)	Fat/Oil (%)	Fibre (%)	Carbohydrate (%)
Wheat flour	95.32[c]	5.32[b]	2.57[a]	7.04[b]	18.19[b]	1.34[a]	69.81[c]
50/50	93.06[a]	6.71[c]	3.17[b]	7.72[a]	16.32[a]	1.72[b]	68.25[b]
75/25	95.32[c]	4.68[a]	2.69[a]	7.16[b]	22.08[d]	1.24[a]	66.27[a]
25/75	93.30[a]	6.94[c]	3.32[b]	8.09[c]	19.11[c]	2.28[c]	71.63[d]
ANOVA							
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
l.s.d.	0.22	0.22	0.13	0.098	0.199	0.096	0.324
Cv	0.1	2	2.3	0.7	0.6	3.1	0.2

50 = Blend of 50% of locust pulp flour and 50% of wheat flour , 75/25 = blend of 75% of wheat flour and 25 parts of locust pulp flour, 25/75 = blend of 25% of wheat flour and 75% of locust pulp flour. In rows and columns, the percentages denoted by the alphabets are not statistically different.
Source: Authors

Table 5. Mineral composition of composite biscuits.

Sample	Phosphorus (µg/g)	Potassium (µg/g)	Sodium (µg/g)	Calcium (%)	Magnesium (%)
Wheat flour	1528[b]	1326[a]	859.1[a]	0.70[b]	0.048[a]
50/50	1680[c]	2776[c]	885.8[a]	0.69[b]	0.051[ab]
75/25	1376[a]	1942[b]	862.7[a]	0.64[a]	0.049[a]
25/75	1697[c]	3259[d]	990.5[b]	0.81[c]	0.054[b]
ANOVA					
p-value	<0.001	<0.001	<0.001	<0.001	0.004
l.s.d.	41.5	98.4	32.24	0.031	0.003
Cv	1.4	2.2	1.9	2.3	3.2

50 = Blend of 50% of locust pulp flour and 50% of wheat flour, 75/25 = blend of 75% of wheat flour and 25 parts of locust pulp flour, 25/75 = blend of 25% of wheat flour and 75% of locust pulp flour. In rows and columns, the percentages denoted by the alphabets are not statistically different.
Source: Authors

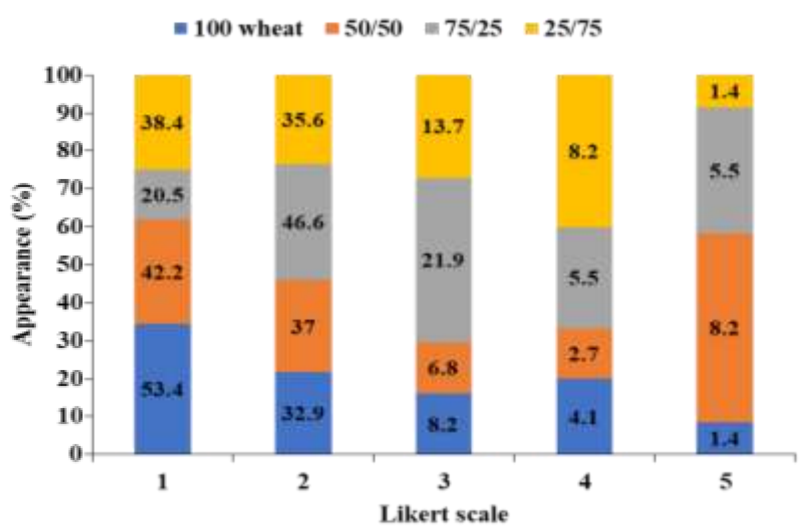


Figure 1. Results of sensory evaluation of the appearance of composite biscuit.
Source: Authors

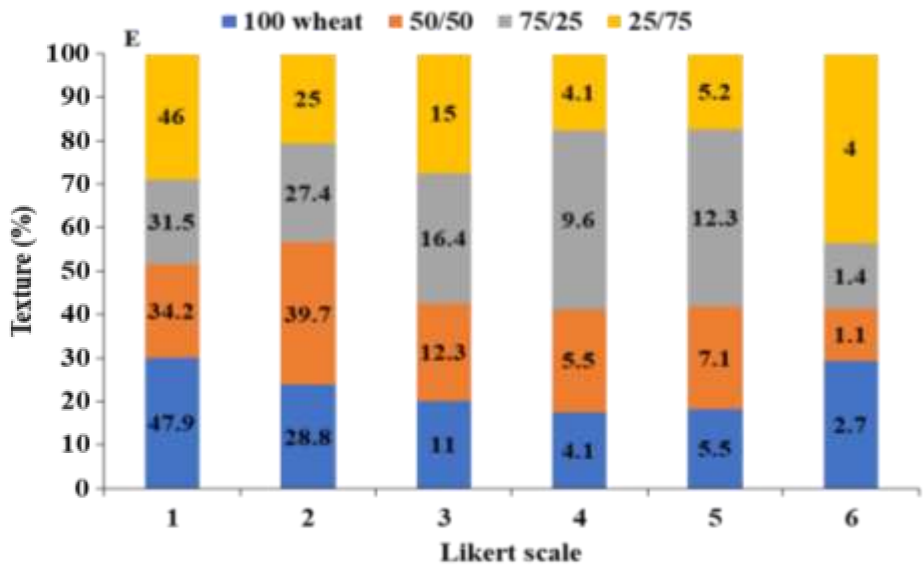


Figure 2. Results of sensory evaluation of the texture of composite biscuits.
Source: Authors

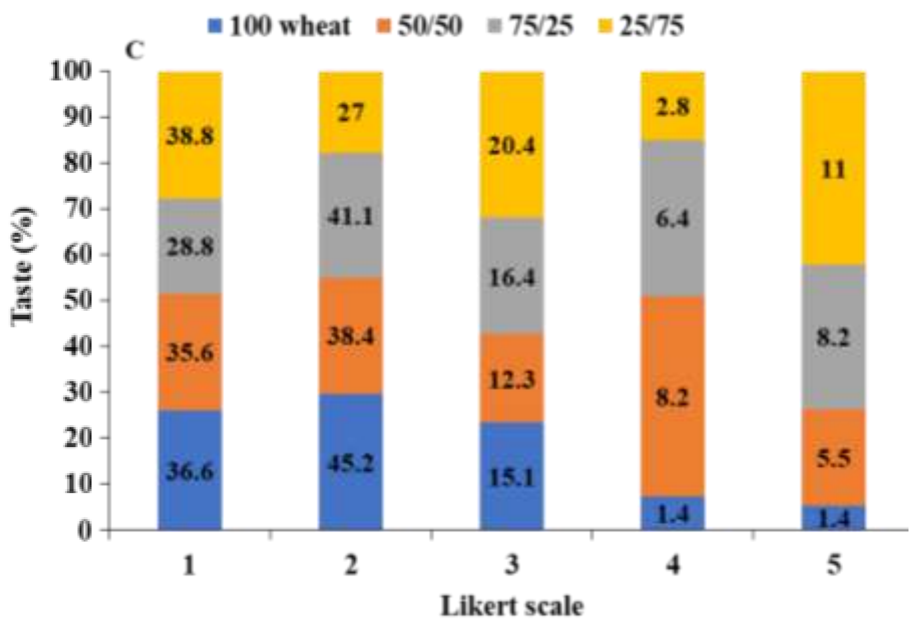


Figure 3. Taste of composite biscuits.
Source: Authors

Overall acceptability

The overall acceptability of the samples increased as the quantities of parkia flour content increased. Almost half of the panelist (46.5%) liked biscuits prepared from 25/75 parts of wheat and parkia flour and 43.8% liked biscuits prepared with equal proportion 50/50 of flour (Figure 4).

DISCUSSION

Physicochemical characteristics of wheat locust pulp and composite flour

The proximate and minerals in African Bean locust fruit pulp (*P. biglobosa*) and biscuits made from composite

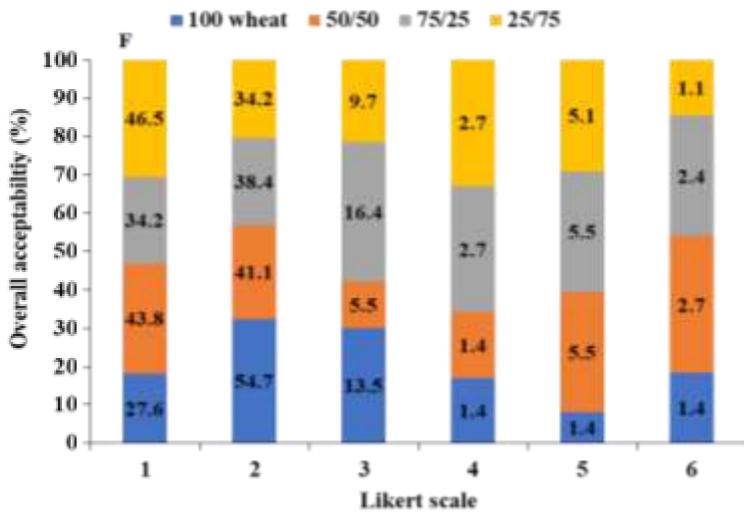


Figure 4. Overall acceptability of composite biscuit.
Source: Authors

flours were assessed. The nutrients and mineral proximate were generally higher in locust pulp flour in relation with the control sample (wheat flour). The protein found in the locust pulp flour and composites was more than 4.29% indicated by Dahouenon-Ahoussi et al. (2012) and akin to 6.56% found by Egbebi et al. (2016). Parkia pulp is a Leguminosae fruit therefore contains a high amount of lysine with about 22.56% crude protein and a rich source of indispensable amino acids (Nyadamu et al., 2017). This biscuit may improve protein intake among populations that need to improve protein nutrition. The composite biscuits had higher crude fibre content compared to wheat flour (WF) and this was similar to that reported by Olujobi (2012). They indicated that the increase in these proximal characteristics including fibres may be attributable to their abundance in parkia flour Olujobi (2012). The dry matter content is similar to the study of Kusuma (2015) and Ogunyinka et al. (2017), who during their study reported dry matter for parkia flour within 77 to 81% and 90.48 to 91.1% (Iheke at al., 2017).

Mineral composition of prepared wheat locust pulp and composite flours

Generally, locust pulp has been reported to have a high mineral content, including calcium, magnesium, potassium, phosphorus, and iron (Ogunyinka et al., 2017). The phosphorus content in the parkia pulp flour obtained was higher than that reported by (2017) and may be due to the variety used for the study and the amounts increased in biscuits as the quantity of parkia flour used augmented. The same pattern was observed for potassium and this has also been reported by Nyadanu et al. (2017) and Iheke et al. (2017)

Jide et al. (2018) indicated sodium composition of 1795 mg/kg for parkia fruit pulp which is greater than the amount of sodium obtained in the study. Iheke et al. (2017) claimed that locust flour is a good source of calcium during their study. Our results agree with the aforementioned since locust pulp flour had 0.98% calcium, which was significantly greater than the calcium content of wheat flour. A direct relationship was observed between the magnesium content of composite flour with augmenting proportion of locust pulp flour.

Mineral content of composite biscuits

Phosphorus matter of the biscuit increased with augmenting content of locust pulp flour substitution. That was because the mineral is high in the pulp flour (Table 3). This could be because of the big initial amount of phosphorus in the locust pulp flour used in blends. The finding is consistent with that reported by Ndekwe and Solomon (2017). Processing into the biscuit did not reduce the amount of the mineral. An increase in potassium content of the biscuit was observed with increasing percentage locust pulp flour as well. Increasing amount of potassium content of the composite with increasing locust pulp flour content could be due to the high amount of potassium in the flour (Ndukwe and Solomon, 2017). Olatoye et al. (2019) reported a substantial amount of potassium in a biscuit prepared from cassava, wheat, and parkia flour blends. The results suggest that processing did not reduce the amount of minerals and therefore these minerals could be available to the body after consumption.

Composite biscuits contained significantly higher amounts of magnesium and calcium than biscuits prepared from wheat flour. This mineral content of composite bread increases when wheat flour is partially replaced with flour from locally cultivated grain legumes (Kennedy et al., 2017).

Sensory attributes

The yellow colour of parkia flour enhanced the overall appearance of the composite biscuits. This finding corroborates those of Adeloye and Agboola (2022) who posited that the yellow colour of parkia makes the product attractive and appealing to consumers. They observed appearance scores increased with increased parkia concentration in a product. Similarly, an observation was made by Ogunyinka et al. (2017) who reported increase in the appearance of parkia based cookies with increasing parkia concentration. The taste score of the parkia blended biscuit increased with increased parkia flour content probably due to highly digestible carbohydrates, such as natural sugars and this was also observed by Stone and Sidel (2004). The overall acceptability of the prepared biscuit samples was high for biscuits prepared with an increased proportion of parkia flour. This might be attributed to the appearance, taste, and texture of the parkia wheat blend biscuit. Such observation could be due to the sweetness of parkia, which improves the taste of the biscuit (Adeloye and Agboola, 2022).

Conclusions

The African locust bean pulp is suitable for composite biscuits with wheat flour. The minerals and nutrients were not lost during processing. Composite biscuits had higher nutrient composition compared to the control sample. Phosphorus, calcium, sodium, and magnesium content increase with increased African locust bean pulp flour, with sample 25/75 recording the highest mineral content. The acceptability of composite biscuit samples was high and this increases for biscuits prepared with an enhanced percentage of African locust bean pulp flour. It is believed that encouraging consumers to patronize the formulated composite biscuits would improve food insecurity and improve nutritional status.

CONFLICT OF INTERESTS

The authors declare no conflict of interests regarding the publication of this manuscript.

ACKNOWLEDGEMENTS

The authors expressed their profound gratitude to all who took part in the study. They also thank the University of Cape Coast for allowing them to use their facilities and trained data collectors.

REFERENCES

Adeloye JB, Agboola OR (2022). Bioactive properties, chemical composition, and sensory acceptance of juice blends from orange and African locust bean (Parkia Biglobosa). Journal of Culinary Science and Technology 20(1):33-50.

Ajayi K, Adepoju OT, Taiwo OM, Omojola ST, Aladetuyi ME (2018) Nutritional potential of underutilized gum arabic tree seeds (*Acacia nilotica)* and locust bean seeds (*Parkia biglobosa*). African Journal of Food Science 12(8):196-203.

Akubor P, Onuh J, Orishagbemi C (2017). Chemical composition and functional properties of African locust bean pulp flour and wheat flour. Asian Journal of Biotechnology and Bioresource Technology 1(4):1-53.

Alissa EM, Ferns GA (2017). Dietary fruits and vegetables and cardiovascular diseases risk. Critical Reviews in Food Science and Nutrition 57(9):1950-1962.

Alrayyes WH (2018). Nutritional and health benefits enhancement of wheat-based food products using chickpea and distiller's dried grains. Electronic Theses and Dissertations 2474. https://openprairie.sdstate.edu/etd/2474

Amoa-Awua WK, Awusi B, Owusu M, Appiah V, Ofori H, Thorsen L, Jespersen L (2014). Reducing the atypical odour of dawadawa: Effect of modification of fermentation conditions and post-fermentation treatment on the development of the atypical odour of dawadawa. Food Control 42:335-342.

AOAC (2019). Official Methods of Analysis of the Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International. 21st Edition, AOAC, Washington DC.

Awogbenja MD, Ndife J (2012). Evaluation of infant feeding and care practices among mothers in nassarawa eggon local government area of nasarawa state. Indian Journal of Scientific Research 3(1):21-29.

Aworh OC (2015). Promoting food security and enhancing Nigeria's small farmers' income through value-added processing of lesser-known and under-utilized indigenous fruits and vegetables. Food Research International 76:986-991.

Awotedu OL, Ogunbamowo PO, Emmanuel IB, Lawal IO (2018). Phytominerals and phytochemical studies of *Azadiracthta indica*, *Leea guineensis* and *Parkia biglobosa* leaves. International Annals of Science 6:28-34.

Burlingame B, Charrondiere UR, Dernini S, Stadlmayr B, Mondovì S (2012). Food biodiversity and sustainable diets: Implications of applications for food production and processing. Green Technologies in Food Production and Processing pp. 643-657.

Bvenura C, Sivakumar D (2017). The role of wild fruits and vegetables in delivering a balanced and healthy diet. Food Research International 99:15-30.

CFSVA Ghana (2020). Comprehensive Food Security and Vulnerability Analysis. Available: https://reliefweb.int/report/ghana/ghana-2020-comprehensive-food-security-and-vulnerability-analysis-cfsva. Accessed 20th April 2022.

Charrondière UR, Stadlmayr B, Rittenschober D, Mouille B, Nilsson E, Medhammar E, Burlingame B (2013). FAO/INFOODS food composition database for biodiversity. Food Chemistry 140(3):408-412.

Chhikara N, Devi HR, Jaglan S, Sharma P, Gupta P, Panghal A (2018). Bioactive compounds, food applications and health benefits of *Parkia speciosa* (stinky beans): A review. Agriculture and Food Security 7(1):1-9.

D'souza SL, Pati RK, Kailasa SK (2014). Ascorbic acid functional gold nanoparticles as a probe for colorimetric and visual read-out determination of dichlorvos in environmental sample. Analytical Methods 6(22):9007-9014.

Dahouenon-Ahoussi E, Adjou ES, Lozes E, Yehouenou LL, Hounye R, Famy N, Sohounhloue DC (2012). Nutritional and microbiological characterization of pulp powder of locust bean (*Parkia biglobosa* Benth.) used as a supplement in infant feeding in Northern Benin. African Journal of Food Science 6(9):232-238.

Egbebi AO, Seidu KT, Muhammad AA (2016). Nutritional and microbiological analyses of fermented locust beans (*Parkia Biglobosa*) and fermented melon (*Citrullus vulgaris*). Savant Journal of Agricultural Research 2(1):1-6.

Ghana Statistical Service (GSS) Ghana Health Service-GHS, and ICF International (2015). Ghana Demographic and Health Survey. Rockville, Maryland, USA: GSS, GHS, and ICF International.

Ifesan BOT, Akintade AO, Gabriel-Ajobiew RAO (2017). Physicochemical and nutritional properties of *Mucuna pruriens* and *Parkia biglobosa* subjected to controlled fermentation. International Food Research Journal 24:2177-2184.

Iheke E, Oshodi A, Omoboye A, Ogunlalu O (2017). Effect of fermentation on the physicochemical properties and nutritionally valuable minerals of locust bean (Parkia biglobosa). American Journal of Food Technology 12(6):379-384.

Ikhimalo OP (2019). African locust beans: More than just a condiment. Journal of Underutilized Legumes 1(1):99-111.

Jide AO, Gbenga A, Karimu O, Alademeyin JO (2018). Proximate and physicochemical properties of flour and oil extracted from raw and boil locust bean (*Parkia biglobosa*). The Pharmaceutical and Chemical Journal 5(4):1-5.

Kennedy G, Stoian D, Hunter D, Kikulwe EM, Termote C, Alders RG, Burlingame B, Jamnadass RH, McMullin S, Thilsted SH (2017). Food Biodiversity for Healthy, Diverse Diets. In: Bioversity international. Mainstreaming Agrobiodiversity in sustainable food systems: Scientific foundations for an Agrobiodiversity index, 23. Italy.

Kusuma SN (2015). Makalah Gandum dan Diversifikasi Olahannya (Ser ealia). Retrieved from http://ucinata.blogspot.co.id/2015/11/makalah gan dum-dan-diversifikasi_11.html.

Maroyi A, Cheikhyoussef A (2017). Traditional knowledge of wild edible fruits in southern Africa: a comparative use patterns in Namibia and Zimbabwe. Indian Journal of Traditional Knowledge 16(3):385-392.

Ndukwe MN, Solomon MD (2017). Proximate and antinutrient composition of some local food condiments in their raw and fermented forms. International Journal of Biochemistry Research and Review 20(1):1-8.

Nyadanu D, Adu Amoah R, Obeng B, Kwarteng AO, Akromah R, Aboagye LM, Adu-Dapaah H (2017). Ethnobotany and analysis of food components of African locust bean (*Parkia biglobosa (Jacq.) Benth*.) in the transitional zone of Ghana: Implications for domestication, conservation and breeding of improved varieties. Genetic Resources and Crop Evolution 64(6):1231-1240.

Ogunyinka BI, Oyinloye BE, Osunsanmi FO, Kappo AP, Opoku AR (2017). Comparative study on proximate, functional, mineral, and antinutrient composition of fermented, defatted, and protein isolate of *Parkia biglobosa* seed. Food Science and Nutrition 5:139-147.

Olatoye KK, Florence AO, Lawal LL (2019). Suitability of African locust bean (*Parkia biglobosa*) pulp as a replacement for sucrose in cassava-wheat composite biscuit production. Acta Periodica Technologica 50:179-188.

Olujobi OJ (2012). Comparative evaluation of the nutritional composition of African locust bean (Parkia biglobosa) fruits from two locations. Nigerian Journal of Basic and Applied Sciences 20(3):195-198.

Quansah L, Mahunu GK, Tahir HE, Mariod AA (2019). Wild Fruits: Composition, Nutritional Value and Products. Springer; Berlin/ Heidelberg, Germany. Parkia biglobosa: Phytochemical Constituents, Bioactive Compounds, Traditional and Medicinal Uses pp. 271-284.

Shaheen S, Ahmad M, Haroon N (2017). Edible Wild Plants: An alternative approach to food security (p. 03). Cham, Switzerland: Springer International Publishing.

Singha P, Muthukumarappan K (2018). Single screw extrusion of apple pomace-enriched blends: Extrudate characteristics and determination of optimum processing conditions. Food Science and Technology International 24(5):447-462.

Stone H, Sidel JL (2004). Sensory evaluation practices Academic press. San Diego, 2nd.

Vaclavik VA, Christian EW, Campbell T, Vaclavik VA, Christian EW, Campbell T (2021). Sugars, sweeteners, and confections. Essentials of Food Science pp. 281-299.

Yu Y, Stomph TJ, Makowski D, Zhang L, Van Der Werf W (2016). A meta-analysis of relative crop yields in cereal/legume mixtures suggests options for management. Field Crops Research 198:269-279.

Zakari UM, Hassan A, Ndife J (2015). Quality characteristics of African locust bean fruit pulp cakes. African Journal. Food Science 9(1):17-22.

Vol. 17(6) pp. 111-121, June 2023
DOI: 10.5897/AJFS2022.2180
Article Number: 3DA9DAD70831
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Influence of extrusion process conditions on bulk density, water absorption capacity and oil absorption capacity of extruded aerial yam-soybean flour mixture

Enobong Okon Umoh[1*] and Madu Ofo Iwe[2]

[1]Department of Agricultural Engineering, Akwa Ibom State University, Ikot Akpaden, P.M.B., 1167, Uyo, Nigeria.
[2]Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Received 17 February, 2022; Accepted 18 June, 2022

The influence of extrusion factors on bulk density, water absorption capacity, and oil absorption capacity of aerial yam-soybean flour mixture was examined utilizing a research facility scale single-screw extruder with the flour blending proportion of 25% aerial yam: 75% soybean. Response surface strategy in light of Box-Behken plan at three factors, five levels of barrel temperature (95, 100, 105, 110, and115℃), screw speed (85, 100, 115, 130, and145 rpm) and feed moisture (31, 33, 35, 37, and 39%) were utilized in 20 runs. The results showed that bulk density ranged from 0.4779±0.003 to 0.7211±0.003 g/cm^3; water absorption capacity from 2.52±0.032 to 3.89±0.007 g/g; while oil absorption capacity ranged from 1.12±0.028 to 2.88±0.007 g/g. The best extrusion condition combinations were 110°C barrel temperature, 130 rpm screw speed and 33% feed dampness for bulk density; 105°C barrel temperature, 115 rpm screw speed and 35% feed dampness for water absorption capacity; and 110°C barrel temperature, 130 rpm screw speed and 37% feed dampness for oil absorption capacity. Analysis of variance showed that barrel temperature, screw speed, and feed dampness significantly (p<0.05) affected the bulk density, water absorption capacity, and oil absorption capacity of the extrudates.

Key words: Optimization, functional properties, extrusion, aerial yam, response surface.

INTRODUCTION

Airborne sweet potato (*Dioscorea bulbifera*) is an arrangement of sweet potato filled in specific region of the planet. This bulbils-bearing sweet potato has a place with the solicitation Dioscoreal, Family Dioscoreaceae, and Genus *Dioscorea*, and is detested by animals among the satisfactory sweet potato species. It is native to Southeast Asia, West Africa, and South and Central America. Furthermore, wild species are predominant in both Asia and Africa (Nwosu, 2014).

Flying sweet potato (*D. bulbifera*) is recorded to be an unsavory sweet potato among the palatable sweet potato species which unlike the conventional sweet potato produces elevated bulbils that appear to be potatoes thus the name elevated/air potatoes (Ojinnaka et al., 2017).

*Corresponding author. E-mail: enoumoh2003@yahoo.com. Tel: +2348035408924.

This kind of sweet potato is consumed by couple of organizations and is generally underutilized both at asset and business levels because of multiple factors (Igyor et al., 2004). These incorporate, having a decently terrible following sensation dissimilar to other sweet potato species, being dark to a significant number of people, and much work has not been completed on it to propose usages to which it will generally be put to. Anyway, there are numerous applications for flying sweet potato, including the use of its wholesome and utilitarian properties to convey grouped current items, as well as its monetary value (Sanful and Engmann, 2016).

D. bulbifera has been for the most part used in the Chinese clinical system as a significant zest during the time spent redoing and staying aware of kidney work (Ahmed et al., 2009). In Asia, this flavor has been enthusiastically proposed for treating diabetes. It has been customarily used to cut down glycemic levels, giving a more upheld sort of energy and better insurance against heftiness and diabetes; regardless, this property has not yet been consistently illustrated (Brand-Miller et al., 2003).

Flying yam (*D. bulbifera*), as a less well-known food crop, has not been financially well-managed. It is only a small portion of the harvest that is processed into second sweet potato flour, which is especially noticeable in Yoruba-speaking areas of West Africa and less so in other parts of the continent (Orkwor et al., 1998). Processing aerial sweet potato to flour can help reduce our reliance on wheat flour for warmed foods and post-harvest adversities (Prince-will and Ezembaukwu, 2015).

Soybean (*Glycine max*), a large oil seed in the Leguminosae family, is primarily grown as a food crop. Soybean processing and use as food dates back to the 11th century B.C. in ancient China. It was then filled in various parts of the world only in the twentieth century. The major transporting nations are the United States, Brazil, China, and Argentina (Iwe, 2003). Soybean is primarily grown for its seeds, which are used for human food and animal feed, as well as for oil extraction. Soy food sources are likely the fastest developing arrangements in the food industry, with things ranging from conventional soy food assortments to protein trimmings and from dairy and meat alternatives to various kinds of Western and traditional food assortments progressed with soybean flour and its parts (Iwe, 2003).

As a food crop, the flying sweet potato has yet to gain global recognition. Handling it into a stable flour/blend and then expulsion handling to make pasta will increase the detectable quality of the gather in the food trade, highlighting its potential food uses/values to the food business (Princewill-Ogbonna and Ezembaukwu, 2015).

Furthermore, the extension of well-known food-handling systems, for example, expulsion cooking, and the use of *D. bulbifera* beyond the pharmacological viewpoint could mean introducing new techniques and food items, thereby offering choice to customers.

This research also highlights the impact of expulsion process limits or factors on the utilitarian properties of an aeronautical sweet potato soybean flour combination using response surface methodology.

MATERIALS AND METHODS

Collection of soybean seeds and aerial yam bulbs

Soybean seeds and aerial yam bulbs used in this study were purchased from Uyo Urban market in Uyo Local Government Area, Akwa Ibom State, Nigeria.

Sample preparation

The flour samples used in this research were prepared in the Food Processing Laboratory, Department of Food Science and Technology, University of Uyo, Uyo, Akwa Ibom State, Nigeria.

Preparation of aerial yam Flour

This was done as shown by the methodology depicted by Olurin et al. (2006). The Aerial sweet potato bulbs were cleaned and organized to kill bothersome materials, before stripping with sharp edge, washed with clean water and sliced to 10 mm thickness using sharp edge. The cuts (chips) were then dried using an oven at a temperature of 60°C for 12 h. The dried cuts (chips) were then handled using utilizing CAST IRON 1A 2A grinding machine and sieved with lab sifter of 600 µm opening size. The flour was packaged in a polyethene pack for following use.

Preparation of soybean flour

This was finished by the method portrayed by Iwe (2003). Seeds were screened to dispense with new materials, parts, and hurt beans, trailed by washing and roll bubbling at 100°C for 30 min. It was then grill-dried at a temperature of 70°C for 12 h and processed, utilizing CAST IRON 1A 2A grinding machine. The handled full-fat soybean was sieved using a 100 µm network standard sifter. The flour was then taken care of in fixed shut polyethene sack at room temperature for additional usage.

Arrangement of sample blend

The aerial sweet potato-soybean flour blend was prepared in the ratio of 25:75, conveyed in proportions of 25% flying sweet potato flour and 75% soybean flour.

Extrusion cooking

Expulsion cooking was done using a privately created single-screw research center scale extruder in the Department of Food Science and Technology Laboratory, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. 200 g of the flour blend (25% airborne sweet potato flour, 75% soybean flour) was definitively assessed and preconditioned by the ideal clamminess levels, allowed to stay for two 2 min to ensure uniform hydration of the raw substance. This was to ensure that any dry community was cleared out (Strahm, 2000). The privately created extruder was turned on, and the barrel temperatures (95 to 115°C) and the screw speeds (in upset each moment rpm) of the extruder were set by the preliminary arrangement. The normal substance was dealt with through the compartment into the extruder. The extrudates were collected as they exit through the die; grill dried, and packaged in impervious zip lock polyethylene sacks for additional laboratory examination. Twenty runs were done by and large, during the expulsion cycle, according to the preliminary arrangement.

Determination of functional properties

The following functional properties of the extruded aerial yam-soybean flour mixture were determined.

Bulk density

The flour test was filled in a 10 ml dried estimating chamber and the lower part of the chamber tapped a few times on the research center table until there could have been no further lessening of the sample level subsequent to filling to the 10 ml mark.

$$\text{The bulk density (g/cm}^3\text{)} = \frac{weight\ of\ sample\ (g)}{volume\ of\ sample\ (cm^3)}$$

Water absorption capacity

Water absorption capacity of the extrudate was determined according to the methods described by Onwuka (2005). Ten milliliters (10 ml) of refined water was blended in with one gram (1 g) of test in a blender and homogenized for 30 s, kept at room temperature for 30 min, and centrifuged at 5000 rpm for 30 min. The volume of the supernatant (free water) in a graduated chamber was noted. The amount of water ingested (all out short free) was increased by its density for transformation to grams. Density of water was thought to be 1 g/ml.

$$Water\ absorption\ capacity = \frac{V_1 - V_2}{W} \times density\ of\ water$$

Where: v_1 = initial volume of water (10 ml); v_2 = final volume after centrifugation; w = weight of sample (1 g)

Oil absorption capacity

The oil absorption capacity of the extrudate was determined according to the methods described by Onwuka (2005). Precisely one gram (1 g) of flour mix test was blended in with 10 ml of vegetable oil. The oil and the sample were homogenized for 30 s and allowed to stand for 30 min at room temperature, and afterward centrifuged at 5,000 rpm for 30 min. The volume of free oil (supernatant) was noted straightforwardly from the graduated rotator tube. The amount of oil ingested (total minus free) was then multiplied by its density to convert into grams. Density of oil was taken to be 0.88 g/ml for faded palm oil.

$$Oil\ absorption\ capacity = \frac{V_{1} - V_2}{w} \times density\ of\ oil$$

Where: V_1 = Initial volume of oil; V_2 = Final volume after centrifugation; w = Weight of sample.

Experimental design/ statistical analysis

Design expert (variant 11.0.1), a Statistical Computer Application Software Package was used in the preliminary arrangement. Focal composite randomized design (CCRD) was used with a three variable preliminary set up at five levels each, with barrel temperature (X1), screw speed (X2), and feed dampness levels (X3) as the free factors (Table 1).

Reaction surface methodology (RSM) was used to examine the effects of the independent components or variables on the reliant elements (the reactions). Coded values for the autonomous elements used were - 2, - 1, 0, 1, 2, where - 2 tends to the least, 0 tends to the medium (mid-point), and 2 tends to most critical levels independently.

RESULTS AND DISCUSSION

Functional properties of extruded aerial yam-soybean flour mixture

The results of the effects of extrusion process conditions on the functional properties of extruded aerial yam-soybean flour mixture are presented in Table 2.

Bulk density

The mass thickness of the extrudates increased in the range of 0.4779 ± 0.003 and 0.7211 ± 0.003 g/cm^3, as shown in Table 2. This range of mass thickness values is greater than 0.24 ± 0.05 to 0.36 ± 0.03 for sorghum-based expelled thing upgraded with soy supper flour (Tadesse et al., 2019); 0.0202 to 0.3503 g/cm^3 for expelled rice flour-pineapple waste squash powder-red gram powder (Anjineyulu et al., 2013); and 0.19 to 0.31 g/cm^3 for fish-maize (Omohimi et al., 2014).

Mass thickness is a measure of puffing and is clearly related to the outer layer of the possible outcome of expanded starch-based extrudate. It is not completely established by the combination of advancement and resulting shrinkage or breakdown of water rage ascends in extrudates and by the effect of kick the can broadening because of the adaptable property of the broken down matrix (Tadesse et al., 2019). Light thickness suggests a sensitive plan, which is appealing in this type of situation.

Water absorption capacity

The eventual outcomes of water absorption capacity of the expelled flying sweet potato soybean flour combination are presented in Table 2. The recorded characteristics ranged from 2.52 ± 0.032 to 3.89 ± 0.007 g/g. This extent of values is imperceptibly higher than 2.5 to 3.56 g/g for cassava/soybean extrudates (Olusegun et al., 2016); 1.667 to 2.320 g/g for meat straightforward from mucuna bean seed flour (Omohimi et al., 2014), yet lower than 3.918 to 5.997 g/g for pineapple waste squash rice flour-red gram powder based extrudates (Anjineyulu et al., 2013); 4.92 to 6.07 g/g for fish-maize based expelled snacks (Nkubana et al., 2020), and 3.922 ± 0.079 to 6.017 ± 0.018 g/g for arranged to-eat beat based snacks (Alemayehu et al., 2019).

Water retention limit provides information about the

Table 1. Coded and actual values of different experimental variables.

Factor	Units	Code	Level					Interval of variation
			-2	-1	0	1	2	
Barrel temp.	℃	X_1	95	100	105	110	115	5.0
Screw speed	rpm	X_2	85	100	115	130	145	15.0
Feed moisture	%	X_3	31	33	35	37	39	2.0

Source: Author

Table 2. Effects of extrusion conditions on functional properties of extruded aerial yam-soybean flour mixture.

S/N	BT (℃)	SS (rpm)	FM (%)	Bulk Density (g/cm^3)	Water Absorption Capacity (g/g)	Oil Absorption Capacity(g/g)
1	105	115	31	0.6969±0.004	2.60±0.003	1.72±0.028
2	105	115	35	0.4885±0.003	3.89±0.007	1.94±0.007
3	105	115	35	0.4790±0.003	3.81±0.007	1.98±0.007
4	105	85	35	0.6708±0.002	2.91±0.014	1.69±0.021
5	100	130	33	0.6712±0.002	3.06±0.004	1.63±0.002
6	110	100	37	0.6249±0.002	2.94±0.014	1.95±0.014
7	100	100	37	0.6175±0.003	2.88±0.021	1.76±0.007
8	110	130	33	0.7211±0.003	2.69±0.014	2.64±0.021
9	105	115	35	0.4787±0.003	3.83±0.007	1.91±0.007
10	115	115	35	0.6933±0.003	2.69±0.003	2.80±0.021
11	95	115	35	0.7167±0.003	2.58±0.141	1.12±0.028
12	105	115	39	0.6755±0.001	2.57±0.007	2.62±0.014
13	105	115	35	0.4779±0.003	3.82±0.007	1.90±0.007
14	100	100	33	0.6598±0.002	2.71±0.014	1.34±0.014
15	110	130	37	0.6043±0.002	2.80±0.007	2.88±0.007
16	110	100	33	0.6985±0.004	2.95±0.071	1.92±0.014
17	105	145	35	0.6982±0.005	2.52±0.032	1.62±0.004
18	100	130	37	0.7011±0.002	2.68±0.022	2.31±0.001
19	105	115	35	0.4788±0.003	3.81±0.007	1.98±0.007
20	105	115	35	0.4784±0.003	3.80±0.007	1.92±0.007

Values are mean ± standard deviation of triplicate determination, BT= Barrel temperature, SS= Screw speed, FM= Feed moisture.
Source: Author

level of gelatinization of starch in feed trimmings in general by assessing how much water is polished off by starch granules as a result of the thing's initial overflow of water (Olusegun et al., 2016). Water retention properties depend on the openness of hydrophilic social affairs which bind water particles and the gel-outlining limit of the macromolecules being referred to.

Oil absorption capacity

In Table 2, the eventual outcomes of the effects of expulsion conditions on the down to earth properties of expelled flying sweet potato-soybean flour combination showed that oil absorption capacity of the extrudates increased from 1.12 ± 0.028 to 2.88 ± 0.007g/g. This recorded extent of values is within the extent of 1.761 to 2.389 g/g for meat basic from mucuna bean seed flour (Omohimi et al., 2014). Oil retention limit can be used as a document of the hydrophobicity of an expelled thing (Tabibloghmany et al., 2020). The results of regression analysis/ANOVA of the models for the responses: functional properties of extruded aerial yam-soybean flour mixture are presented in Table 3.

Model selection/equation for optimization of extrusion process parameters for bulk density

The final regression model for bulk density is given in Equation 1.

$$B_D = 36.44 - 0.3947BT - 0.04170SS - 0.7262FM - 0.00016BTSS + 0.0023BTFM + 0.00012SSFM + 0.00233BT^2 + 0.00024SS^2 - 0.0134FM^2 \quad (1)$$

Table 3. Coefficient of Regression/ANOVA for Functional properties.

	Bulk density		Water absorption capacity		Oil absorption capacity	
	Coeff.	**p-values**	**Coeff.**	**p-values**	**Coeff.**	**p-values**
X_O	36.44		-250.14		-10.11	
Linear						
X_1	-0.394	0.6366	2.55	0.5611	0.0714	< 0.0001
X_2	-0.04170	0.1513	0.4482	0.0448	0.0097	0.0355
X_3	-0.7262	0.0307	5.39	0.7130	0.0991	0.0069
Interaction						
X_1X_2	-0.00016	0.2079	-0.00092	0.1140		
X_1X_3	0.0023	0.0276	0.00388	0.3520		
X_2X_3	0.00012	0.6835	-0.001792	0.2055		
Quadratic						
${X_1}^2$	0.000233	< 0.0001	-0.0123	< 0.0001		
${X_2}^2$	0.00024	< 0.0001	-0.00128	< 0.0001		
${X_3}^2$	-0.0134	< 0.0001	-0.0799	< 0.0001		
Test for model adequacy						
R^2	0.9663		0.9757		0.7418	
Pred. R^2	0.7415		0.8240		0.5159	
Model F-value	31.85		44.63		15.32	
Lack of fit	70.80		164.46		77.84	

X_o = intercept, X_1 = Barrel temperature (BT), X_2 = Screw speed (SS), X_3 = Feed moisture (FM), Significance at p< 0.005.
Source: Author

Where, B_D = Bulk density (g/cm^3), *BT* = Barrel Temperature (°C), *SS* = Screw Speed (rpm), *FM* = Feed moisture (%)

In Equation 1, the positive terms suggest direct association between the expulsion cycle limits (BT, SS and FM), and their correspondences (straight and quadratic) with mass thickness, while the negative terms show a converse association between them. It was seen that all the three expulsion process limits (BT, SS and FM) have switch relationship with the response, mass thickness (BD), construing that mass thickness decreased with development in the expulsion cycle limits. The results of regression analysis/ANOVA of the models for viable properties in 3 show a model F-worth of 31.85 for mass thickness, which is exactly what the model recommends. Potential gains of "prob>F" under 0.0500 gathers that the model terms are basic, beside BT, SS, BT×SS and SS×FM with p-potential gains of 0.6366, 0.1513, 0.2079, and 0.6835 independently (Table 3).

The "Shortfall of fit F-value" of 70.80 for mass thickness recommends that the "Shortfall of fit" is not basically similar with the pure slip-up. This model can subsequently be used to investigate the arrangement space. The model was tremendous with a decent coefficient of confirmation, R^2 of 0.9663 (Table 3). The high coefficient of confirmation showed astonishing connection between the free factors (barrel temperature, screw speed and feed clamminess) and the response, and this implies that the response (mass thickness) model is adequate, and can figure out 96% of the total irregularity in the response.

Model selection/equation for optimization of extrusion process parameters for water absorption capacity

The final regression model for water absorption capacity is given in Equation 2.

$$W_{AC} = -250.14 + 2.55BT + 0.4482SS + 5.39FM - 0.00092BTSS + 0.00388BTFM - 0.001792SSFM - 0.0123BT^2 - 0.00128SS^2 - 0.0799FM^2 \quad (2)$$

Where, W_{AC} = Water absorption capacity (g/g), *BT*= Barrel Temperature (^{0}C), *SS* = Screw Speed (rpm), *FM* = Feed moisture (%)

In Equation 2, the positive terms suggest direct association between the expulsion cycle limits and their participations with the levels of water retention limit, however, the negative terms show a retrogressive association between them. For this present circumstance, it was seen that all the three expulsion process limits (BT, SS and FM) have direct relationship with the response (water ingestion limit). This proposes that water retention limit (WAC) showed a straight addition with development in the expulsion cycle limits.

Table 4. Output for numerical optimization of extrusion process parameters for functional properties.

Extrusion criteria	Unit	Lower limit	Upper limit	Optimization goal	Relative importance	Output
Barrel temperature	℃	95.00	115.00	Maximize	3	112.85
Screw Speed		85.00	145.00	Maximize	3	144.99
Feed Moisture		31.00	39.00	Range	3	35.12
Bulk Density		0.4779	0.7211	Range	3	0.8165
WAC		2.52	3.89	Range	3	1.58
OAC		1.12	2.88	Range	3	2.85
Desirability						0.972

WAC = Water absorption capacity, OAC = Oil absorption capacity.
Source: Author

The model F-value of 44.63 induces that the model is basic. Potential gains of "prob>F" under 0.0500 surmises that the model terms are basic, beside BT, FM, BT×SS, BT×FM and SS×FM, with p-potential gains of 0.5611, 0.7130, 0.1140, 0.3520 and 0.2055 exclusively (Table 3).

The "Shortfall of it F-value" of 164.46 for water assimilation limit in Table 3 indicates that the "Shortfall of fit" isn't fundamentally similar to the pure bungle. As a result, this model could be used to investigate the arrangement space at any time. The model was massive, with a satisfying coefficient of confirmation, R^2 of 0.9750 (Table 3). This implies that the response (water retention limit) model is adequate and can account for 97% of the response's total variance.

Model selection/equation for optimization of extrusion process parameters for oil absorption capacity

The final regression model for oil absorption capacity is given in Equation 3.

$$O_{AC} = -10.11 + 0.0714BT + 0.0097SS + 0.0991FM \quad (3)$$

Where, O_{AC} = Oil absorption capacity (g/g), BT= Barrel Temperature (°C), SS = Screw Speed (rpm), FM = Feed moisture (%)

In Equation 3, the positive terms suggest direct association between the expulsion cycle limits and the level of oil assimilation limit. All the expulsion interaction limits (BT, SS and FM), apparently had direct relationship with the response (OAC). This suggests that oil retention limit (OAC) of the extrudates extended with extension in barrel temperature (BT), screw speed (SS), as well as feed soddenness (FM).

From the outcomes of regression assessment/ANOVA in Table 3, the model F-value of 15.32 shows that the picked model is gigantic, and potential gains of "prob>F" under 0.0500 deduces that the model terms are basic. Here, the model straight terms; BT, SS, and FM recorded p-potential gains of < 0.0001, 0.0355, and 0.0069 independently, showing that they are basic ($p< 0.05$) (Table 3).

The "Shortfall of fit F-value" of 77.84 for oil assimilation in Table 3 recommends that the "Shortfall of it" is not colossal similar with the pure bumble. This model can subsequently be used to investigate the arrangement space. The high coefficient of confirmation, R^2 worth of 0.7418 (Table 3), showed a fair connection between the independent elements (barrel temperature, screw speed and feed moistness) and the response, showing that the model is adequate, and can figure out 74% of the total capriciousness in the response.

Mathematical optimization of extrusion process parameters for functional properties

The most extreme conceivable barrel temperature and screw speed, followed by the reach for feed moisture, were the fundamental rules for imperatives advancement of the expulsion interaction boundaries. The enhancement objective for the reactions was the reach. The ideal enhancement objectives and result for every expulsion cycle boundary and reaction is introduced in Table 4.

The ideal extrusion process boundaries were 112.85°C for barrel temperature, 149.99 rpm for screw speed, and 35.12% for feed dampness. Likewise, the ideal practical properties were 0.8165 g/cm^3 for bulk density, 1.58 g/g for water absorption capacity, and 2.85 g/g for oil absorption capacity, with an attractiveness of 0.972%. In the interim, the advancement results got for the objective of upgrading the reach for the reactions were 0.4779 to 0.721 g/cm^3 for bulk density, 2.52 to 3.89 g/g for water absorption capacity, and 1.12 to 2.88 g/g for oil absorption capacity.

Response surface plots for the functional properties of aerial yam-soybean flour mixture

Effects of extrusion process parameters on bulk density

Figures 1 to 3 depict the response surface plot showing

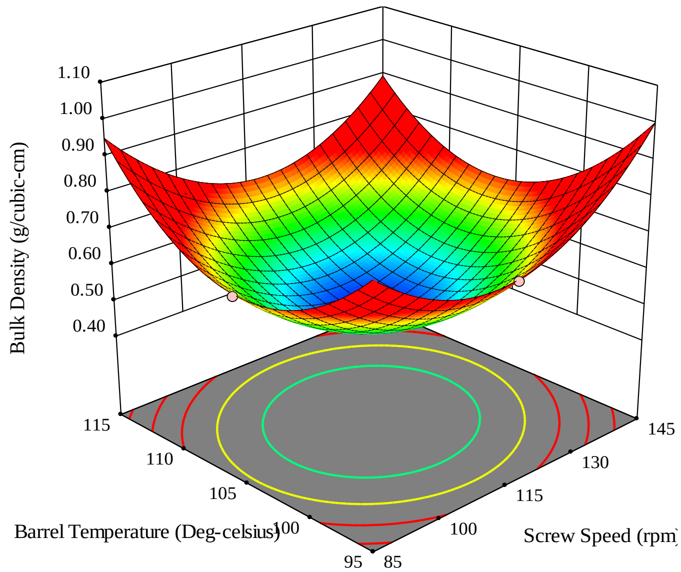


Figure 1. Response surface plot showing the influence of barrel temperature and screw speed on bulk density.
Source: Author

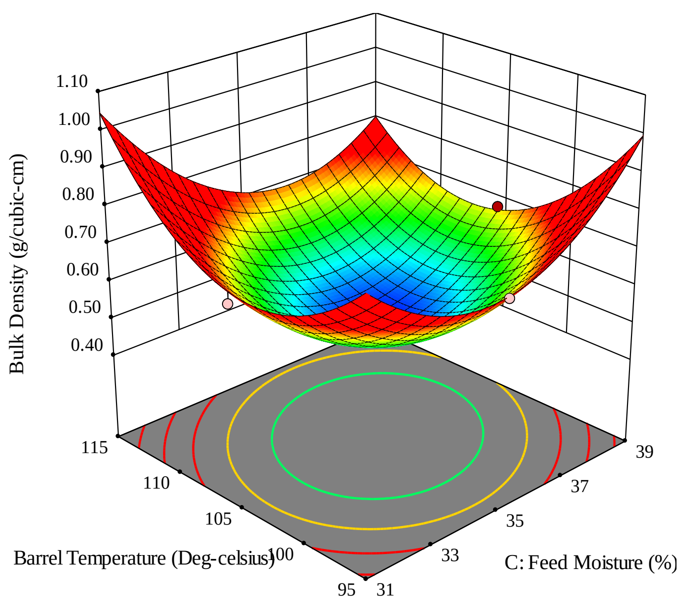


Figure 2. Response surface plot showing the influence of barrel temperature and feed moisture on bulk density
Source: Author

the impact of barrel temperature and screw speed; impact of barrel temperature and feed clamminess; impact of screw speed and feed soddenness on mass thickness of expelled ethereal sweet potato soybean flour combination.

Figure 1 shows the response surface plot for impact of barrel temperature and screw speed of the extruder on mass thickness of the extrudates. It was seen from the

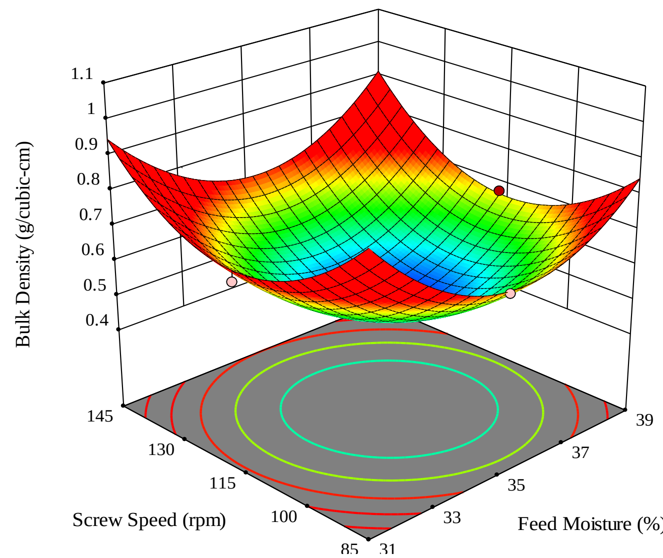


Figure 3. Response surface plot showing the influence of screw speed and feed moisture on bulk density.
Source: Author

plot that, development in barrel temperature and screw speed achieved quadratic extension in mass thickness of the extrudates. This insight is at distinction with that of Omohimi et al. (2014); Alemayehu et al. (2019), and simultaneously with that of Anjineyulu et al. (2013).

Moreover, the response surface plot showing the effects of barrel temperature and feed moisture on mass thickness (Figure 2) showed that extension in both barrel temperature and feed sogginess achieved quadratic development in mass thickness of the extrudates. The discernment that development in feed moisture extended the mass thickness is in agreement with that of Peluola-Adyemi and Idowu (2014); Tiwari and Jha (2017), and despite a past report by Guldiken et al. (2019) for desi chickpea-grain extrudates. Extension in mass thickness with extension in feed soddenness may be attributed to diminished flexibility of combination and lower improvement (Anjineyulu et al., 2013; Tiwari and Jha, 2017).

In Figure 3, the response surface plot showing the effects of screw speed and feed clamminess on mass thickness exhibited that increasing the screw speed and feed sogginess achieved quadratic development in mass thickness of the extrudates. This discernment that accelerates results in extended mass thickness of the extrudates is in agreement with that of Omohimi et al. (2014), but disregarding that of Tiwari and Jha (2017). The extension in mass thickness as screw speed additions might be a direct result of heightened effect of temperature on extrudate mellow under extended shear environment, which could construct the level of gelatinization process subsequently gave extrudates with higher mass thickness (Omohimi et al., 2014).

Examination of vacillation (ANOVA) at 5% significance

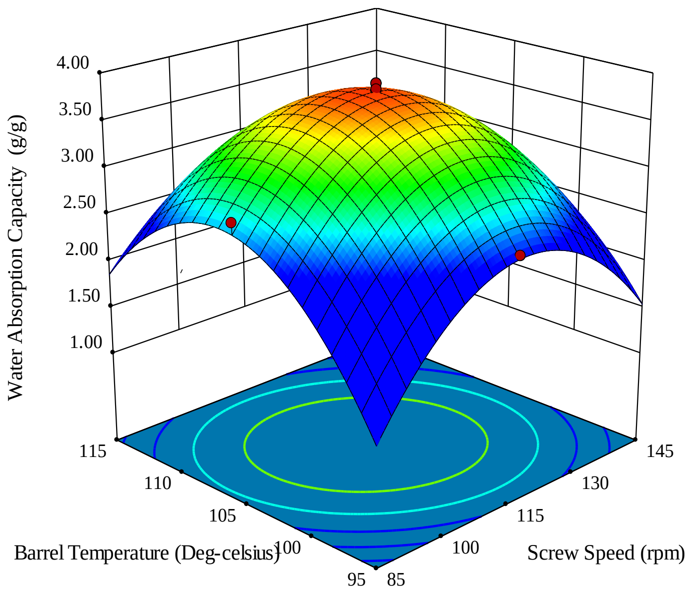


Figure 4. Response surface plot showing the influence of barrel temperature and screw speed on Water absorption Capacity.
Source: Author

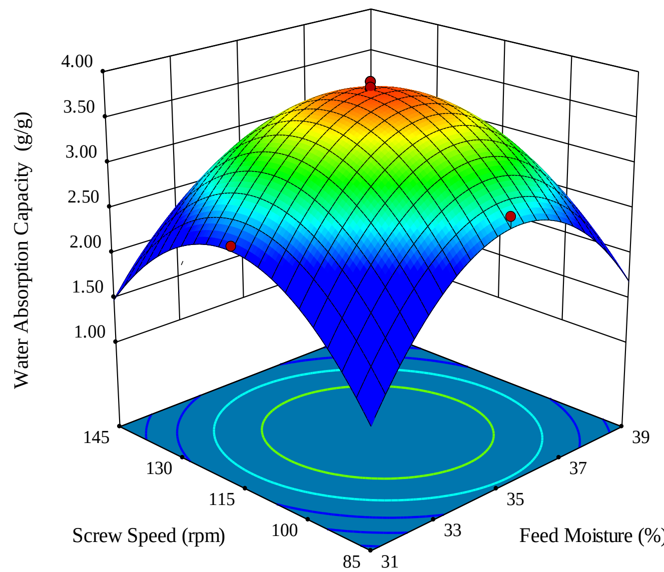


Figure 6. Response surface plot showing the impact of screw speed and feed dampness on Water Absorption Capacity.
Source: Author

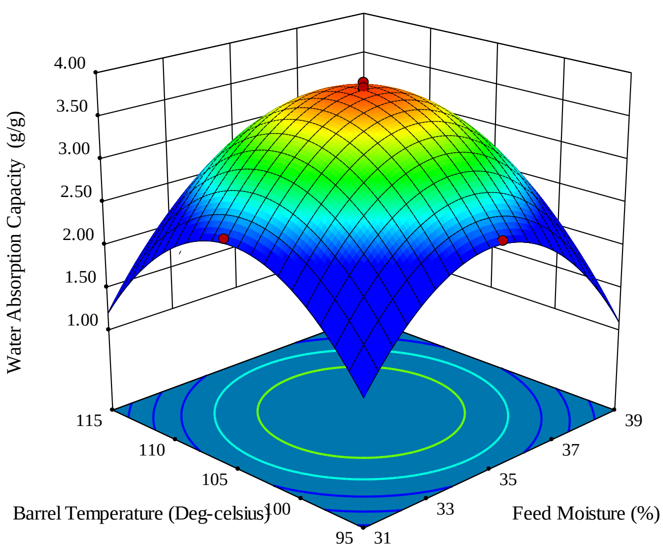


Figure 5. Response surface plot showing the influence of barrel temperature and feed moisture on Water Absorption Capacity
Source: Author

level, for the effect of barrel temperature, screw speed and feed moistness on mass thickness of the expelled flying sweet potato soybean flour combination showed that the expulsion interaction conditions (Barrel temperature, Screw speed and Feed moisture) had colossal effect ($p < 0.05$) on mass thickness of the extrudates.

The "Preliminary of between-subjects" effects of the expulsion interaction conditions on mass thickness showed that the cycle limits, including their associations, similarly had gigantic effect ($p < 0.05$) on mass thickness of the extrudates, except for SS×FM, which showed non-basic ($p > 0.05$) influence on mass thickness.

Effect of extrusion process parameters on water absorption capacity

Figures 4 to 6 show response surface plot for the impacts of barrel temperature, screw speed and feed dampness on water retention limit of the extrudates. In Figure 4, the response surface plot for the effect of barrel temperature and screw speed on water assimilation limit exhibited that extension in barrel temperature and screw speed achieved quadratic diminishing in water retention limit of the extrudates. This validation is like that of Omohimi et al. (2014), yet contrary to that of Anjineyulu et al. (2013).

Basically, Figure 5, which shows the response surface plot for effect of barrel temperature and feed clamminess, exhibited that climbing the barrel temperature of the extruder and feed sogginess provoked a quadratic decreasing in water retention limit of the extrudates. This affirmation is in any case, contrary to that of Lin et al. (2000); Lazou and Krokida (2010).

In Figure 6, the response surface plot showing the effect of screw speed and feed soddenness exhibited that accelerating the extruder up to 115 rpm and increasing feed moistness up to 35% caused development in water assimilation limit. These insights confirm the past revelations by Peluola-Adeyemi and Idowu (2014) and Tabibloghmany et al. (2020). Further increase in the screw speed beyond 115 rpm and feed sogginess above

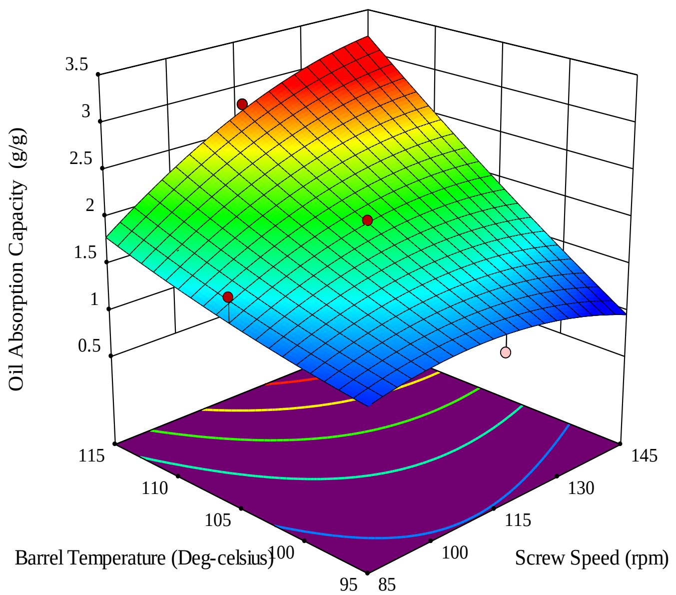


Figure 7. Response surface plot showing the effect of barrel temperature and screw speed on Oil Absorption Capacity.
Source: Author

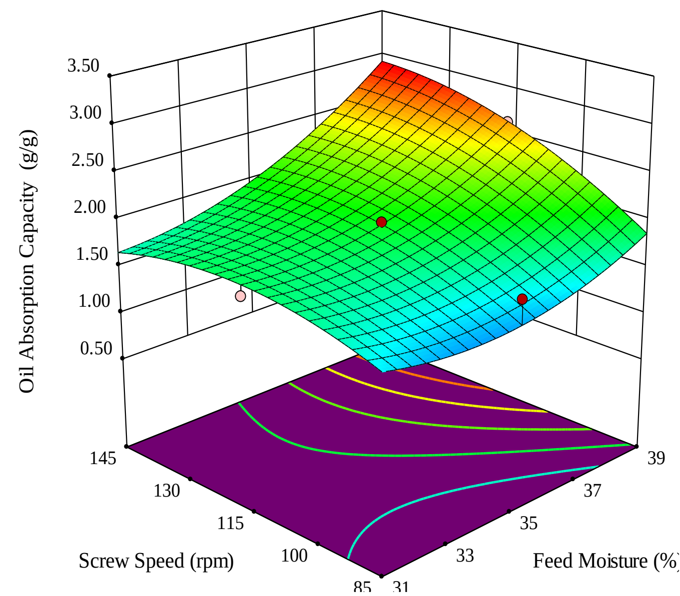


Figure 9. Response surface plot showing the effect of screw speedand feed moisture on Oil Absorption Capacity.
Source: Author

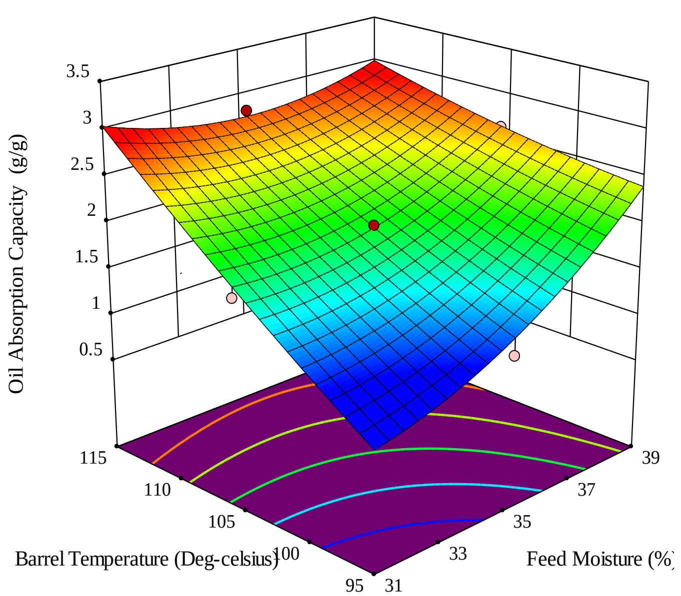


Figure 8. Response surface plot showing the effect of barrel temperature and feed moisture on Oil Absorption Capacity.
Source: Author

35%, achieved a slight decrease in water retention limit of the extrudates.

Water retention limit or record gives information about the level of gelatinization of starch in the feed fixing generally by assessing how much water is polished off by starch granules following expansion in excess water at first present in the thing (Altan et al., 2008). Gelatinization, the change of unrefined starch to a cooked and eatable material by the utilization of hotness and water, is one of the huge effects of expulsion of the starch portions of food sources (Ding et al., 2006).

Along these lines, the decrease in water retention limit of the extrudates may be credited to the weakening or defilement of starch. Examination of vacillation (ANOVA) at 5% significance level, for the effect of barrel temperature, screw speed, and feed sogginess on water assimilation limit of the extrudates showed that the expulsion interaction conditions (barrel temperature, screw speed and feed clamminess) had enormous effect ($p < 0.05$) on water ingestion limit of the extrudates. The "preliminary of between-subject effect" of the expulsion interaction limits on water assimilation limit showed that the expulsion cycle limits, including their correspondences, had immense effect ($p < 0.05$) on the water retention limit of the extrudates.

Effect of extrusion process parameters on oil absorption capacity

Figures 7 to 9 present the response surface plot for the effect of barrel temperature and screw speed on oil retention limit; effect of barrel temperature and feed clamminess on oil limit; effect of screw speed and feed moistness on oil assimilation limit.

Oil ingestion limit is the limit of a thing to absorb oil, and this deal with the flavor and augmentation mouth feel of a food material. In Figure 7, the response surface plot exhibited that development in barrel temperature provoked an immediate extension in oil retention limit, while acceleration achieved a decrease in oil assimilation limit of the extrudates. This discernment agrees with the earlier revelations by Omohimi et al. (2014). The extension in oil assimilation limit may be credited to increased level of starch defilement in the extrudates due to high commitment of atomic power (Omohimi et al., 2014).

The response surface plot showing the effect of barrel temperature and feed moistness on oil assimilation limit is presented in Figure 8. It was seen from the plots that extension in both barrel temperature and feed sogginess achieved a sharp development in oil retention limit of the extrudates. In Figure 9, the response surface plot showing the effect of screw speed and feed moisture exhibited that acceleration was achieved early on extension in oil assimilation limit. Further acceleration achieved decrease in oil retention, while development in feed clamminess provoked extension in oil assimilation limit of the extrudates. These discernments are in agreement with the earlier disclosures of Tabibloghmany et al. (2020).

Examination of distinction (ANOVA) at 5% significance level, for the effect of barrel temperature, screw speed and feed soddenness on oil ingestion limit showed that the expulsion cycle limits: barrel temperature (BT); screw speed (SS); feed moistness (FM) generally ($p < 0.05$) influenced the oil assimilation limit of the extrudates.

The "Preliminary of between-subject effect" of expulsion process conditions on oil assimilation limit showed that the expulsion cycle conditions and their associations, beside BT×SS×FM, had tremendous effect ($p < 0.05$) on oil ingestion limit of the extrudates.

Conclusion

This study has shown that extrusion process conditions: barrel temperature; screw speed; feed dampness, and their interactions have both positive and adverse impact on bulk density, water absorption capacity, and oil absorption capacity of the extruded aerial yam-soybean flour mixture. The bulk density of the extrudates was altogether impacted by all the extrusion process conditions. With the exception of the connection of screw speed and feed dampness, which significantly affected the bulk density of the extrudates, the associations of the extrusion conditions also had a meaningful effect on bulk density. The extrusion boundaries and their co-operations significantly affected the water absorption capacity of the extrudates. Oil absorption capacity of the extrudates was altogether impacted by the three extrusion conditions. The co-operations of the process conditions likewise affected oil absorption capacity, with the exception of the connection of barrel temperature, screw speed, and feed dampness. The best extrusion condition blends were 110°C barrel temperature, 130 rpm screw speed and 33% feed dampness for bulk density; 105°C barrel temperature, 115 rpm screw speed and 35% feed dampness for water absorption capacity; and 110°C barrel temperature, 130 rpm screw speed and 37% feed dampness for oil absorption capacity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ahmed Z, Chishti MZ, Johri RK, Bhagat A, Gupta KK, Ram G (2009). Antihyperglycemic and antidyslipidemic activity of aqueous extract of *Dioscorea bulbifera* tubers. Diabetologia Croatica 38(3):63-72.

Alemayehu H, Emire SA, Henry C (2019). Effects of extrusion process parameters on the quality properties of ready-to-eat pulse-based snacks. Cogent Food and Agriculture 5(1):1641903.

Altan A, McCarthy KL, Maskan M (2008). Evaluation of snack foods from barley–tomato pomace blends by extrusion processing. Journal of Food Engineering 84(2):231-242.

Anjineyulu K, Navdeep J, Thimmaiah B (2013). A study on evaluation and characterization of extruded product by using various by-products. African Journal of Food Science 7(12):485-497.

Brand-Miller J, Burani J, Foster-Powell K. (2003). The new glucose revolution pocket guide to the top 100 low GI foods.2nd ed. Marlowe and Company.

Ding QB, Ainsworth P, Plunkett A, Tucker G, Marson H (2006). The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. Journal of Food Engineering 73(2):142-148.

Guldiken B, Yovchev A, Nosworthy MG, Stone AK, House JD, Hood-Niefer S, Nickerson MT (2020). Effect of extrusion conditions on the physical properties of desi chickpea-barley extrudates and quality attributes of their resulting flours. Journal of Texture Studies 51(2):300-307.

Igyor MA, Ikyo SM, Gernah DI (2004). The food potential of potato yam (*Dioscorea bulbifera*). Nigerian Food Journal 22(1):209-215.

Iwe MO (2003). The Science and Technology of Soybean: Chemistry, Nutrition, Processing, Utilization. Rojoint Communication Services Ltd, Enugu, Nigeria. 1-6. ISBN: 978-3212-8-6.

Lazou A, Krokida M (2010). Structural and textural characterization of corn–lentil extruded snacks. Journal of Food Engineering 100(3):392-408.

Lin S, Huff HE, Hsieh F (2000). Texture and chemical characteristics of soy protein meat analog extruded at high moisture. Journal of Food Science 65(2):264-269

Nkubana A, Dusabumuremyi JC, Yadufashije C (2020). Optimization of extrusion conditions for development of fish-maize based extruded snacks by response surface methodology. African Journal of Biological Sciences 2(2):88-99.

Nwosu JN (2014). Evaluation of the proximate and sensory properties of biscuits produced from aerial yam flour (Dioscorea bulbifera). American Journal of Research Communication 2(3):119-126.

Ojinnaka MC, Okudu H, Uzosike F (2017). Nutrient composition and functional properties of major cultivars of aerial yam (*Dioscorea bulbifera*) in Nigeria. Food Science and Quality Management 62(1):10-16.

Olurin TO, Arisa NU, Aworh OC (2006). Influence of pretreatments of drying characteristics of pretreated yam slices. InInternational Conference on Engineering Research and Development (ICER&D 2006) Proceedings held at Benin City, Nigeria pp. 5-7.

Olusegun AA, Stephen AA, Folasade BI, Oladejo D (2016). Effect of extrusion conditions on cassava/soybean extrudates. MOJ Food Processing and Technology 3(1):237-245.

Omohimi CI, Sobukola OP, Sarafadeen KO, Sanni LO (2014). Effect of thermo-extrusion process parameters on selected quality attributes of meat analogue from mucuna bean seed flour. Nigerian Food Journal 32(1):21-30.

Onwuka GI (2005). Food analysis and instrumentation (Theory and practice).Naphtali printers, Lagos Nigeria. ISBN 978047686.

Orkwor GC, Asiedu RS, Ekanayak IJ (1998). Food yams. Advances in Research: International Institute Tropical Agriculture (IITA) Ibadan and National Root Crops Research Institute, (NRCRI) Umudike pp. 187-215.

Peluola-Adeyemi OA, Idowu MA (2014). Effect of extrusion parameters on the physical and functional properties of cocoyam (*Colocasia esculenta*) flour. IOSR Journal of Environmental Science, Toxicology and Food Technology 8:29-34.

Princewill-Ogbonna, I.L., Ezembaukwu, N.C. (2015).Effect of Various Processing Methods on the Pasting and Functional Properties of Aerial Yam (*Dioscoreabulbifera*) Flour.*British* Journal of Applied Science & Technology 9(5): 517-526.ISSN: 2231-0843.

Sanful RE, Engmann FN (2016). Physico-chemical and pasting characteristics of flour and starch from aerial yam. American Journal of Food Science and Nutrition 3(1):1-7.

Strahm BS (2000) Preconditioning. In: Extruders in food applications. M. N. Riaz, (Ed). Boca Raton: CRC Press pp. 115-126.

Tabibloghmany FS, Mazaheri Tehrani M, Koocheki A (2020). Optimization of the extrusion process through response surface methodology for improvement in functional and nutritional properties of soybean hull. Journal of Food Science and Technology 57(11):4054-4064.

Tadesse SA, Bultosa G, Abera S (2019). Functional and physical properties of sorghum-based extruded product supplemented with soy meal flour. Cogent Food and Agriculture 5(1):1707608.

Tiwari A, Jha SK (2007). Extrusion cooking technology: Principal mechanism and effect on direct expanded snacks–An overview. International Journal of Food Studies 6(1).

Vol. 17(6) pp. 122-129, June 2023
DOI: 10.5897/AJFS2022.2186
Article Number: 094050070875
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Nutritional evaluation of flour obtained from *Tacca leontopetaloides* used as an alternative food in Muanza-Mozambique

Arminda Uachisso[1,2,3], Marta Nunes da Silva[4], Daniel Agostinho[1], Olívia Pinho[5,6], Marta W. Vasconcelos[4] and Susana M. P. Carvalho[2]*

[1]Universidade Pedagógica de Maputo, Rua João Carlos Raposo Beirão 135, Maputo, Moçambique.
[2]GreenUPorto – Sustainable Agrifood Production Research Centre/Inov4Agro, DGAOT, Faculty of Sciences, University of Porto, Campus de Vairão, Rua da Agrária 747, 4485-646 Vairão, Portugal.
[3]Universidade Licungo, Faculdade de Ciências e Tecnologias, Campus Universitario do Dondo, Estrada Nacional 6, Sofala, Moçambique.
[4]Escola Superior de Biotecnologia, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Universidade Católica Portuguesa, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal.
[5]Faculdade de Ciências da Nutrição e Alimentação, Universidade do Porto, Rua do Campo Alegre 823, 4150-180 Porto, Portugal.
[6]LAQV/REQUIMTE, Laboratório de Bromatologia e Hidrologia, Departamento de Ciências Químicas, Faculdade de Farmácia da Universidade do Porto, Rua Jorge de Viterbo Ferreira 228, 4050-313 Porto Portugal.

Received 15 March, 2022; Accepted 10 March, 2023

Tubers from wild *Tacca leontopetaloides* plants are frequently used as a food commodity, but when consumed raw it has a bitter taste and can be toxic, thus threatening food security. This study aimed to evaluate the nutritional composition of flour from *T. leontopetaloides* subjected to distinct washing treatments, hoping to improve its suitability as a pivot food commodity in regions affected by poverty and food insecurity, such as Muanza (Sofala, Mozambique). To remove the bitter taste and potentially toxic compounds, flour from *T. leontopetaloides* was subjected to a single washing (SW) and to 13 sequential deep washing cycles (DW). Samples were analysed for several nutritional and mineral parameters, including carbohydrates, proteins, lipids, fibre, energy, phosphorous, potassium, calcium, magnesium, and sodium. Flours prepared with SW had (per 100 g): 5.25 mg proteins, 0.73 mg fats, 0.43 mg fibres, 935 mg phosphorous, 833.7 mg potassium, 120 mg calcium, 275.3 mg magnesium, and 333.6 mg sum. Deep washing significantly decreased protein (80%) and mineral contents (by at least 27%) and eliminated the presence of glycosides and quinones, but a rich nutritional profile was still preserved after this procedure. Overall, *T. leontopetaloides* flour has a balanced nutritional profile when adequately washed, thus serving as a promising food commodity.

Key words: Food processing, food safety, macronutrients, micronutrients, nutritional composition, mineral profiling, washing process.

INTRODUCTION

Muanza is one of the poorest districts in Sofala Province, where agriculture is the basis for the population's sustenance (Pacheco, 2009). However, the prevalence of drylands and cyclical droughts, which characterize this region, compromise subsistence agriculture, leading the population to resort to wild tubers that may be poisonous for food consumption (Ogbonna et al., 2017). This is the case of *Tacca leontopetaloides*, locally known as “pirinde”, which is commonly used as a flour for human consumption (Uachisso et al., 2019). *T. lentopetaloides* is a perennial herbaceous species with a tuberous rhizome, belonging to the Taccaceae family. Tubers of *T. leontopetaloides* are similar in appearance to potatoes, usually with 10 to 15 cm in diameter but reaching 30 cm in rich soils, average weight from 70 to 340 g, but up to 1 kg. They are rich in starch but are generally bitter and almost unpalatable when raw (Murai et al., 1958; Kay, 1987). Several studies have shown that this tuber has anti-nutritional compounds, including cyanogenic compounds such as taccalonolides, which can cause death when the flour is not processed properly (Jiang et al., 2014; Ogbonna et al., 2017; Agus et al., 2021). Processing by immersion in water at room temperature tends to minimize the concentration of these anti-nutritional factors, some of which have beneficial health effects if present in minimal amounts (Ogbonna et al., 2017), allowing to significantly increase its safety for human consumption. The flour from *T. leontopetaloides* is commonly used as a food source in the District of Muanza, in Mozambique, to make a traditional bread (locally known as “micate”) and porridge (“xima”), thus contributing to mitigating hunger arising from the unavailability of food, especially during the dry season. However, its agronomical exploitation is still limited because this tuber is not cultivated in Africa, having persisted in its wild state. Moreover, there is scarce accurate information about its nutritional properties. For many of the developing world's poorest farmers and food-insecure people, tubers, serve as a critical source of food, nutrition and cash income, and they have been particularly important in areas where local agri-food systems are under stress (Scott, 2021).

According to FAO, the number of people affected by hunger has been growing in the last three years, arising to similar values of a few decades ago. This problem is further exacerbated by climate changes, which contributed to the economic slowdown due to extreme climatic variations, negatively impacting food security and sustainable agriculture (FAO, 2018). Extreme climatic variability is the key factor behind the increase in hunger and the cause of serious food crises, hence, the need to invest in the consumption of foods that do not depend much on climatic variations, such as *T. leontopetaloides* that grows in the forest, and can be found even in the dry season. When properly processed before consumption, the flour from *T. leontopetaloides* has great potential as a food source, since it provides several minerals including calcium, iron, potassium, and other micronutrients necessary for the proper functioning of the human organism (Ogbonna et al., 2017). However, the methods used to prepare the flour vary from region to region, potentially resulting in different nutritional compositions (Murai et al., 1958; Roger et al., 2012; Omojola, 2013; Ogbonna et al., 2017). In Muanza region, flour can be obtained by two processes. The first consists of leaving the tubers immersed in the running water of the rivers for seven days, to be later peeled, air-dried and turned into flour. The second process consists of peeling and subsequent immersion and washing cycles (changing the water with each wash). For making traditional bread (micate), a portion of the flour is used still moist (sluge), while the remaining portion is air-dried fully for later use. Most of the population in the district of Muanza uses these techniques; however, there is a lack of knowledge of the effect of these handling procedures on the nutritional value of the flour obtained. As such, this study aimed to evaluate the nutritional composition of flour obtained from *T. leontopetaloides*, after the tubers were submitted to single and multiple washing procedures, in order to identify the nutritional values of the final product consumed by the population.

MATERIALS AND METHODS

Plant and sample preparation

Tubers (*ca*. 5-6) of *T. leontopetaloides* were harvested from 35 plants growing in wild conditions in the District of Muanza (Sofala, Mozambique, latitude 19° 16'43 "S, longitude 34° 53'60" E, altitude 109.7 m), with hot and humid tropical climate and poorly evolved alluvial soils. Samples, collected during the month of October after their physiological maturation (assessed through organoleptic evaluation), had an approximate diameter of 15 cm and 300 g of weight.

For flour preparation (summarized in Figure 1), tubers (with a starting weight of 11 kg) were washed with running water to remove soil residues, peeled and further washed and weighed again (10 kg). Thereafter they were grossly laminated with a cutter, and exposed to room conditions under the sun until drying.

Grinding was carried out in a shredder, and the flour obtained was subjected to immersion in water to separate the sediment from the supernatant, which was discarded. In each washing cycle, samples were submerged in 15 L of water (inside a fabric mesh), hand mixed, and left to rest for 6 min. After this procedure, they were strained using a plastic mosquito net (with a mesh diameter of 0.8 mm) and allowed to settle for 40 min. Sample SW corresponded to flours subjected to a single washing cycle (final weight *ca*. 4 kg), while samples DW were prepared through the same washing procedure repeated until the reddish colour disappeared from the supernatant (13 times, final weight 2.5 kg).

The sedimented portion of each sample, corresponding to the flour, was air-dried during 12 h at 28°C, mown using a sieve (mesh size of 0.6 mm), and stored in plastic jars with a screw cap at 4°C until analysis.

*Corresponding author. E-mail: susana.carvalho@fc.up.pt. Tel: +351 220 402 850.

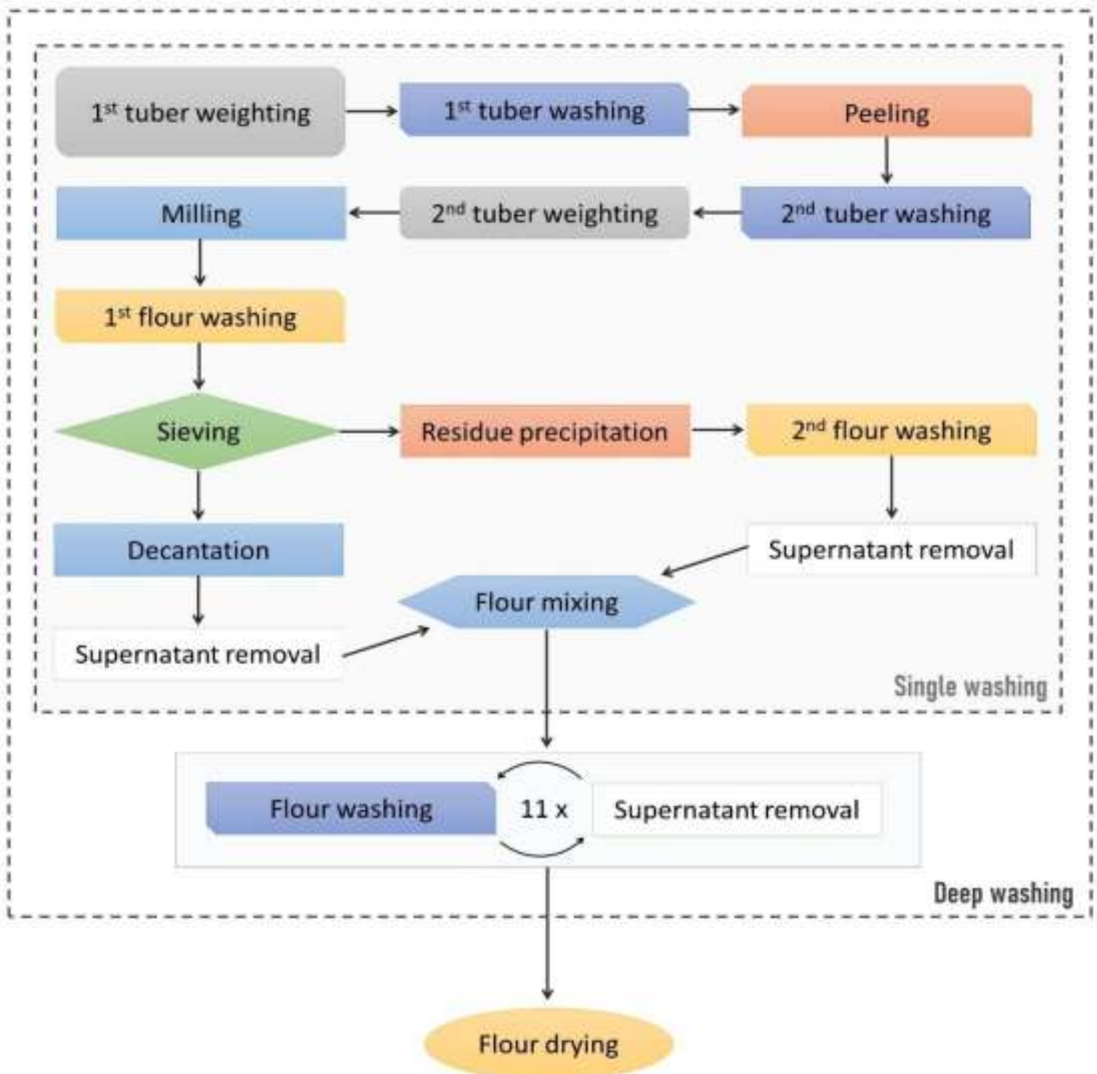


Figure 1. Schematic overview of the procedure used for the preparation of flour from *T. leontopetaloides*.
Source: Authors.

This methodology was implemented to mimic, as much as possible, the procedure most commonly applied by the local population. Samples were subjected to bromatological analysis for the determination of humidity, dry matter, ash, crude fibre and fat, nitrogen (N, for protein calculation), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), and phosphorus (P) (at the Institute of Agricultural Research of Mozambique). Phytochemicals qualitative analysis was performed at the Faculty of Natural Sciences and Mathematics of the Pedagogical University of Maputo (Mozambique).

Bromatological analysis

For the determination of humidity and total ash, 5 g of each flour sample was placed in a preheated oven at 105°C for 2 h, followed by cooling in the desiccator. Sample moisture percentage was determined by the weight difference before and after drying. Total ash was obtained by sample calcination at 600°C for 24 h (AACC, 1995). Fibre determination was based on the destruction of the non-cellulosic organic matter and part of the mineral matter in two successive digestions (acid digestion, followed by basic digestion), as described by Campos et al. (2004). Fat content was determined by the Soxhlet method for 6 h in an extractor, using n-hexane as a solvent (AOAC, 1980). Total proteins were determined by the Kjeldahl method based on the determination of total nitrogen and using the conversion factor 6.25 for conversion to crude protein (AOAC, 1980). Carbohydrates were obtained by difference between 100 and the sum of the percentages of other nutrients (Quadros et al., 2009).

The determination of sodium (Na) and potassium (K) was done by flame photometry (Model DM-ESPEC1, Digimed, São Paulo, Brazil), phosphorus (P), magnesium (Mg) and calcium (Ca) by complexometric titration, as described by Campos et al. (2004).

Phytochemical analysis

Tannins were determined according to Matos (1997), by heating sample extracts in a water bath at 60°C, after which they

Table 1. Nutritional composition of the flours obtained from *T. leontopetaloides* tubers, collected in the wild in Mozambique, after single washing (SW), and after 13 sequential deep washing cycles (DW) (n = 3).

Parameter (%)	Single washing (SW)	Deep washing (DW)	*p*-value
Humidity	12.47 ± 0.14	15.82 ± 0.01	< 0.0001
Dry matter	87.46 ± 0.28	84.13 ± 0.01	< 0.0001
Carbohydrates	78.80 ± 0.12	75.36 ± 0.04	< 0.0001
Proteins	5.23 ± 0.01	0.88 ± 0.01	< 0.0001
Lipids	0.73 ± 0.01	0.75 ± 0.01	> 0.9999
Fibre	0.42 ± 0.01	0.13 ± 0.01	0.9956
Ash	2.35 ± 0.03	7.06 ± 0.01	< 0.0001
Energy	342.67 ± 0.53	312.02 ± 0.41	< 0.0001

Significant *p*-values are highlighted in bold case.
Source: Authors.

were filtered, and 5% ferric chloride was added. The presence of tannins was evaluated by the intensity of the dark green colour resulting from the reaction. Saponins were determined by the foam-agitation test, involving the addition of 5 mL of distilled water to a portion of the sample extract, followed by strong agitation and the addition of a few drops of oil. The formation of permanent foam indicated the presence of saponins (Matos, 1997). Steroids were determined using 2 mL of sample extract, 2 mL of chloroform, followed by 2 mL of concentrated sulfuric acid. The appearance of a reddish-brown ring indicated the presence of steroids (Zucula, 2011).

The presence of flavonoids was determined by the Shinoda test, through reaction with concentrated hydrochloric acid and fragments of magnesium oxide. The appearance of a pink colour indicated the presence of flavonoids. Glycosides were evaluated by the Liebermann test, using 2 mL extract to which 2 mL of chloroform and 2 mL of acetic acid were added. The presence of glycosides was indicated by the appearance of violet to blue to green colouration. The Salkowski test was used for alkaloids quantification, using 2 mL of extract, to which a few drops of Hager's reagent were added. The appearance of a yellow precipitate indicated the presence of alkaloids.

Terpenoids were assessed using a mixture of 5 mL of sample extract with 2 mL of chloroform and 3 mL of H_2SO_4. The appearance of a reddish-brown colour in the interface layer indicated a positive result. The identification of quinones was evaluated by adding 1 mL of an alcoholic extract of each sample to 0.5 mL of 10% NaOH. After gentle stirring for 2 min, the appearance of pink, red or violet colour indicated the presence of quinones. The aforementioned determinations were based on the method of Matos (1997), adapted by Yadav et al. (2014) and Soni and Sosa (2013).

Statistical analysis

Differences between treatments were tested through analysis of variance (ANOVA) and mean separation was done using Student's T-test ($p < 0.05$) in GraphPad Prism v7.0 (GraphPad Software, Inc., California, USA).

RESULTS

The washing procedure affected the yield of flour obtained from *T. leontopetaloides* tubers as the single washing procedure yielded 36% of flour, whereas the deep washing procedure resulted in a yield of 23%. The analysis of the proximal composition of the flours before and after a prolonged wash is as shown in Table 1. Flours subjected to a single wash (SW) had (per 100 g): 78.80 mg carbohydrates, 5.23 mg proteins, 0.73 mg fats, and 0.42 mg fibre, providing 342.67 kcal. Significant differences between samples from SW and DW were observed in terms of humidity, dry matter, carbohydrates, protein, ash and energy, whereas fat and fibre were not affected by the washing procedure. Protein content was the most affected by the washing procedures, with the flour subjected to deep washing (DW) having only 0.88 mg protein per 100 g of flour (that is, 83.1% less than SW). After deep washing, dry matter and carbohydrates also decreased (by 3.8 and 4.4%, respectively), but flour humidity and ash content significantly increased (by 26.9 and 200%, respectively).

Mineral analysis (Table 2) revealed a significant reduction in phosphorus (89.7%), potassium (98.8%), calcium (50.0%), magnesium (27.3%) and sodium (91.4%) after deep washing. Nevertheless, the mineral composition of these flours (DW) remained high, with 96.3 mg of phosphorus, 9.7 mg of potassium, 60.0 mg of calcium, 200.2 mg of magnesium and 28.7 mg of sodium.

Qualitative analysis of phytochemical compounds revealed the presence of alkaloids, glycosides, quinones and saponins in flour samples subjected to just one washing procedure (Table 3). After deep washing, only alkaloids and saponins were detected, that is glycosides and quinones were successfully removed from the *T. leontopetaloides* flour. Steroids, flavonoids, tannins and terpenoids were not detected in none of the flour types (Table 3).

DISCUSSION

In Mozambique, the wild production of *T. leontopetaloides*, locally known as "pirinde", constitutes an important food source from which flour can be

Table 2. Mineral composition of the flours obtained from *T. leontopetaloides* after a single washing (SW), and after 13 sequential washings (deep washing, DW) (n = 3).

Minerals (mg/100 g)	Single washing (SW)	Deep washing (DW)	*p*-value
Phosphorous	937.43 ± 1.48	96.27 ± 0.01	<0.0001
Potassium	833.37 ± 0.24	9.73 ± 0.01	<0.0001
Calcium	120.00 ± 0.12	60.0 ± 0.12	<0.0001
Magnesium	275.30 ± 0.17	200.20 ± 0.12	<0.0001
Sodium	333.57 ± 0.12	28.67 ± 0.09	<0.0001

Significant *p*-values are highlighted in bold case.
Source: Authors

Table 3. Qualitative phytochemical composition of the flours obtained from *T. leontopetaloides* after a single washing (SW), and after 13 sequential washings (deep washing, DW).

Phytochemical compound	Analytical procedure	Result	
		Single washing (SW)	Deep washing (DW)
Alcaloids	Hager test	Present	Present
Steroids	Salkowski test	Absent	Absent
Flavonoids	Shinoda test	Absent	Absent
Glycosides	Liebermann test	Present	Absent
Quinones	Bortraenger test	Present	Absent
Saponins	Foam test	Present	Present
Tannins	Braymer test	Absent	Absent
Terpenoids	Salkowski test	Absent	Absent

Source: Authors

extracted and used to make traditional bread and porridge.

Here, different washing procedures resulted in distinct flour yields, with multiple washing cycles resulting in the lowest yield (23%), likely due to biomass loss during supernatant removal after soaking. Nevertheless, this value is still higher than the yield of flour recovery from *T. leontopetaloides* tubers estimated in previous reports (18 to 20%) (Vu et al., 2017). Previous works by other authors have demonstrated a great heterogeneity in the proximal nutritional and mineral composition of this tuber (Table 4), most likely related to the distinct procedures used to obtain the final product destined for consumption, or to the specific climatic edaphic conditions of each region and time of harvest that can influence its composition (Borokini, 2012; Binh and Dao, 2020).

In the present work, although the 13 subsequent washes of the flour allowed to remove its naturally bitter taste (based on the experience and familiarity with the product from members of this research team and colleagues, which performed a sensorial evaluation), this procedure significantly increased the humidity (Table 1). Therefore, the drying time of the final product should be increased to more than 12 h (which was the drying period used in this work) to improve its shelf life. Due to the washing procedure, a significant reduction in protein content was observed (Table 1). Nevertheless, deep-washed flours from this study had similar or higher protein contents when compared with previous works by other authors, in which no washing or saltwater washing were employed (Murai et al., 1958; Roger et al., 2012; Omoloja, 2013) (Table 4). This evidence supports the use of the deep washing procedure employed in the present work to improve the consumption of flours from *T. leontopetaloides*.

In fact, *T. leontopetaloides* could be a good source of protein to mitigate its nutritional deficit in children, pregnant women and adults who are subject to a great deal of physical effort during their activities in the agricultural fields. Carbohydrates and energy were also slightly decreased with the deep-washing procedure, but their contents remained high, with carbohydrates being inclusively higher in this work than in previous ones by other authors (Murai et al., 1958; Roger et al., 2012; Omoloja, 2013) (Tables 1 and 4).

Nonetheless, as potential losses of protein, carbohydrates or energy in this food commodity are of upmost relevance for the local population (Uachisso et al., 2019), additional efforts in the agronomical and processing handling of *T. leontopetaloides* should be dully pursued to improve its nutritional profile. Lipids and fibre contents were not affected by the washing

Table 4. Description of the traditional processes used in the preparation of flours from *T. leontopetaloides*, and its nutrient and mineral composition. Abbreviations: NA = not analysed.

Reference	Ogbonna et al. (2017)	Omojola (2013)	Roger et al. (2012)	Murai et al. (1958)
Study site and year	Nigeria (Shendam), 2017	Nigeria (Abuja), 2013	Cameroons, 2012	Marshall Islands, 1958
Grinding procedure	Milling device	Grate	Adapted pottery facility	Sharp stone
Washing procedure	No washing	No washing	No washing	Repeated immersion in salt water (inside a cloth)
Filtration procedure	Sari fabric	No filtration	Adapted pottery facility	Cloth
Sedimentation	Phase present	Phase present	Phase absent	Phase present
Humidity (%)	8.66 ± 0.01	9.15 ± 0.02	85 ± 10	12.10
Ash (%)	0.41 ± 0.04	0.20 ± 0.04	1.1 ± 0.0	1.89
Fibre (%)	5.44 ± 0.03	2.10 ± 0.06	2.5 ± 0.7	NA
Lipids (%)	0.51 ± 0.04	0.09 ± 0.01	0.1 ± 0.0	NA
Proteins (%)	6.79 ± 0.02	1.5 ± 0.02	0.99 ± 0.00	0.18
Carbohydrates (%)	78.2 ± 0.05	88.1 ± 0.00	10.31 ± 5.30	85.74
Energy (Kcal)	340	354	46	346
Phosphorous (mg/100 g)	0.06 ± 0.02	NA	NA	7.2
Potassium (mg/100 g)	40.2 ± 0.12	NA	NA	NA
Calcium (mg/100 g)	0.25 ± 0.13	NA	2.6 ± 0.2	58.0
Magnesium (mg/100 g)	1.40 ± 0.01	NA	0.2 ± 0.0	NA
Sodium (mg/100 g)	34.7 ± 0.55	NA	NA	NA
Copper (mg/100 g)	0.68 ± 0.04	NA	1.2 ± 0.0	NA
Iron (mg/100 g)	1.37 ± 0.15	NA	3.7 ± 0.8	0.55
Zinc (mg/100 g)	NA	NA	8.2 ± 1.7	NA
Manganese (mg/100 g)	0.72 ± 0.26	NA	7.3 ± 1.2	NA

Source: Authors

procedure and, while the flours of the present work had higher lipid content than the ones from previous works, fibre content was lower (Tables 1 and 4). It is clear that the handling procedures used to obtain the final product play a major role in the final composition of the flour, but it is noticeable that even after thirteen washes *T. leontopetaloides* flour still has a high nutritional value and can serve as a food amenity for the local community, particularly during critical drought periods where the food crisis is aggravated.

The flour from *T. leontopetaloides* of the present work was very rich in ash, compared with previous works by other authors (Tables 1 and 4), providing an indication of its richness in minerals. As macrominerals make up more than 0.005% of the human body and we require more than 100 mg of macrominerals per day including calcium, magnesium, phosphorus, potassium, sodium and sulphur (Hark, 2005), the flour from *T. leontopetaloides* has potential to meet this dietary requirement, making it a good resource as food and feed (Bosha et al., 2015). Nevertheless, we observed that the method used to obtain the flour plays a major role not only in its ash content, but also in its mineral composition (Table 2). Although deep washing significantly decreased phosphorous, potassium, calcium, magnesium and sodium (from 27.3 to 98.8%), compared with flours resulting from a single washing, phosphorous, calcium, magnesium remained elevated, being inclusively higher than the values reported by other authors (Tables 1 and 4). The daily intake of phosphorous, required for several metabolic processes of the muscular and nervous systems and an integral part of many enzymatic systems, should be around 700 mg/day, while calcium, the main mineral present in bones and teeth and involved in the blood clotting process and neuromuscular functions, has a daily intake value of 600 to 1000 mg/day. A fraction of these levels could be met by a provision of *T. leontopetaloides*-derived food products, after safety components have been assured. Phosphorous and calcium deficiency can remain hidden for several years, causing e.g., anaemia, bone and muscle weakness and stunted growth (Hark, 2005). Thus, to suppress their dietary needs, the daily intake of deep-washed flours from *T*. *leontopetaloides* should be at least 700 g, reason why its consumption should be complemented with other food amenities to guarantee the minimum daily intake of these minerals. In contrast, 175 g of deep-washed flours from *T*. *leontopetaloides* are sufficient to ensure the minimum daily intake of magnesium (350 mg/day). This mineral plays a vital role in the formation of bones and teeth, and together with other minerals it is involved in the transmission of nervous signals and muscle contraction, also contributing to the synthesis of proteins (Hark, 2005). Therefore, *T*. *leontopetaloides* is a good source of magnesium, particularly for the population of the district of Muanza that have access to a limited variability in their food options (Uachisso et al., 2019).

It has been demonstrated that the preparation process negatively affects the content of the several anti-nutrient compounds in flours from *T*. *leontopetaloides*. Repeated immersion of the tuber for 36 h led to a 90% reduction in these compounds (Ndouyang et al., 2015). Variations in the presence of alkaloids and glycosides were observed in leaves and tubers of *T*. *leontopetaloides*, with environmental factors having a small effect on the phytochemical content of plants from different locations (Borokini et al., 2012).

Qualitative analysis of the phytochemical composition of the flours from *T*. *leontopetaloides* (Table 3) revealed the presence of alkaloids and saponins. Similar results were observed by Borokini et al. (2012) in flours of this tuber, raising questions on food security due to their toxicity and anti-nutritional character. Nevertheless, this limitation can be overcome with heat treatment during the cooking procedures, improving the beneficial role of these metabolites in promoting human health when consumed in lower concentrations (Benevides et al., 2011).

Borokini et al. (2012) also reported the presence of tannins, anthraquinones and glycosides, which were not detected or were lost with the deep-washing procedure. Contrastingly, increased concentrations of antinutrients, such as oxalates, phenolics, tannins and cyanides, were reported after tuber soaking for 72 h (Ndouyang and Schinzoumka, 2022). These differences in the phytochemical composition of flours from *T*. *leontopetaloides* likely result from intraspecific differences among distinct geographical areas and, most importantly, from the preparation procedure employed. As such, the consumption of this flour would benefit from a standardized preparation method to minimize the toxic effects and enhance the nutritional properties of this wild plant (Omojola, 2013). Therefore, it will be relevant for governmental entities to make recommendations both in agricultural production, concerning the cultivation of this tuber, and in the technology applied to obtain this food amenity.

Conclusion

Results showed that *T*. *leontopetaloides* flour has a relevant nutritional value to serve as an alternative source of food for the population of the district of Muanza, where food shortages and "hidden hunger" are a reality. It is also concluded that the studied deep washing procedure (13 times) leads to relevant losses in terms of nutrients and bioactive compounds (glycosides and quinones). Therefore, further studies are needed to evaluate the impact of less intensive washing procedures, to minimize the loss of beneficial minerals and nutrients, but still ensuring food safety. The implementation of standardized procedures by official entities concerning the production of flours from *T*. *leontopetaloides* could increase its nutritional value and consumption, thus contributing to mitigating the dietary challenges endured by local populations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors thank Fundação para a Ciência e a Tecnologia (FCT) for funding within the scope of UIDB/05748/2020, UIDP/05748/2020, UIDB/50016/2020.

REFERENCES

Agus W, Suganda AG, Fidrianny I (2021). Acute toxicity of jalawure (*Tacca leontopetaloides* (L.) Kuntze) and gadung tikus (*Tacca palmata* Blume) using zebrafish (*Danio rerio*) embryos as a model. International Journal of Research in Pharmaceutical Sciences 12:1247-1253.

American Association of Cereal Chemists (AACC) (1995). Ash – Basic method" in approved methods of the American Association of Cereal Chemists, 9th edition.

Association of Official Analytical Chemists (AOAC) (1980). Official methods of analysis of the Association of Official Analytical Chemists. 13th edition (in Ed. Horwitz, W.), pp. 211-232.

Benevides MJ, Souza MV, Souza RDB, Lopes MV (2011). Fatores antinutricionais em alimentos. Campinas, Segurança Alimentar e Nutricional 18(2):67-79.

Binh HT, Dao VT (2020). Study on the effects of harvesting time and storage conditions of *Tacca leontopetaloides* (L.) Kuntze Tuber in an Giang Province, Vietnam. Earth and Environmental Science 515:012033.

Borokini T, Ayodele A., Plantation M (2012). Phytochemical screening of *Tacca leontopetaloides* (L.) Kuntze collected from four geographical locations in Nigeria. International Journal of Modern Botany 2(4):97-102.

Bosha JA, Anaga A, Asuzu IU (2015). Chemical composition of the marc of a wild tropical plant *Tacca involucrata* (Schumach and Thonn, 1827). Food and Nutrition Sciences 6(1):135-140.

Campos FP, Nussio CMB, Nussio LG (2004). Métodos de análise de alimentos. FEALQ, Piracicaba, Brazil, 135 p. Available at: https://repositorio.usp.br/item/001385689.

Food and Agriculture Organization (FAO) of the United Nations (2018). The state of food security and nutrition in the world 2018: Building climate resilience for food security and nutrition. In The State of the World series. Available at: http://www.fao.org/3/i9553en/i9553en.pdf.

Hark L (2005). Saúde e Nutrição. Livraria Civilização Editora, Porto, Portugal, 62-63p.

Jiang J, Yang H, Wang Y, Chen Y (2014). Phytochemical and pharmacological studies of the genus Tacca: a review. Tropical Journal of Pharmaceutical Research 13:635-648.

Kay DE (1987). Crop and Product Digest Nº 2 - Root Crops (revised by Gooding EGB), 2nd Edition. Tropical Development and Research Institute, London, United Kingdom, 380p.

Matos FJA (1997). Introdução à Fitoquímica Experimental, Edições UFC, Fortaleza, Brazil. 2nd Edition, 141p.

Murai M, Pen F, Miller CD (1958). Some Tropical South Pacific Island Foods: Description, History, Use, Composition, and Nutritive Value. University of Hawaii Press, Hawai. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ctahr.hawaii.edu/oc/freepubs/pdf/B-110.pdf

Ndouyang CJ, Njintang NY, Facho B, Scher J, Mbofung CM (2015). Effect of processing method on the antinutrient content of *Tacca leontopetaloides* (L.) Kuntze flour. British Journal of Applied Science and Technology 5:258-269.

Ndouyang CJ, Schinzoumka PA (2022). Effect of uncontrolled fermentation and soaking on antinutrients of *Tacca leontopetaloides* (L) Kuntze (Taccaceae) tuber flour. International Journal of Agricultural Policy and Research 10(1):1-9.

Ogbonna AI, Adepoju SO, Ogbonna CIC, Yakubu, T, Itelima JU, Dajin VY (2017). Root tuber of *Tacca leontopetaloides* L. (Kunze) for food and nutritional security. Microbiology: Current Research 1(1):7-13.

Omojola MO (2013). Tacca starch: a review of its production, physicochemical properties, modification and industrial uses. African Journal of Food, Agriculture, Nutrition and Development 13(4):7972-7985.

Pacheco JAA (2009). Estratégias para sustentabilidade da flora bravia nas comunidades do distrito de Muanza, província de Sofala-Moçambique. MSc Dissertation, Universidade Estadual do Ceará, Centro de Ciências e Tecnologia, Fortaleza, Brazil, 117 p. Available at: http://bdtd.ibict.br/vufind/Record/UECE-0_004e304b4fdf831b5db6cd4428e92631.

Quadros DA, Iung MC, Ferreira SM, Freitas RJ (2009). Composição química de tubérculos de batata para processamento, cultivados sob diferentes doses e fontes de potássio. Journal of Food Science and Technology 29:316-323.

Roger DD, Justin ENJ, Francois-Xavier E (2012). Nutritional properties of “Bush Meals” from north Cameroon’s biodiversity. Advances in Applied Science Research 3(3):1482-1493.

Scott GJ (2021). A review of root, tuber and banana crops in developing countries: past, present and future. International Journal of Food Science and Technology 56:1093-1114.

Soni A, Sosa S (2013). Phytochemical analysis and free radical scavenging potential of herbal and medicinal plant extracts. Journal of Pharmacognosy and Phytochemistry 2:22-29.

Uachisso A, Padrão P, Carvalho SMP, Agostinho D, Pinho O (2019). Analysis of the nutritional composition of the typical meals of the rural workers in the Muanza District in Sofala - Mozambique. Proceedings of the Third Doctoral Congress in Engineering, 27-28 June 2019, Porto, Portugal.

Vu QT, Le PT, Huy PH, Nguyen TT, Nguyen TK (2017). Characteristics of *Tacca leontopetaloides* L. Kuntze collected from An Giang in Vietnam. AIP Conference Proceedings 1878:020022.

Yadav M, Chatterji S, Gupta S, Watal G (2014). Preliminary phytochemical screening of six medicinal plants used in traditional medicine. International Journal of Pharmacy and Pharmaceutical Sciences 6(5):539-542.

Zucula CV (2011). Avaliação *in vitro* da actividade antifúngica de extractos de plantas Kigelia africana, *Combretum molle* e *Trichilia emetica* para o controlo de fitopatógenos. BSc Dissertation, Universidade Eduardo Mondlane, Faculdade de Ciências, 62p. Available at: http://monografias.uem.mz/jspui/handle/123456789/262.

Related Journals: