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Valorization of Yams into Enriched Cossettes and Flours

Khady Ndiaye[1,2,*], Nouria Hadhirani Ali[2], Mamadou Faye[1,2,3], Seyni Bineta Ndiaye[1,2], Bou Ndiaye[1,4]

[1]Water, Energy, Environment, and Industrial Processes Laboratory (LE3PI), ESP, UCAD BP 5085, Senegal.
[2]Cheikh Anta DIOP University, Dakar-Fann BP 5005, Senegal.
[3]Department of Chemical Engineering and Applied Biology, ESP BP 5085, Senegal.
[4]Sine Saloum University El Hadj Ibrahima Niass USSEIN, Kaolack BP 52, Senegal.

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Corresponding author: Khady Ndiaye, Water, Energy, Environment, and Industrial Processes Laboratory (LE3PI), ESP, UCAD BP 5085, Senegal; Cheikh Anta DIOP University, Dakar-Fann BP 5005, Senegal.

Abstract

Yams are a starchy food with high nutritional value, originating mainly in West Africa, Southeast Asia, and America. They belong to the Dioscorea genus, which includes many species cultivated for their floury tubers rich in carbohydrates, the main component of which is starch. However, fresh yams deteriorate rapidly, resulting in huge annual losses. The aim of this study is to add value to yams by processing them into flakes and enriched flour in order to extend their shelf life and improve the nutritional and organoleptic qualities of the flour. Three types of yam-based flour were formulated. Formula F1 is composed of three varieties of yams, while formulas F2 and F3 have been enriched with peanuts and maize. The results showed that enriched flours F2 and F3 are richer in protein (11.17% and 13.57% respectively) than flour F1, which is made exclusively from three varieties of yams (8.78%). All three flours are rich in important minerals (Ca, Fe, Mn, Zn, K, Se). However, formula F1 has a higher K, Ca, S, and Fe content than formulas F2 and F3. The organoleptic qualities of formulas F2 and F3 are better (taste, color, smell, and texture) than those of formula F1. Thus, yams can be used to make high-quality, consumable, and preservable finished products, thereby contributing to food security.

Keywords

Yams; Valorization; Nutrients; Flours

1. Introduction

Yam is a common name for several species of plants belonging to the genus Dioscorea, family Dioscoreaceae, cultivated in all tropical regions of the world for food, for their starch-rich tubers [1, 2].

Yam is a food crop of primary importance, with a production of 71 million tons in 2017. Yams are the staple food for more than 500 million people in certain tropical countries in Africa, particularly in West Africa, where 92% of global production comes from this area now known as the yam belt, as well as in the Caribbean, Oceania, Latin America, and Asia [3-5].

Yams are the second most widely cultivated tropical root crop after cassava and are a highly prized foodstuff due to their tubers, which are rich in starch, minerals, proteins, lipids, and carbohydrates. In addition to their nutritional value, yams improve intestinal transit, aid digestion thanks to their high fiber content, and can help combat famine and malnutrition [6-8].

In addition to its high nutritional value, yams have functional properties that are beneficial to health: their high dietary fiber content promotes intestinal transit and improves digestion[9].

In addition to its highly appreciated organoleptic qualities, mainly taste and texture, yams enjoy a reputation as a prestigious product with high nutritional and dietary value, enabling them to compete with other starchy foods such as cereals and cassava [1, 10].

The introduction of yams to the Comoros (an archipelago located in the Indian Ocean, between the Mozambique Channel and Madagascar) and their cultivation probably dates back to the arrival of the Bantu or the Malagasy raiders who settled in the country [11]. It has become a profitable source of income for many producers, especially in rural areas [12], as it can produce several tubers in less space than any other major crop, even in the harshest climatic conditions. Since then, yams have contributed to ensuring food security and reducing poverty in this country, which depends on foreign income, notably 75% of imports of primary products [13].

Most African countries face food security issues [14]. Their agricultural production comes from family farms intended for self-consumption. It is therefore essential to identify ways of adding value to agricultural products in order to reduce dependence on food imports by ensuring availability, stability, and access to products; increase the income of those involved in the sector in order to generate exportable surpluses to promote the country's development [15-17].

However, fresh yam tubers are difficult to store and spoil very quickly, resulting in huge annual losses.

Previous work has been undertaken by several researchers in this area:

Flora M'modjou N'Goran et al. [18] studied the nutritional composition of yams grown in association with rubber trees and cocoa.

R H Gampoula et al. [18] developed a process for formulating infant flour based on yam (Discorea cayenensis) enriched with protein through the incorporation of food additives.

H. ATTAIE et al. [19] reviewed the current state of knowledge and research on the processing and food uses of yams.

The overall objective of this study is to contribute to the promotion of yams by processing them into flakes and flours enriched with good nutritional and organoleptic qualities.

2. Materials and Methods

2.1 Materials

2.1.1 Plant Material

Four varieties of yams (*Dioscorea alata L., Dioscorea rotundata, Dioscorea spp., Dioscorea esculenta L.*), maize, and peanuts were used as plant material.

The four yam varieties are shown in Figure 1.

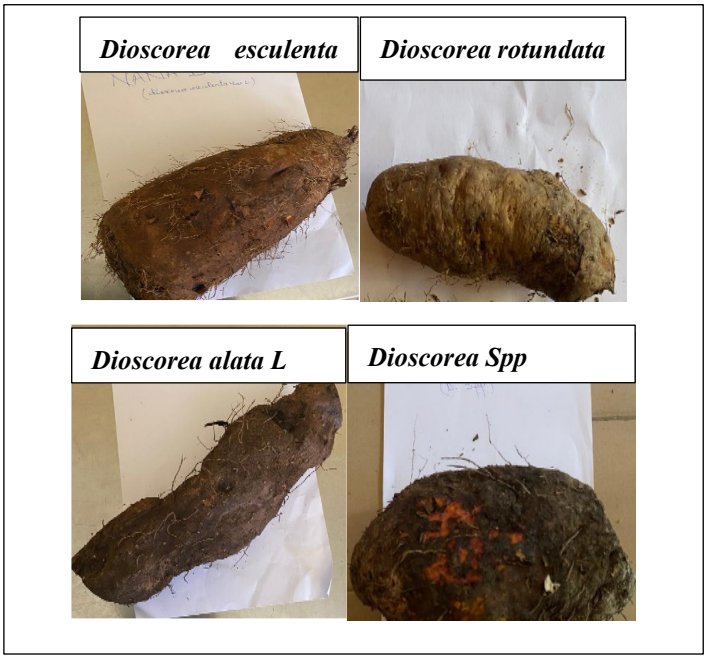

Figure 1. Yam varieties.

The maize and peanuts used are shown in Figure 2.

Figure 2. Illustrative image of corn and peanuts.

2.2 Methods

2.2.1 Analytical Methods

Mineral characterization was performed by X-ray fluorescence spectrometry using a Niton XL3T XRF analyzer connected to a computer running NDTr 6.5.2 software.

Protein content was determined using the NFV 18-100 method.

Microbial load was characterized using the NF V08-051 method.

Quantitative color analysis was performed using a Minolta CR-5 colorimeter with the CIELab system.

2.2.2 Seed Roasting Method

The roasting of maize and peanuts was carried out in an oven. The roasting time/temperature combination was determined using the design of experiments (DOE) method. JMP Pro software was used, and the composite central design model was applied.

Temperature (°C) and time (h) were the parameters imposed on the software (minimum values of 80°C for temperature and 1 h for time). Maximum values were 110°C for temperature and 5 h for time. The execution of the design generated ten trials, the parameter combinations of which are shown in Table 1.

Table 1. Experimental Matrix for Roasting

Test numbers	Température (°C)	Time (h)
1	110	5
2	80	5
3	95	3
4	80	1
5	110	3
6	95	3
7	110	1
8	95	5
9	95	1
10	80	3

The temperature/time combination (110°C/3h) was chosen because it offered the best organoleptic qualities.

2.2.3 Formulation Protocol

2.2.3.1 Cossette Formulation Diagram

The steps in the cossette formulation are shown in Figure 3.

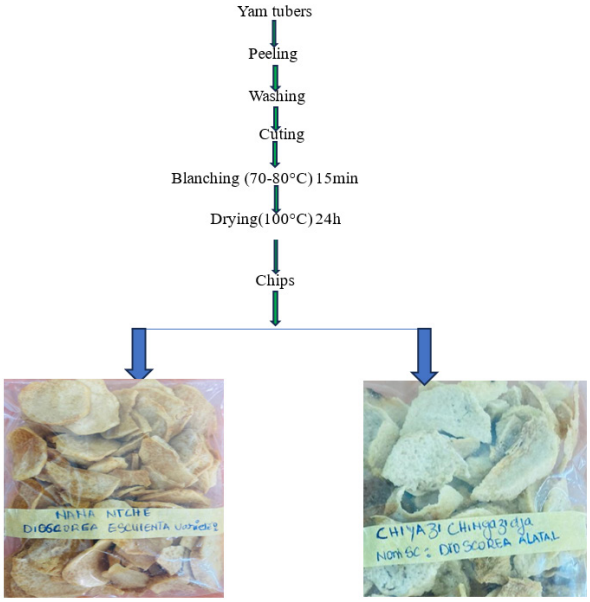

Figure 3. Formulation diagram of cossettes of the varieties *Dioscorea Esculenta* and *Dioscorea Alata. L*.

2.2.3.2 Flour Formulation Diagram

The formulation of the yam-based flours was carried out in three stages:

- A yam flour only, named (F1), composed of the varieties *Dioscorea Esculenta* variety 1, *Dioscorea spp.*, and *Dioscorea alata L.*
- A yam flour combined with equal proportions of peanut and maize flour, named (F2).
- A yam flour incorporated with peanut and maize flour, in which the yam flour is the largest component (50%) and the other two are in equal proportions (25%), named (F3).

The formulation diagram for flour F1 is shown in Figure 4, that for flour F2 in Figure 5, and the diagram for flour F3 in Figure 6.

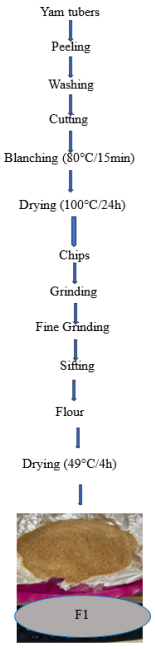

Figure 4. Formulation diagram of flour F4.

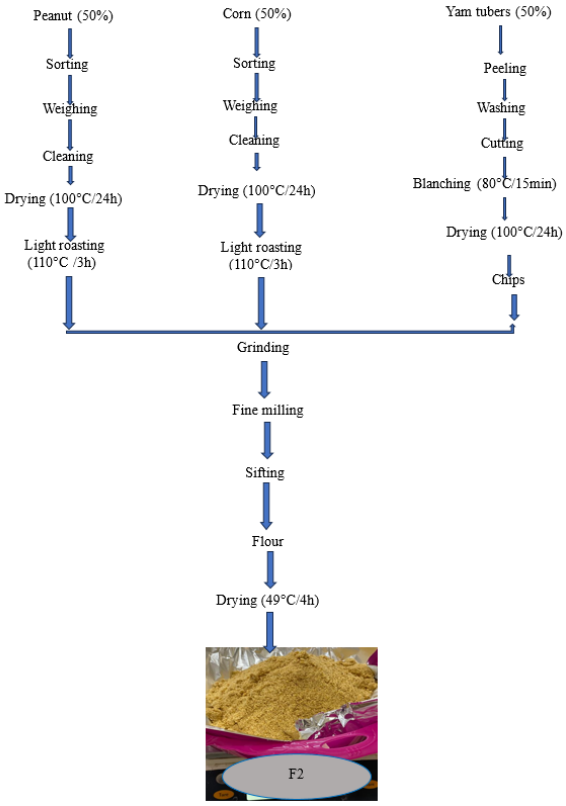

Figure 5. Steps in the formulation of enriched flour F2.

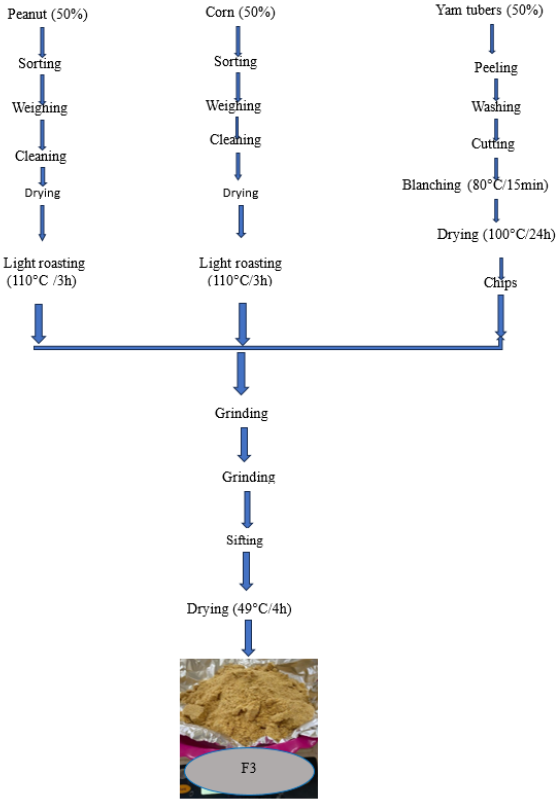

Figure 6. Steps in the formulation of enriched flour F3.

3. Results and Discussion

3.1 Characterization of Total Protein

Three yam-based flours were formulated. Formula F1 is 100% yam. F2 is 50% yams, 25% peanuts, and 25% maize. Formula F3 is composed of 50% yams, 50% peanuts, and 50% maize. Table 2 presents the protein content of the three formulas F1, F2, and F3.

Table 2. Protein Content of Flours (F1, F2, F3)

ELEMENTS	RESULTS	METHODS
	Protein (N*6.25) (%)	
F1	8.78	NFV 18 - 100
F2	11.17	NFV 18 - 100
F3	13.57	NFV 18 - 100

Flour F3, enriched with 50% legumes (peanut, maize), and flour F2, enriched with 25% legumes, are richer in protein (13.57%) and (11.17%), respectively, than formula F1, which is composed of 100% yam. This result was predictable since the protein content per 100g of maize is 9.42g and approximately 25.8g/100g of peanut [21, 22].

The protein content (8.78%) of yam-based flour F1 is close to that of gofio flour (7.9%) [23], which is very popular in Senegal. The protein content of flour F1 is similar to the FAO standard of 7.7% of the total protein content of yams, as well as the study on yam protein by J. Berthaud et al., who obtained a value of 7.41%.

3.2 Characterization of Total Minerals

The mineral characterization of the three yam-based formulas F1, F2, and F3 was carried out by X-ray fluorescence spectrometry. Table 3 presents the results obtained.

Table 3. Mineral content of flours F1, F2 and F3

Formulas (ppm)	Mo	Se	Zn	Cu	Ni	Co	Fe	Mn	Ca	K	S
F2	1.70	0.80	40.48	3.97	0.62	0.03	80.08	8.06	456.54	1819.42	604.59
F3	1.46	0.40	32.86	4.32	0.40	0.02	86.28	5.46	509.96	2293.33	643.27
F1	1.48	0.49	17.10	2.43	0.41	0.03	94.27	5.41	538.33	2654.78	752.45

Notes. All three formulas are rich in potassium, calcium, sulfur, iron, and zinc.

Formula F1 has a higher potassium (K) content than F2 and F3. Flora M'modjou N'Goran reported a potassium content of 1814 mg/100g, with traces of manganese, copper, and calcium for the undergrowth yam. The high calcium, iron, zinc, and sulfur content could therefore be explained by the blending of three different varieties.

3.3 Sensory Testing

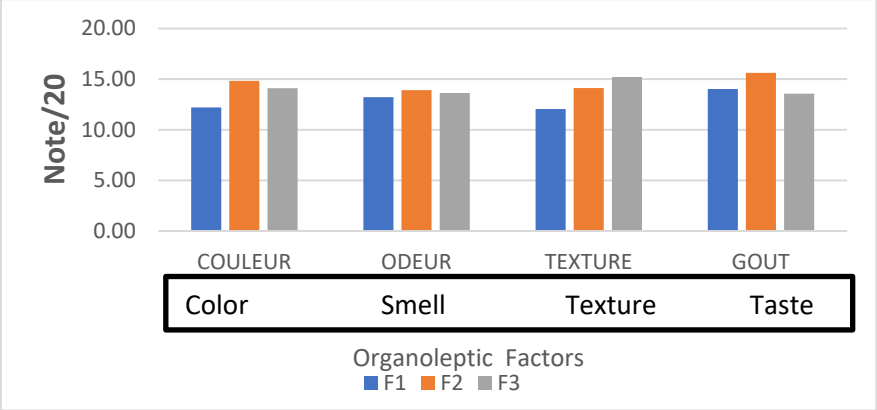

Figure 7. Average Sensory Test Scores for Flours F1, F2, and F3.

The sensory quality of the three formulations (F1, F2, and F3) was evaluated. Color, odor, texture, and taste were tested by 24 carefully selected individuals. The average scores for the organoleptic parameters are shown in Figure 7.

The taste, color, and aroma of formula F2 were the most appreciated. The taste of formula F1 was also well rated, but its texture and color were not well appreciated.

3.4 Color Characterization

The results of the quantitative color analysis of formulas F1, F2, and F3, performed using a colorimeter, are presented in Table 4.

Table 4. Color parameters L (luminescence), a* (red/green color ratio), b* (yellow/blue color ratio), and YI (Yellowing Index) of flours F1, F2, and F3

	F1	F2	F3
L	68.54	66.2	67.53
a*	5.66	5.83	5.9
b*	19.2	29.91	27.56
YI	34.44	50.82	47.05

Notes. Quantitative color analysis confirms the qualitative results (sensory tests). Indeed, the yellow color of formula F2 (b*=29.91 and YI=50.82) is greater than that of F3 (b*=27.56 and YI=47.25). Formula F1 is less yellow than the others. These results corroborate those of the sensory test.

4. Conclusion

The results of this study on the valorization of Comorian yams into chips and fortified flour have made it possible to:

Highlight practical methods for the long-term preservation of yams;

Demonstrate that there is a way to incorporate other products to improve the organoleptic and nutritional value of yam flour;

Understand that blending several varieties results in a flour richer in nutrients than a flour made from a single variety.

Formula F3 (composed of 50% yams, 50% peanuts, and 50% corn) is richer in protein (13.57%). Formula F2 (25% yams, peanuts, and corn) has 11.17% protein, while formula F1, without any added ingredients, is lower in protein (8.78%).

All the formulated flours are rich in minerals (Ca, K, Mn, Fe, Zn).

F2 flour is particularly appreciated for its color, taste, aroma, and texture.

These enriched flours and the cossettes can therefore contribute to strengthening the nutritional intake of adults. Furthermore, they can help prevent annual losses and thus significantly boost the local economies of African countries.

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