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Effect of cooking time on some proximate and mineral composition of bulbils flour from yam (*Dioscorea bulbifera*)

Yapi Jacques ACHY [1,*], Daouda KONE [2], Akissi Arlette N'GUESSAN [1] and Patrice Lucien KOUAME [2]

[1] *Department of Biology and Geology, University Alassane Ouattara, BP V 18 Bouaké 01, Côte d'Ivoire.*

[2] *Department of Food Science and Technology, University Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire.*

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Abstract

The bulbils of yam (*Dioscorea bulbifera*) cultivar "dougou-won", grown in Côte d'Ivoire, are mainly consumed in rural areas during periods of food scarcity. Their consumption requires various cooking methods, including baking. The present study aimed to evaluate the impact of baking time on the levels of physicochemical and mineral parameters in order to determine whether this cooking method is suitable for human consumption. The bulbils used in this study were harvested at physiological maturity in Agou, a village located in southeastern Côte d'Ivoire. After harvesting, the samples were transported to the laboratory where they were processed into three types of flour after being baked in an oven for 10, 20 and 30 minutes respectively. These flours were designated as FF10, FF20 and FF30, corresponding respectively to flours obtained from bulbils yam cooked for 10, 20 and 30 minutes. The physicochemical and mineral contents of these flours were subsequently determined using standard analytical methods. Excepted for proteins, starch, phosphorus, sodium and magnesium, whose levels decreased in the flours, baking after 30 minutes preserved the contents of total carbohydrates, ash, dry matter and potassium, with no significant effect on these components. In contrast, baking significantly increased the levels of lipides, total sugars, calcium and iron. Therefore, baking method appears to be an appropriate cooking method for the consumption of bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won".

Keywords: Baking; Physicochemical Parameters; Dougou-Won; Food Scarcity; Côte d'Ivoire

1. Introduction

Food constitutes an essential factor in maintaining human health and in the socio-economic developments of communities. In tropical countries, particularly in Côte d'Ivoire, food crops play a significant role in dietary habits and contribute significantly to household food security. Among these crops, yam is a staple food for people in several regions and remains the country's main food crop, ahead of cassava, plantain and rice [1]. The yam belongs to the genus *Dioscorea*, which comprises more than 600 species [2]. Among these species, *Dioscorea bulbifera*, cultivated for its bulbils, constitutes an important food resource, particularly during periods of food scarcity [3]. These bulbils are rich in carbohydrates, contain proteins as well as essential minerals ([4], [5]). Despite this nutritional potential, the bulbils of yam (*Dioscorea bulbifera*) remain underutilized and undervalued. The processing of these bulbils into flour constitutes a promising approach not only for their preservation but also for diversification of their food uses. Several technological processes exist to improve the nutritional quality of flours. However, the effect of baking on the biochemical and mineral characteristics of bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won", remains poorly understood.

* Corresponding author: Achy Yapi Jacques

Thus the objective of this study is to evaluate the impact of baking time on biochemical and mineral compositions of bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won", in order to determine whether this cooking method is suitable for human consumption.

2. Materials and Methods

2.1. Materials

The bulbils from yam (*Dioscorea bulbifera*) used in this study (Figure 1) are harvested at physiological maturity, six months after planting in a field located in Agou, a village in south-eastern Côte d'Ivoire. After harvesting, the samples are immediately transported to the Biocatalysis and Bioprocesses Laboratory, where they are stored under controlled conditions at a temperature of 28 °C ± 3 °C and a relative humidity of 82 ± 5 %.

Figure 1 Bulbils from yam (*Dioscorea bulbifera*) cultivar **"**dougou-won"

3. Methods

3.1. Preparation of cooked bulbils flours

Bulbils of yam (*Dioscorea bulbifera*) (2 kilograms) are washed in drinking water to remove any impurities, then peeled using a stainless-steel knife. The peeled samples are rinsed twice in clean water and cut into pieces weighing approximately 50 grams. They are baked in an oven at 100°C for periods of 10 minutes, 20 minutes and 30 minutes respectively. The hot samples are removed from the oven and left to cool in the open air for 25 minutes. They are then dried at 45°C in a forced- air oven (MEMMERT) for 48 hours. After removal from the forced-air oven, the dried samples were ground into various fine flours. These different flours are obtained after sieving using a 250 micrometers mesh sieve. The various flours are packaged in airtight plastic bags and stored in the refrigerator for subsequent analysis.

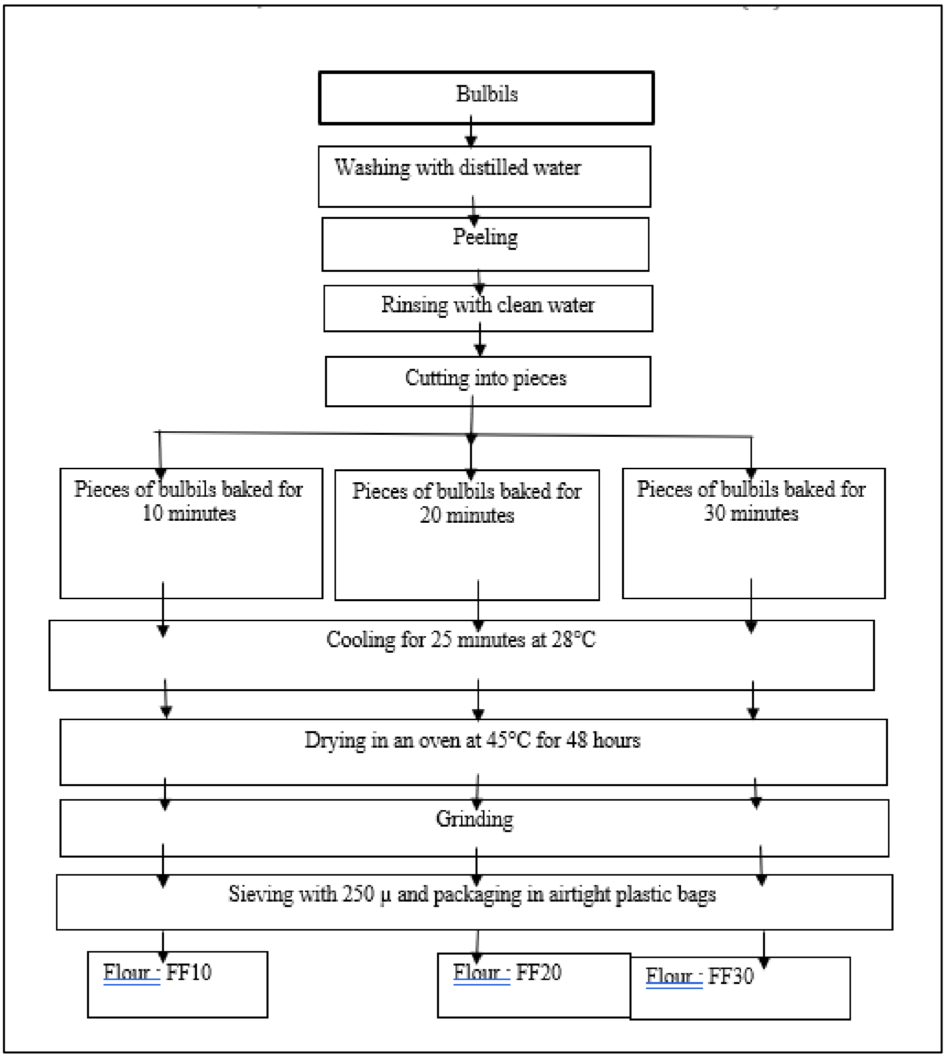

Figure 2 Flowchart for production of baked bulbil flours from yam (*Dioscorea bulbifera*)

3.2. Proximate composition

The dry matter contents of flour are determined by oven drying at 105°C during 24 hours until constant weight is obtained [6].

The total ash contents are determined by incinerating 2 grams of flour in a muffle furnace at 550°C for 6 hours, then weighing the residue after cooling to room temperature in a desiccator [6].

- The method described by [7] is used for the total sugar contents analysis.
- The reducing sugar contents are determined according to the method [8], using 3,5-dinitrosalicylic acid.
- Crude protein contents are calculated from nitrogen contents (N × 6.25) obtained using the Kjeldahl method by [6].
- The crude fat contents are determined by continuous extraction in a Soxhlet apparatus for 8 hours using hexane as solvent [6].
- Total carbohydrate contents are determined by deference that is deducting the mean values of other parameters that are determined from 100 [9]. Therefor,

$$\text{Carbohydrate (\%)} = 100 - [\text{total ash (\%)} + \text{crude protein (\%)} + \text{crude fat (\%)} + \text{moisture (\%)}]$$

Starch content is determined using the polarimetric method described by [10].

3.3. Mineral composition

Minerals of bulbils flour, such as sodium (Na), magnesium (Mg), iron (Fe), calcium (Ca) and potassium (K), are determined using the [6] method. Flours are acid- digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L), and analyzed using an atomic absorption spectrophotometer (VARIAN, model AA-20). Total phosphorus (P) is determined using the micro-colorimetric method described by [11]. The results were expressed in mg/100 g dry matter.

3.4. Statistical Analysis

All analyses are carried out in triplicate. Statistical significance is established using analysis of Variance (ANOVA) models to estimate effect of cooking time on some proximate and mineral composition of bulbils flour from yam at 5% level. Means comparison is carried out using Duncan's multiple range test (P≤ 0.05), with the help of the software STATISCA 7.1 (Stat Soft Inc, Tulsa USA Headquarters).

4. Results

4.1. Proximate composition

Table 1 shows the effect of baking after 30 minutes on the proximate composition of bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won". This study shows that baking after 30 minutes had varying effects on proximate composition of bulbils' flours.

Table 1 Proximate composition of flours from baked bulbils yam (*Dioscorea bulbifera*) cultivar **"dougou-won"**

	FF10	**FF20**	**FF30**
Dry matter (%)	93.83 ± 0.03^{A}	93.93 ± 0.03^{A}	94.04 ± 0.03^{A}
Total ash (%)	3.43 ± 0.01^{A}	3.42 ± 0.01^{A}	3.40 ± 0.01^{A}
Crude protein (%)	8.06 ± 0.01^{B}	7.98 ±0.02^{AB}	7.89 ± 0.01^{A}
Crude fat (%)	2.37 ± 0.02^{A}	2.40 ± 0.01^{B}	2.45 ± 0.02^{C}
Total sugar (%)	3.28 ± 0.02^{A}	3.40 ± 0.05^{B}	3.51 ± 0.04^{C}
Reducing sugar (%)	0.49 ± 0.05^{A}	0.56 ± 0.06^{B}	0.62 ± 0.07^{C}
Total carbohydrate (%)	79.97 ± 0.03^{A}	80.11 ± 0.03^{A}	80.3 ± 0.03^{A}
Starch (%)	70.18 ± 2.17^{C}	64 ± 1^{B}	60 ± 3^{A}

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of common letter are significantly different between them on the threshold of 5% according to the test of Duncan. FF10, FF20, FF30 means flours from bulbils of yam (*Dioscorea bulbifera*) baked at 100°C during 10, 20 and 30 minutes respectively.

For certain components, such as crude fat, reducing sugar and total sugar, baking resulted in a significant (P ≤ 0.05) increase in their level after 30 minutes. Their value ranges from 2.37 ± 0.02 to 2.45 ± 0.02 (%), 0.49 ± 0.05 to 0.62 ± 0.07 (%) and 3.28 ± 0.02 to 3.51 ± 0.04 (%) respectively.

For others, such as starch and protein, baking resulted in a significant decrease (P ≤ 0.05) in their respective content after 30 minutes. Their value ranges from 70.18 ± 2.17 to 60 ± 3 (%) and 8.06 ± 0.01 to 7.89 ± 0.01 (%) respectively.

Furthermore, baking has no significant effect (P ≤ 0.05) on the dry matter, ash and total carbohydrate content of flours from these bulbils, despite slight variations. Their value ranges from 93.83 ± 0.03 to 94.04 ± 0.03 (%), 3.43 ± 0.01 to 3.40 ± 0.01 (%), and 79.97 ± 0.03 to 80.3 ± 0.03 (%) respectively.

4.2. Mineral composition

Table 2 shows effect of baking after 30 minutes on mineral contents of bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won". This study shows that baking after 30 minutes had varying effects on the mineral composition of flours from these bulbils.

With regard to minerals such as calcium and iron, baking resulted in a significant (P ≤ 0.05) increase in their content in the bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won". Their value ranges from 79 ± 2 to 94 ± 1 mg/100 g DM and 7.15 ± 0.03 to 7.20 ± 0.03 mg/100 g DM, respectively.

In contrast, baking resulted in a significant reduction (P ≤ 0.05) in phosphorus, sodium and magnesium content of bulbils flour from the same yam. Their value ranges from 36 ± 1.73 to 30 ± 1.73 mg/100 g DM, 46.1 ± 1.01 to 33 ± 1 mg/100 g DM and 85 ± 1 to 33 ± 1 mg/100 g DM, respectively.

Furthermore, baking for 30 minutes do not significantly (P ≤ 0.05) affect the potassium content in the flours obtained from the bulbils of yam (*Dioscorea bulbifera*). Their potassium content ranges from 850 ± 1 to 857 ± 1 mg/100 g DM.

Table 2. Minerals composition of flours from baked bulbils yam (*Dioscorea bulbifera*) cultivar **"dougou-won"**

	FF10	**FF20**	**FF30**
Sodium (mg/100 g DM)	46.1 ± 1.01^{C}	43 ± 2^{B}	33 ± 1^{A}
Magnesium (mg/100 g DM)	85 ± 1^{C}	80 ± 1.73^{B}	76 ± 1.73^{A}
Iron (mg/100 g DM)	7.15 ± 0.03^{A}	7.17 ± 0.03^{AB}	7.20 ± 0.03^{B}
Calcium (mg/100 g DM)	79 ± 2^{A}	85 ± 3^{B}	94 ± 1^{C}
Potassium (mg/100 g DM)	850 ± 1$^{\mathbf{A}}$	85**2** ± 1.73$^{\mathbf{A}}$	857 ± 1$^{\mathbf{A}}$
Phosphorus (mg/100 g DM)	36 ± 1.73$^{\mathbf{C}}$	34 ± 1$^{\mathbf{B}}$	30 ± 1.73$^{\mathbf{A}}$

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of common letter are significantly different between them on the threshold of 5% according to the test of Duncan. DM=dry matters. FF10, FF20, FF30 means flours from bulbils of yam (*Dioscorea bulbifera*) baked at 100°C during 10, 20 and 30 minutes respectively

5. Discussion

5.1. Proximate composition

The significant (P ≤ 0.05) increase in levels of reducing sugar and total sugar in the bulbils flour from yam *(Dioscorea bulbifera*) cultivar "dougou-won" after baking for 30 minutes could be explained by the gelatinization of starch that occurs in bulbil during cooking. Indeed, under the effect of heat and in the presence of water, starch granules swell and burst, releasing their contents, which consist mainly of amylose and amylopectin [12]. As these molecules break down, they yield reducing sugars and total sugars. The results of this study are consistent with those of [13], who observed an increase in reducing sugar content under the influence of heat when studying physicochemical characteristics of sweet potato powder and starch (*Ipomoea batatas*), grown in Côte d'Ivoire.

With regard to crude fat content, a significant (P ≤ 0.05) increase is observed after baking for 30 minutes. Our results are in agreement with the results of [14], who also found similar increment in crude fat content in roasted white Dana flour. Increase in lipid content could result from their retention and release into the bulbil as cooking time increases. It should be noted that lipids are essential in children's diets, as they promote the absorption of fat-soluble vitamins and are also a highly energy-dense nutrient [15].

In contrast, baking significantly (P ≤ 0.05) reduced starch content in bulbils flour after 30 minutes. This reduction in starch content is also reported by [16], who observed in their work a significant (P ≤ 0.05) decrease in the starch content of bulbils flour from yam (*Dioscorea alata*) cultivar "bètè-bètè" after cooking in boiling water. The decrease in the starch content from bulbils flour is thought to be due to their degradation and the release of their contents under the effect of heat.

Similarly, baking significantly (P ≤ 0.05) reduced the protein content of bulbils flour after 30 minutes. Our results are consistent with those of [14], who also observed a decrease in protein content of white yam (*Dioscorea bulbifera*) flour after roasting. It should be noted that proteins play an essential role in the body's defense mechanisms and are also important for children's growth and development. They also contribute to the proper functioning of enzymes and hormones [17].

Furthermore, levels of certain biochemical parameters, such as dry matter, total ash and total carbohydrates in bulbils flour are not significantly ($P \leq 0.05$) altered by baking after 30 minutes.

Firstly, with regard to total ash content, the absence of a significant ($P \leq 0.05$) effect of cooking on its content is confirmed by [16] in their study on the effect of boiling time on certain biochemical parameters of yam (*Dioscorea alata*) tubers cultivar “bètè-bètè”. This suggests that baking helps to preserve the total ash content in bulbil four from yam *(Dioscorea bulbifera*) cultivar **“**dougou-won**”**. However, ash content is an indicator of the minerals present in a given food sample and plays a very important role in numerous biochemical reactions that ensure physiological functioning of human body [18].

Similarly, we found no significant ($P \leq 0.05$) various in dry matter content after baking for 30 minutes. Our results contradict those found by [19] who observed a significant increase in dry matter content in flour from yam (*Dioscorea cayenensis-rotundata*) cultivar “kponan” after boiling. The absence of significant change in dry matter content suggests that baking helped to preserve it in the flour from these bulbils’ yam.

Finally, total carbohydrate content of bulbils flour do not change significantly ($P \leq 0.05$) after the same baking time. Our results do not correspond to those found by [20], who observed an increase in total carbohydrate content in flour from yam (*Dioscorea esculenta*) tubers after boiling. The absence of significant ($P \leq 0.05$) variation in total carbohydrate content suggests that baking helped to preserve this carbohydrate in bulbil flour from yam (*Dioscorea bulbifera*). Furthermore, carbohydrates give energy to the body directly; considered as a major source of energy and contribute to breakdown of body protein. Some are used in body fundamental tissues including cartilage, nucleic acid, mucous formation and some antigenic constitutes [17].

5.2. Mineral composition

Firstly, with regard to calcium, we found that baking led to a significant ($P \leq 0.05$) increase in its content after 30 minutes in bulbils flour from yam (*Dioscorea bulbifera*) cultivar “dougou-won”. Our results are contrary to those obtained by [21], who reported a decrease in calcium content in flour from yam (*Dioscorea alata*) tubers cultivar “bètè-bètè**”** after roasting. Indeed, the increase in calcium content in bulbil flour may be due to the fact that certain antinutritional factors which interfere with the availability of this mineral by binding it within their structure [22] have been degraded by heat, thereby releasing it into the food matrix. Furthermore, calcium is essential for infants and children (0–5 years) to consume sufficient amounts to support the development of their teeth, bones, nervous system and muscles, as well as to ensure proper blood clotting and strengthen their immune system [23].

Similarly, baking resulted in a significant increase ($P \leq 0.05$) in iron content in bulbils flour from the same yam after 30 minutes. These results differ from those obtained by [24], who observed a significant decrease ($P \leq 0.05$) in iron content in flour from yam (*Dioscorea cayenensis-rotundata*) tubers cultivar “kponan” after boiling. It is also important to note that iron is essential in an infant diet for hemoglobin synthesis and their mental and physical welfare as its deficiency adversely impacts the growth of infants during the weaning period [25].

In contrast, levels of phosphorus, sodium and magnesium decreased significantly ($P \leq 0.05$) in bulbils flour after baking for 30 minutes.

This reduction in phosphorus content in flour from baked bulbil, is consistent with the findings of [24], who observed a decrease ($P \leq 0.05$) in phosphorus content in flour from yam (*Dioscorea cayenensis-rotundata*) tubers cultivar “kponan” after boiling. It should be noted that phosphorus is the second most abundant mineral in the body after Calcium. This mineral performs as wide variety of essential functions such as its role in the liberation and utilization of energy from food [26].

Similarly, the reduction in sodium content in flour from baked bulbils could be attributed to sodium loss during the scraping of the calcined bulbils. It should be noted, however, that a high sodium intake is harmful to health, as it can significantly ($P \leq 0.05$) increase the risk of cardiovascular disease and mortality [27].

Finally, the decrease in magnesium content in flour from baked bulbils could be due to their breakdown under the effect of heat. Magnesium is crucial for good infant health as it keeps the heart rhythm steady, strengthens the bones, supports a healthy immune system, and maintains normal muscle and nerve function [28].

Furthermore, the potassium content of flour from baked bulbils do not vary significantly ($P \leq 0.05$). This suggests, therefore, that baking helps to preserve this mineral. Our findings contradict those of [21], who observed an increase in potassium content in flour from yam (*Dioscorea alata*) cultivar "bètè-bètè" after roasting. However, it is important to note that potassium plays a major role in sustaining normal water equilibrium in the cells, nerve impulse transmission, keeping equilibrium in [29].

6. Conclusion

At the end of this study, it can be conclude that bulbils flour from yam (*Dioscorea bulbifera*) cultivar "dougou-won", contains various physicochemical and mineral components essential for the proper functioning of the human body, such as protein, lipid, starch, magnesium, iron, potassium, calcium and phosphorus Furthermore, baking for 30 minutes resulted in either a decrease or an increase in the levels of certain parameters, whereas no significant effect ($P \leq 0.05$) was observed for others. Nevertheless, overall, this baking process helps to preserve a significant amount of nutrients in bulbils flour from yam (*Dioscorea bulbifera*). Thus, baking could be recommended to consumers of bulbils from yam (*Dioscorea bulbifera*) cultivar "dougou-won",.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

Statement of ethical approval

The ethical approval for this study was obtained from the Departmental Research and Ethics committee from the University Alassane Ouattara.

Statement of informed consent

The authors declare that this research did not involve human participants or animals; therefore, consent for participation and publication was not applicable. All authors have reviewed and approved the final manuscript and consent to its publication.

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