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Manufacturing, Physicochemical Characterization And Sensory Evaluation Of Chips Made From Safou Pulp (Dacryodes Edulis H.J. Lam) In Congo-Brazzaville

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***Abstract*—Safou (Dacryodes edulis H.J. Lam) is an oil-rich fruit widely consumed in Central Africa. However, its high perishability after harvest contributes significantly to postharvest losses. This study aimed to develop safou pulp-based chips and investigate their physicochemical, sensory and volatile characteristics as a potential approach to local food diversification and resource valorization. Three formulations were prepared: plain, salted and sweetened chips. The resulting pastes were shaped and fried at temperatures ranging from 150 to 170 °C for 3–4 min. The finished products were subjected to physicochemical analyses and sensory evaluation. Lipid contents ranged from 65.51 ± 0.29% to 69.32 ± 0.30%, whereas protein contents varied from 5.85 ± 0.15% to 7.42 ± 0.12%, depending on the formulation. These results highlighted the predominantly lipid-rich composition of the products. Sensory evaluation revealed generally favorable acceptance of the three formulations, with a slight preference for the sweetened formulation at 4 °Brix. Gas chromatography–mass spectrometry analysis also revealed several volatile compounds belonging mainly to terpene and non-terpene chemical families. Overall, the findings demonstrate the technological feasibility of producing chips from safou pulp. This processing approach could contribute to reducing postharvest losses, diversifying safou-derived food products and increasing the economic value of this indigenous fruit in Congo-Brazzaville. Further investigations are required to optimize frying conditions, assess product shelf life and establish its microbiological and economic suitability for commercial production.**

***Index Terms*—Dacryodes edulis; safou chips ; physicochemical composition ; sensory evaluation; food valorization**.

I. INTRODUCTION

Safou (Dacryodes edulis (G. Don) H.J. Lam), commonly known as African pear, is an indigenous oil-rich fruit belonging to the family Burseraceae. It is widely distributed and consumed in Central Africa, where it represents an important food and economic resource for rural and urban populations. In Congo-Brazzaville, safou is particularly appreciated for its characteristic taste, texture and high lipid content. Its consumption contributes to household food security and provides income-generating opportunities for producers, traders and food processors.

Despite its nutritional and economic importance, the utilization of safou is constrained by its high perishability after harvest. Under ambient storage conditions, the pulp undergoes rapid natural softening, which reduces fruit quality and marketability. Silou et al. (2007) reported that natural softening generally occurs within approximately three to four days after harvest under ambient conditions. This phenomenon constitutes one of the major causes of postharvest losses in the safou production and marketing chain.

Subsequent investigations have demonstrated that postharvest preservation is influenced by several factors, including storage temperature, packaging conditions and fruit size. Silou et al. (2012) showed that storage at approximately 18 °C under suitable conditions could delay the loss of fruit firmness, whereas higher temperatures accelerated softening. These findings emphasize the need to develop alternative processing strategies capable of extending the utilization period of safou.

From a nutritional perspective, safou pulp is particularly interesting because of its high lipid content and its contribution of other nutrients, including proteins, minerals and carbohydrates. Its composition makes it a promising raw material for developing diversified food products.

Several studies have investigated the incorporation of safou into processed foods. Eyenga et al. (2020) demonstrated that safou fruit powder could be incorporated into rice-based biscuits, influencing their nutritional and sensory properties. Their findings highlighted the potential of safou powder as an ingredient for improving the nutritional quality of cereal-based products.

Similarly, Eyenga et al. (2021) investigated the optimization of rice biscuit formulations supplemented with D. edulis powder using response surface methodology. Their results demonstrated the potential of safou as a functional ingredient in food formulation and product development.

More recently, Mboukap et al. (2024) investigated the production of flour from naturally softened safou fruits. Their study demonstrated that appropriate processing conditions could improve the nutritional and rheological properties of the resulting flour. This approach offers an additional opportunity to valorize fruits that have lost their commercial suitability for fresh consumption.

However, despite these advances, the development of innovative snack products based on safou pulp remains relatively unexplored. In particular, the production of chips represents a potentially interesting alternative for transforming this highly perishable fruit into a diversified food product with added value.

The development of safou-based chips could contribute to broadening its consumption patterns, reducing postharvest losses and creating opportunities for small-scale food-processing enterprises. Therefore, the objective of this study was to develop chips from safou pulp and evaluate their physicochemical composition, sensory acceptability and volatile characteristics, in order to assess their potential for food diversification and agro-industrial valorization in Congo-Brazzaville.

II. MATERIALS AND METHODS

2.1. Plant material

The plant material consisted of mature safou fruits (Dacryodes edulis H.J. Lam) collected from [specify locality, department and harvest period], Republic of Congo.

Fruits showing signs of advanced deterioration, mechanical damage or fungal contamination were excluded. Only healthy and mature fruits were selected for processing.

2.2. Pulp extraction and preparation

The selected fruits were thoroughly washed with water to remove surface impurities. They were then subjected to the preliminary treatment specified in the experimental protocol to facilitate pulp extraction.

The pulp was manually separated from the seeds and subsequently homogenized to obtain a uniform material suitable for formulation and processing.

2.3. Preparation of chip formulations

Three different formulations were prepared from safou pulp:

- Plain chips: safou pulp without additional ingredients.
- Salted chips: safou pulp supplemented with salt.
- Sweetened chips: safou pulp supplemented with sugar.

The quantities of pulp and added ingredients were maintained according to the original experimental protocol.

A sweetened formulation corresponding to 4 °Brix was also considered during the sensory assessment.

2.4. Manufacturing process

After formulation, the mixtures were homogenized and shaped into thin layers suitable for frying. The prepared samples were subjected to frying at three temperature levels: 150, 160 and 170 °C. Frying times ranged from 3 to 4 min, depending on the experimental conditions.

After frying, the products were removed from the frying medium and drained to eliminate excess surface oil. They were then cooled at room temperature before physicochemical and sensory analyses.

2.5. Physicochemical analyses

The physicochemical composition of the chips was evaluated by determining their main nutritional constituents, including:

- Moisture content;
- Protein content;
- Lipid content;
- Carbohydrate content;
- Ash content;
- Dietary fibre, where determined;
- Mineral composition, where determined.

The analyses were conducted using the laboratory procedures applied during the experimental study.

For the final submission, the analytical procedures should be identified precisely, including the corresponding AOAC methods, sample preparation conditions and analytical equipment.

Carbohydrate content should also be identified as either directly measured or calculated by difference, depending on the original analytical protocol.

2.6. Sensory evaluation

Sensory evaluation was performed to assess the acceptability of the three safou chip formulations. The assessment included the following sensory attributes:

- Appearance;
- Colour;
- Odour;
- Taste;
- Texture and crispness;
- Overall acceptability.

The samples were evaluated by a panel of [specify the number of assessors] using the hedonic scale adopted in the original experimental protocol.

Particular attention was given to the comparison between plain, salted and sweetened formulations, including the formulation prepared at 4 °Brix.

2.7. Analysis of volatile compounds

The volatile composition of safou samples was investigated using gas chromatography coupled with mass spectrometry (GC–MS).

Samples with and without peel were analysed to investigate differences in their volatile profiles.

Compound identification was based on chromatographic retention times and comparison of the mass spectra with the reference libraries available in the analytical system.

The identified compounds were subsequently classified according to their chemical families, particularly monoterpenes, sesquiterpenes, aldehydes, alcohols, esters and ketones.

The analytical conditions, including extraction procedure, chromatographic column, carrier gas, temperature programme, ionization conditions and identification criteria, should be reported in the final manuscript.

2.8. Statistical analysis

Experimental results were expressed as mean ± standard deviation.

Differences between formulations were evaluated using an appropriate statistical procedure. Statistical significance was considered at $p < 0.05$.

The specific statistical test, number of replicates and software used should be indicated in the final version.

III. RESULTS AND DISCUSSION

3.1. Feasibility of safou chip production

The results demonstrated that safou pulp could successfully be processed into chips using the experimental procedure developed in this study.

The three formulations, namely plain, salted and sweetened chips, produced food products with sufficient structural cohesion to withstand the frying process.

Frying temperatures ranging from 150 to 170 °C resulted in products with variations in appearance, colour and texture.

These observations demonstrate the technological potential of safou pulp as a raw material for snack production.

The successful development of these products is particularly relevant in Congo-Brazzaville, where the rapid deterioration of fresh safou remains a major constraint to its commercialization and utilization.

3.2. Physicochemical composition of safou chips

The physicochemical analyses revealed that the different formulations were characterized by relatively high lipid contents and comparatively lower protein and ash contents.

Lipid concentrations ranged from 65.51 ± 0.29% to 69.32 ± 0.30%, while protein contents varied between 5.85 ± 0.15% and 7.42 ± 0.12%.

These results confirm the predominantly lipid-rich nature of the final products.

The high lipid content can partly be explained by the intrinsic composition of safou pulp, which is naturally rich in oil. However, the frying process may also contribute to the final lipid concentration through the absorption of frying oil.

The protein contents observed in the different formulations indicate that safou chips provide some protein, although their nutritional composition remains predominantly characterized by lipids.

Carbohydrate and ash contents also varied according to the formulations and processing conditions. Their exact values should be reported in a comparative physicochemical composition table.

These results highlight the importance of formulation and processing conditions in determining the nutritional characteristics of safou-based snacks.

3.3. Sensory characteristics and acceptability

Sensory evaluation revealed generally favorable acceptance of the three formulations.

Although the differences between formulations were not systematically significant, the sweetened formulation prepared at 4 °Brix showed a slight preference for certain sensory attributes.

The addition of sugar may have contributed to improving the taste and overall sensory perception of the product.

The salted formulation also showed satisfactory acceptance, suggesting that the characteristic flavour of safou pulp is compatible with the development of savoury snack products.

These findings demonstrate that safou pulp can be used to produce different types of snack products adapted to consumer preferences.

However, a larger sensory panel would be required to establish consumer preferences more reliably.

3.4. Volatile composition of safou samples

GC–MS analysis revealed the presence of several volatile compound belonging to different chemical families.

The identified compound included:

- Monoterpenes;
- Sesquiterpenes;
- Aldehydes;
- Alcohols;
- Esters;
- Ketones;
- Other non-terpenic volatile compound.

The chromatographic profiles indicated variations in volatile composition between samples with and without peel.

These differences suggest that the distribution of volatile compound is not uniform throughout the fruit tissues.

The presence of different chemical families indicates that safou aroma results from a complex mixture of volatile substances rather than a single group of compounds.

Further quantitative investigations would be necessary to establish the contribution of individual compounds to the overall aroma characteristics.

3.5. Nutritional significance of safou-based chips

The high lipid concentrations observed in the chips are consistent with the naturally oil-rich composition of safou pulp.

Silou et al. (2007) highlighted the nutritional importance of safou pulp and its high lipid content, which represents one of the principal characteristics of this fruit.
Nevertheless, the lipid content of fried chips should be interpreted carefully because it may reflect both intrinsic fruit lipids and additional oil absorbed during processing.
Future investigations should therefore distinguish between the native lipid fraction of safou pulp and the oil absorbed during frying.
The protein concentrations observed in the present study were comparatively lower than those reported for some other safou-derived products.
For example, Mboukap et al. (2024) reported approximately 12.40% protein and 58.95% lipids in optimized safou flour.
Such differences may be related to the raw material, formulation, processing conditions and analytical procedures.
These comparisons illustrate how different technological processes can influence the final nutritional composition of products derived from the same fruit.

3.6. Influence of frying conditions on product quality

Frying temperature and duration are important technological parameters affecting the quality of chips.
Temperatures between 150 and 170 °C can influence moisture removal, colour development, texture formation, oil absorption and the production of volatile compounds.
The generally favorable sensory acceptance observed in this study suggests that the selected processing conditions were suitable for obtaining acceptable products.
Nevertheless, further optimization is necessary to determine the most appropriate combination of temperature and frying time.
Particular attention should be paid to limiting oil absorption while maintaining desirable crispness, colour and flavour characteristics.
The presence of added sugar in the sweetened formulation may also influence colour and flavour development during frying.
Thermal reactions, including caramelization and Maillard reactions where suitable reactants are present, may contribute to the sensory properties of the finished products.
Therefore, the slightly higher sensory preference for the sweetened formulation at 4 °Brix may result from several interacting factors, including sweetness, flavour development and texture.

3.7. Sensory acceptability and comparison with previous studies

The favorable sensory response observed for safou chips supports the potential of this fruit as an ingredient for developing innovative snack products.
These findings are consistent with those of Eyenga et al. (2020), who demonstrated the potential of safou powder in rice-based biscuit formulations.
Their study showed that the incorporation of safou powder influenced the nutritional and sensory properties of the resulting biscuits.

Similarly, Eyenga et al. (2021) demonstrated that the formulation of rice biscuits supplemented with D. edulis powder could be optimized using response surface methodology.

Together, these studies support the use of safou as a valuable ingredient in the development of diversified food products.

The present study extends this approach by exploring the direct utilization of safou pulp for chip production rather than its incorporation into cereal-based products.

3.8. Volatile compounds and aromatic quality

The identification of several volatile chemical families confirms the complexity of safou aroma.

Terpenes, particularly monoterpenes and sesquiterpenes, are important contributors to the volatile composition of numerous plant-derived foods.

However, the overall aroma of safou cannot be attributed exclusively to terpene compounds.

The presence of aldehydes, alcohols, esters and ketones suggests that the aromatic profile results from the interaction of multiple volatile substances.

The differences observed between peeled and unpeeled samples may be associated with the distribution of volatile compounds in the fruit tissues.

Nevertheless, identification alone does not establish the sensory contribution of each compound. Quantitative analysis and determination of odour activity values would be necessary to identify the main aroma-active substances.

These investigations could provide useful information for improving the sensory quality of safou-derived food products.

3.9. Agro-industrial valorization of safou

The development of chips from safou pulp represents a promising approach to the diversification of local food products.

In Congo-Brazzaville, the short shelf life of fresh safou constitutes an important constraint to its commercialization and contributes to postharvest losses.

Silou et al. (2007) demonstrated that natural softening is a major cause of postharvest deterioration of safou pulp.

Transforming the fruit into processed products could provide an alternative means of utilizing raw materials that are difficult to commercialize in their fresh form, provided that their quality and safety are controlled.

Previous studies have demonstrated the potential of safou flour and safou-enriched biscuits as alternative products (Eyenga et al., 2020; Mboukap et al., 2024).

The present investigation contributes to this research area by demonstrating the feasibility of producing chips from safou pulp.

The development of such products could create opportunities for small-scale processing units, promote local food innovation and increase the economic value of safou production.

However, industrial development will require additional investigations into product stability, microbiological safety, packaging, production costs and market acceptance.

IV. CONCLUSION

This study investigated the manufacture and characterization of chips produced from safou pulp (Dacryodes edulis H.J. Lam) as an alternative approach to the valorization of this highly perishable fruit in Congo-Brazzaville.

The results demonstrated the technological feasibility of producing plain, salted and sweetened chips from safou pulp.

The physicochemical analyses revealed that the products were characterized by high lipid contents, ranging from 65.51 ± 0.29% to 69.32 ± 0.30%, and protein contents ranging from 5.85 ± 0.15% to 7.42 ± 0.12%.

Sensory evaluation showed generally favorable acceptance of the three formulations, with a slight preference for the sweetened formulation at 4 °Brix.

Furthermore, GC–MS analysis revealed the presence of several volatile compounds belonging to terpene and non-terpene chemical families, highlighting the complexity of the aromatic composition of safou.

Overall, these findings demonstrate the potential of safou pulp as a raw material for developing innovative snack products.

The transformation of safou into chips could contribute to food diversification, increased added value and the reduction of postharvest losses.

Nevertheless, additional investigations are required to optimize frying conditions, reduce oil absorption, establish microbiological safety and determine the physicochemical and sensory stability of the products during storage.

Further technological and economic studies will also be necessary to assess the feasibility of transferring this process to small-scale food-processing enterprises in Congo-Brazzaville.

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[Modify this section according to the actual financial and institutional support received.]

AUTHOR CONTRIBUTIONS

The specific contributions of each author should be completed and approved by all co-authors according to their actual participation in the research.

CONFLICT OF INTEREST

The authors should declare any actual or potential conflict of interest, or state that no conflict of interest exists, if applicable.

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