



### RESEARCH ARTICLE

## EFFECT OF FERMENTATION TIME ON THE AMINO ACID PROFILE AND SENSORY CHARACTERISTICS OF FOUR COOKIES FORMULATIONS MADE FROM SOUCHET (CYPERUS ESCULENTUS L)

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### Abstract

The souchet (*Cyperus esculentus* L.) is an underutilized plant whose rough-textured tubers are commonly found in local food markets in Côte d'Ivoire and are used primarily as a snack. However, the souchet cultivated and consumed in Côte d'Ivoire remains a marginalized agri-food resource, often limited to traditional consumption in the form of beverages or raw tubers. The overall objective of this study is to contribute to the valorization of souchet flour (*Cyperus esculentus* L.) through the production of cookies at different fermentation times. The experimental approach involved developing four (4) biscuit formulations made from unfermented tubers (BFST) and fermented tubers for 24 hours (BFSF24), 48 hours (BFSF48), and 72 hours (BFSF72), respectively, all produced without added sugar. Proximate analyses focused on determining the amino acid profile. Sensory evaluation was conducted by a panel of 20 tasters using a nine-point (9) hedonic scale. The 48-hour fermentation period proved to be optimal, yielding the highest concentrations of essential amino acids and phenolic compounds. Sensory evaluations showed that all formulations scored above 5/9. Only aroma revealed a significant difference among the formulations ( $p = 0.029$ ); the control formulation (BFST) received the highest overall score (7.05/9). This study suggests that cookies made with souchet flour fermented for 48 hours should be recommended to optimize their nutritional quality.

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### Introduction:-

Cookies are among the most popular and widely consumed baked goods worldwide (Aderinola et al., 2020). These baked goods come in a wide variety of shapes and sizes, with a crisp texture and a color ranging from light brown to golden; they have a dry appearance and are typically no more than 3 to 4 mm thick (Ihekoronye, 1999). These products are also characterized by a high caloric content and a high concentration of fats and sugars, while being low in protective nutrients such as fiber and vitamins, making them unsuitable for daily consumption (Tsen et al.,

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2006 ; Olugbenga et al., 2017). The basic matrix of cookies consists mainly of wheat flour, sugar, and fat (Chandana and Navaratne, 2015). Variations in major and minor ingredients allow for the production of a wide variety of cookie products (Faridi, 1994). Although these ingredients give cookies specific organoleptic and nutritional qualities, their high content of saturated fatty acids, sugars, and refined wheat flour presents a critical combination. Such a matrix is particularly ill-suited to the nutritional needs of people suffering from obesity, diabetes, or celiac disease (à chronic autoimmune disease of the intestine triggered by the ingestion of gluten) (Ajay and Pradyuman, 2018). To For this reason, demand for healthy cookies is constantly increasing. Furthermore, cookie formulations can be easily adapted to meet the nutritional needs of target consumers (Ashaye et al., 2015). Soft wheat flour is the main ingredient in the production of cookies and other baked goods (Dendy, 1993). However, wheat is low in certain essential amino acids such as lysine, methionine, and threonine (Saleh et al., 2012).

Furthermore, wheat is not produced in Côte d'Ivoire. Research is increasingly being conducted to encourage the use of local flours (corn, barley, oats, sorghum) (Ashgan and Hala, 2022) in order to reduce wheat imports. Supplementing wheat flour with fermented tiger nut flour is a highly effective way to limit these wheat imports and improve the nutritional quality of cookies. Regular consumption of tiger nut protects the body from numerous health complications such as diabetes, cardiovascular disease, hyperlipidemia, prostate cancer, colon cancer, hernias, fibrosis, and painful menstruation. Nutritionally, tiger nut is rich in dietary fiber, unsaturated fatty acids, plant proteins, and minerals such as potassium and magnesium (Oladele and Aina, 2007 ; Chukwuma et al., 2010). Tigernut is naturally gluten-free, making it particularly suitable for people with gluten intolerance. Its nutritional properties make it highly valuable for the development of functional food products. Despite these nutritional qualities, the tigernut which is cultivated and consumed in Côte d'Ivoire remains a marginalized agri-food resource, often limited to traditional consumption in the form of beverages or raw tubers. The overall objective of this study is to contribute to the valorization of souchet flour through the production of cookies with varying fermentation times.

## Materials and Methods:-

### Plant material:-

Jerusalem artichoke tubers (*Cyperus esculentus* L.) were used as the biological material for this study. These tubers were purchased at the main market in Yamoussoukro. A total of 3 kg of Jerusalem artichokes were used.

### Methods

#### Production of tiger nut flour



**Figure 1 : Jerusalem artichoke tubers (*Cyperus esculentus* L. (Kouadio, 2026)**

The tiger nut tubers were first sorted to remove moldy or damaged tubers and impurities. They were then washed in soapy water to remove grains of sand and other impurities, followed by a rinse to remove the soap. Afterward, they were disinfected in a chlorine solution ("La Croix" brand bleach at 8° chlorine eq), followed by three rinses to remove the chlorine. Four (04) kilograms of tiger nuts were divided into four (4) batches of one kilogram each. The first batch, serving as an unfermented control, was immediately dried at a temperature of 70°C for 24 hours in a

drying oven. The other three batches, consisting of moist tubers, were packaged in hermetically sealed food-grade bags and then subjected to three fermentation periods (24 hours, 48 hours, and 72 hours). The three batches of fermented tubers and the batch of unfermented tiger nut tubers were ground into a powder and sieved through a 200  $\mu\text{m}$  mesh sieve to obtain tiger nut flour (figure 2).

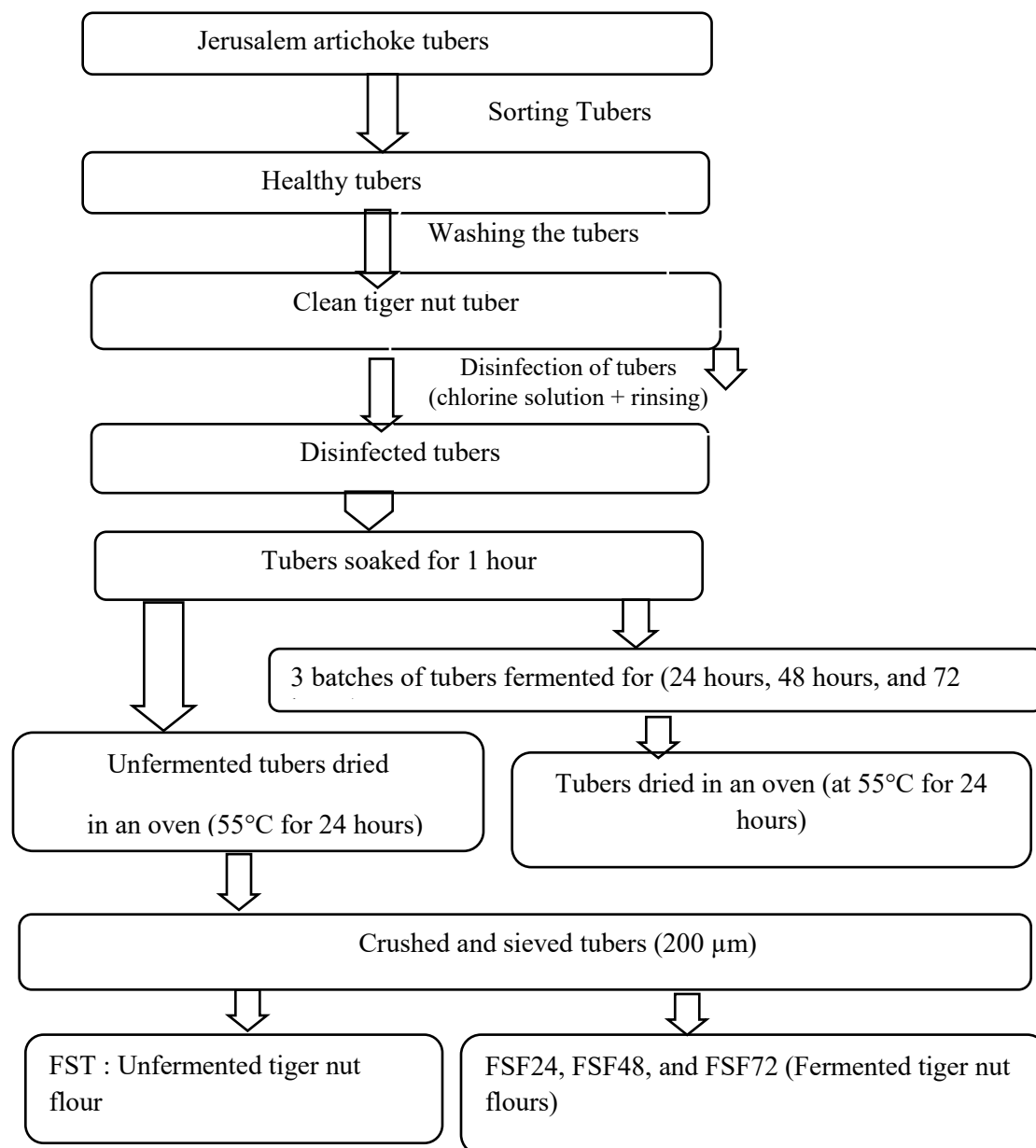


Figure 2 : Production flowchart for unfermented and fermented tigernut flour (Kouadio, 2026)

#### Composition of the various cookies formulations:-

Table 1: Composition of the various cookie formulations

| Ingredients              | Cookie recipe |         |         |         |
|--------------------------|---------------|---------|---------|---------|
|                          | BFST          | BFSF24  | BFSF48  | BFSF72  |
| Tarragon tuber flour (g) | 150           | 150     | 150     | 150     |
| Sugar (g)                | 0             | 0       | 0       | 0       |
| Egg (g)                  | 1 in 50       | 1 in 50 | 1 in 50 | 1 in 50 |

|                         |    |     |    |    |
|-------------------------|----|-----|----|----|
| Yeast (g)               | 1  | 1   | 1  | 1  |
| Salt (g)                | 1  | 1 g | 1  | 1  |
| Olive oil (mL)          | 11 | 11  | 11 | 11 |
| Flavoring (vanilla) (g) | 2  | 2   | 2  | 2  |

**BFST** : cookie made from unfermented tiger nut flour ; **BFSF24** : cookie made from tiger nut tuber flour fermented for 24 hours ; **BFSF48** : cookie made from tiger nut tuber flour fermented for 48 hours ; and **BFSF72** : cookie made from tiger nut tuber flour fermented for 72 hours

### Cookies production:-

#### Dough preparation:-

Dough preparation began by mixing the liquid and semi-liquid ingredients. The eggs were beaten in a bowl. Next, vanilla extract and salt were added to create a smooth, lightly flavored base. Melted extra virgin olive oil was added to improve the dough's workability and crumbly texture. In a separate bowl, the flours corresponding to the different formulations (FST, FSF24, FSF48, or FSF72) were thoroughly mixed with the baking powder to ensure even distribution of the leavening agents. This dry mixture was then gradually incorporated into the liquid mixture, and the whole mixture was kneaded for about five minutes until a homogeneous, supple, and easy-to-work dough was obtained. The dough was then left to rest in the refrigerator for 30 minutes.



Figure 3 : Dry mix (Kouadio,2026)



Figure 4 : Wet mixture (Kouadio,2026)

#### Dough rolling:-

Rolling is the most common method for forming cookie dough into sheets. It involves producing a thick sheet of dough, the thickness of which is reduced as it passes through various rotary rollers (Menasra, 2020). After mixing, the resulting dough was subjected to a rolling process. This step involves flattening the dough mass uniformly to obtain a sheet of dough of consistent thickness set at approximately 4 mm using a rolling pin. Rolling is a critical step in cookie production, as the thickness of the dough directly determines the physical properties of the finished product, including the diameter, final thickness, and spread ratio of the cookies after baking (El-Hadad, N. et al. 2022).

#### Rolling out the dough and cutting the dough pieces:-

The dough pieces were cut from the rolled-out dough sheet using a circular cookie cutter 4 cm in diameter. Cutting the dough pieces is a fundamental step in the cookie production process, as it determines the shape, initial diameter, and uniformity of the pieces before baking (Manley, 2011 ; Yadav et al., 2012) (**figure 5**).



**Figure 5 : rolling out the dough (Kouadio, 2026)**

According to method (AACC, 2010) cookie dough pieces must be cut with a standardized cookie cutter to ensure uniform diameter, a key parameter for calculating the spread ratio. (Nagi et al., 2012) specify that in studies on cookies made with blended flours, the dough is cut using a 4.5-cm-diameter cookie cutter, which corresponds to the dimensions used in this study (figure 6).



**Figure 6 : Cutting the dough pieces (Kouadio, 2026)**

#### **Baking and cooling the dough pieces:-**

The dough pieces arranged on the baking sheet were baked for 15 to 20 minutes in a professional Xinxingnan / Xinnanfang (新南方 / 新南大) deck oven manufactured in China, which had been preheated to 1700 °C. At the end of baking, the baking sheets were removed, and the baked cookies were turned out into small bowls (figure 7 and figure 8).



**Figure 7 : Baking cookies in the oven (Kouadio,2026)**



**Figure 8 : Baked Cookies BFSF48H (Kouadio,2026)**

Amino acid profile and sensory characteristics of cookies made from fermented jerusalem artichoke at different fermentation times

#### **Determination of the amino acid profile:-**

Amino acid analysis of the various cookie formulations was performed using high-performance liquid chromatography (HPLC). Essential and nonessential amino acids were extracted from 1 gram of flour using 20 mL of sodium citrate (0.2 N) at a pH of 2.3 (Deguine & Hau, 2001). The amino acids were analyzed using a SUPERCOSIL LC-18-DB column measuring 250 × 4.6 mm ID with 5 µm particles. The mobile phases, injected using a gradient, consisted of 0.7 M sodium acetate containing 2.5 mL of triethylamine per liter (pH = 6.4), water, and an acetonitrile–water mixture (80/20). The extract (20 µL) was injected at a flow rate of 1 mL/min at 45 °C, and detection was performed at 254 nm in the UV range. Amino acid standard solutions were injected at a concentration of 1 g/100 mL.

**The content of each amino acid was calculated using the following equation:-**

$$C(\mu\text{g}/100\text{g}) = \frac{A \times CS \times \text{Extract volume} \times 100}{As \times \text{Sample Weight}}$$

**A:** Peak area of the amino acid in the sample

**As:** Peak area of the standard for a given amino acid

#### **Sensory analysis:-**

Sensory analysis of the four cookie formulations was conducted at LAPISEN (Laboratory of Industrial Synthesis, Environmental, and New Energy Processes at the INP-HB in Yamoussoukro) of the Félix Houphouët-Boigny National Polytechnic Institute in Yamoussoukro, Côte d'Ivoire. A panel of twenty (20) tasters was assembled for this evaluation. The panelists were selected based on their availability and willingness to participate in the tasting session. Before the test began, each panelist was informed of the study's objectives and provided informed consent to participate. The four tiger nut flour-based cookie formulations (BFST, BFSF24, BFSF48, and BFSF72) were prepared under identical, standardized conditions to minimize biases related to preparation conditions. Each formulation was presented to the tasters in neutral containers, coded B0, B1, B2, and B3, respectively, and assigned at random to ensure the anonymity of the samples and avoid any bias related to prior knowledge of their composition. The tasting was conducted at room temperature. Between each sample, the panelists were asked to rinse their mouths with mineral water to eliminate any residual flavors that might interfere with the evaluation of the next sample.

#### **Evaluated parameters and rating scale:-**

The panelists were asked to evaluate each formulation based on five sensory attributes: color, taste, aroma, texture/crunchiness, and overall liking. These attributes were selected because of their relevance to the organoleptic evaluation of cookies and baked goods (Meilgaard et al., 2007). The evaluation was conducted using a nine-point hedonic scale, ranging from 1 ("extremely unpleasant") to 9 ("extremely pleasant"), in accordance with the recommendations of ISO 11136. (2014) on hedonic methods in sensory analysis. The evaluation forms (see appendix) provided to the panelists also included sociodemographic information such as last name, first name,

ethnicity, nationality, age group, and gender, to enable an analysis of the influence of these variables on the expressed sensory preferences.

#### Statistical analyses:-

Data were collected using a sensory analysis form on which the taster's observations and responses to the tasting tests were recorded. Analysis of variance (ANOVA) was performed using XLSTAT software, and the significance level was set at 5%. Tukey's multiple comparison test was used to determine significant differences between the formulations.

### Results and Discussion:-

#### Results:-

##### Essential and non-essential amino acid profiles of cookies:-

Table 2 shows the essential amino acid profiles of unfermented cookies (BFST) and fermented cookies (BFSF24, BFSF48, and BFSF72). The results show that the essential amino acid contents of the different types of non-fermented and fermented biscuits (BFSF24, BFSF48, and BFSF72) differed significantly at the 5% level. It should be noted from this table that the biscuits fermented for 48 hours (BFSF48) are rich in essential amino acids, particularly leucine ( $8.217 \pm 0.03$  a mg/100 g DM), isoleucine ( $4.843 \pm 0.02$  mg/100 g DM), lysine ( $5.143 \pm 0.02$  mg/100 g DM), valine ( $5.677 \pm 0.02$  mg/100 g DM), and phenylalanine ( $5.010 \pm 0$  mg/100 g DM) are the most abundant. Overall, the cookies fermented for forty-eight hours had higher levels of essential amino acids than those fermented for twenty-four hours and seventy-two hours, as well as compared to the unfermented cookies.

The non-essential amino acid profiles of the control cookies (BFST) and the fermented cookies (BFSF24, BFSF48, BFSF72) are presented in Table 3. It was found that the essential amino acid contents of the various types of non-fermented and fermented cookies (BFSF24, BFSF48, and BFSF72) showed a significant difference at the 5% significance level. It is observed that the biscuits fermented for 48 hours (BFSF48) exhibit high levels of non-essential amino acids, particularly glutamic acid ( $19.337 \pm 0.03$  mg/100 g DM), arginine ( $11.830 \pm 0.008$  mg/100 g DM), aspartic acid ( $9.550 \pm 0.02$  mg/100 g DM), serine ( $5.140 \pm 0.02$  mg/100 g DM), glycine ( $4.093 \pm 0.01$  mg/100 g DM), proline ( $4.853 \pm 0.02$  mg/100 g DM), and alanine ( $4.363 \pm 0.02$  mg/100 g DM). In summary, the BFSF48 cookies are distinguished by a higher content of nonessential amino acids compared to the samples fermented for twenty-four or seventy-two hours, as well as to the (BFST) cookies.

**Table 2 : Essential amino acid composition of the cookies (mg/100 g of dry matter)**

| Cookie Type                 | Leucine                 | Isoleucine              | Lysine                  | Tryptophan               | Histidine                | Threonine               | Valine                  | Phenylalanine            | Methionine              |
|-----------------------------|-------------------------|-------------------------|-------------------------|--------------------------|--------------------------|-------------------------|-------------------------|--------------------------|-------------------------|
| BFST                        | 7,907±0,03 <sup>c</sup> | 4,510±0,02 <sup>d</sup> | 4,710±0,01 <sup>d</sup> | 1,010±0,008 <sup>c</sup> | 2,333±0,01 <sup>d</sup>  | 3,627±0,02 <sup>d</sup> | 5,383±0,02 <sup>d</sup> | 4,707 ±0,02 <sup>d</sup> | 1,517±0,02 <sup>c</sup> |
| BFSF 24                     | 8,127±0,01 <sup>b</sup> | 4,750±0,02 <sup>b</sup> | 5,040±0,02 <sup>b</sup> | 1,070±0,008 <sup>b</sup> | 2,510±0,01 <sup>b</sup>  | 3,827±0,01 <sup>b</sup> | 5,590±0,02 <sup>b</sup> | 4,927 ±0,01 <sup>b</sup> | 1,690±0,01 <sup>a</sup> |
| BFSF 48                     | 8,217±0,03 <sup>a</sup> | 4,843±0,02 <sup>a</sup> | 5,143±0,02 <sup>a</sup> | 1,097±0,009 <sup>a</sup> | 2,620±0,01 <sup>a</sup>  | 3,910±0,01 <sup>a</sup> | 5,677±0,02 <sup>a</sup> | 5,010±0 <sup>a</sup>     | 1,740±0,02 <sup>a</sup> |
| BFSF 72                     | 8,047±0,02 <sup>b</sup> | 4,647±0,02 <sup>c</sup> | 4,893±0,01 <sup>c</sup> | 1,050 ±0 <sup>b</sup>    | 2,420±0,008 <sup>c</sup> | 3,740±0,01 <sup>c</sup> | 5,477±0,02 <sup>c</sup> | 4,820±0,02 <sup>c</sup>  | 1,617±0,00 <sup>b</sup> |
| Pr > F(Model) Significant   | < 0,0001                | < 0,0001                | < 0,0001                | < 0,0001                 | < 0,0001                 | < 0,0001                | < 0,0001                | < 0,0001                 | < 0,0001                |
|                             | Oui                     | Oui                     | Oui                     | Oui                      | Oui                      | Oui                     | Oui                     | Oui                      | Oui                     |
| Pr > F(Samples) Significant | < 0,0001                | < 0,0001                | < 0,0001                | < 0,0001                 | < 0,0001                 | < 0,0001                | < 0,0001                | < 0,0001                 | < 0,0001                |
|                             | Oui                     | Oui                     | Oui                     | Oui                      | Oui                      | Oui                     | Oui                     | Oui                      | Oui                     |

Mean  $\pm$  standard deviation, n=3 ; within columns, means labeled with different letters indicate a significant difference at the (P<0.05) level. BFST : cookie made from unfermented tiger nut flour ; BFSF24 : cookie made from tiger nut tuber flour fermented for 24 hours; BFSF48: cookie made from tiger nut tuber flour fermented for 48 hours; and BFSF72: cookie made from tiger nut tuber flour fermented for 72 hours.

**Table 3 : Non-essential amino acid composition of the cookies (mg/100 g of dry matter).**

| Cookies types               | Serine                        | Glycine                        | Proline                       | Alanine                       | Glutamic acid                  | Arginine                        | Aspartic acid                  |
|-----------------------------|-------------------------------|--------------------------------|-------------------------------|-------------------------------|--------------------------------|---------------------------------|--------------------------------|
| BFST                        | 4,710 $\pm$ 0,01 <sub>d</sub> | 3,827 $\pm$ 0,03 <sub>d</sub>  | 4,587 $\pm$ 0,01 <sub>c</sub> | 4,077 $\pm$ 0,04 <sub>c</sub> | 18,740 $\pm$ 0,02 <sub>d</sub> | 11,103 $\pm$ 0,01 <sub>d</sub>  | 9,020 $\pm$ 0,008 <sub>d</sub> |
| BFSF 24                     | 4,953 $\pm$ 0,02 <sub>b</sub> | 3,977 $\pm$ 0,01 <sub>b</sub>  | 4,750 $\pm$ 0,02 <sub>b</sub> | 4,297 $\pm$ 0,01 <sub>a</sub> | 19,053 $\pm$ 0,03 <sub>b</sub> | 11,637 $\pm$ 0,02 <sub>b</sub>  | 9,320 $\pm$ 0,02 <sub>b</sub>  |
| BFSF 48                     | 5,140 $\pm$ 0,02 <sub>a</sub> | 4,093 $\pm$ 0,01 <sub>a</sub>  | 4,853 $\pm$ 0,02 <sub>a</sub> | 4,363 $\pm$ 0,02 <sub>a</sub> | 19,337 $\pm$ 0,03 <sub>a</sub> | 11,830 $\pm$ 0,008 <sub>a</sub> | 9,550 $\pm$ 0,02 <sub>a</sub>  |
| BFSF 72                     | 4,867 $\pm$ 0,02 <sub>c</sub> | 3,910 $\pm$ 0,008 <sub>c</sub> | 4,637 $\pm$ 0,01 <sub>c</sub> | 4,207 $\pm$ 0,01 <sub>b</sub> | 18,903 $\pm$ 0,01 <sub>c</sub> | 11,193 $\pm$ 0,02 <sub>c</sub>  | 9,160 $\pm$ 0,02 <sub>c</sub>  |
| Pr > F(Model) Significant   | < 0,0001                      | < 0,0001                       | < 0,0001                      | < 0,0001                      | < 0,0001                       | < 0,0001                        | < 0,0001                       |
|                             | Oui                           | Oui                            | Oui                           | Oui                           | Oui                            | Oui                             | Oui                            |
| Pr > F(Samples) Significant | < 0,0001                      | < 0,0001                       | < 0,0001                      | < 0,0001                      | < 0,0001                       | < 0,0001                        | < 0,0001                       |
|                             | Oui                           | Oui                            | Oui                           | Oui                           | Oui                            | Oui                             | Oui                            |

Mean  $\pm$  standard deviation, n=3 ; within columns, means labeled with different letters indicate a significant difference at the (P<0.05) level. BFST : cookie made from unfermented tiger nut flour ; BFSF24 : cookie made from tiger nut tuber flour fermented for 24 hours ; BFSF48 : cookie made from tiger nut tuber flour fermented for 48 hours ; and BFSF72 : cookie made from tiger nut tuber flour fermented for 72 hours.

#### Sensory evaluation of cookies:-

Statistical tests showed that there were no significant differences ( $p > 0.05$ ) in color, taste, texture (crunchiness), and overall liking among the cookie formulations. However, there was a significant difference in aroma among the various biscuit formulations made with fermented tiger nut (BFST, BFSF24, BFSF48, and BFSF72). Color scores ranged from 6.40 (BFSF72) to 6.90 (BFST), with no significant difference among the formulations. Aroma is the descriptor showing the most significant differences. BFST received the highest score (7.10) and BFSF72 the lowest (6.00), with the other two formulations falling in between. For taste, no significant differences were observed; the BFSF24 formulation received the highest score (6.60). Texture (crunchiness) showed no significant differences among the formulations. Scores ranged from 5.85 (BFSF72) to 6.35 (BFST). Finally, the overall evaluation revealed non-significant differences. BFST was the highest-rated formulation (7.05), though not significantly higher than BFSF24 (6.85), with BFSF48 (6.90) and BFSF72 (6.60) falling in between. These results are shown in Table 4.

**Table 4 : Sensory evaluation of four cookie formulations (scores out of 9)**

| Cookies types | color                        | taste                        | flavor                        | texture/<br>crunchiness      | overall<br>assessment        |
|---------------|------------------------------|------------------------------|-------------------------------|------------------------------|------------------------------|
| BFST          | 6,90 $\pm$ 0,55 <sup>a</sup> | 6,40 $\pm$ 1,47 <sup>a</sup> | 7,10 $\pm$ 1,33 <sup>a</sup>  | 6,35 $\pm$ 1,04 <sup>a</sup> | 7,05 $\pm$ 0.89 <sup>a</sup> |
| BFSF 24       | 6,65 $\pm$ 0,59 <sup>a</sup> | 6,60 $\pm$ 1,31 <sup>a</sup> | 6,85 $\pm$ 1,27 <sup>ab</sup> | 6,05 $\pm$ 1,32 <sup>a</sup> | 6.85 $\pm$ 1.04 <sup>a</sup> |
| BFSF 48       | 6,80 $\pm$ 0,62 <sup>a</sup> | 6,50 $\pm$ 0,95 <sup>a</sup> | 6,50 $\pm$ 0,95 <sup>ab</sup> | 6,25 $\pm$ 1,29 <sup>a</sup> | 6.90 $\pm$ 0.85 <sup>a</sup> |
| BFSF 72       | 6,40 $\pm$ 1,10 <sup>a</sup> | 6,05 $\pm$ 1,54 <sup>a</sup> | 6,00 $\pm$ 1,21 <sup>b</sup>  | 5,85 $\pm$ 1,53 <sup>a</sup> | 6.60 $\pm$ 1.35 <sup>a</sup> |

Mean  $\pm$  standard deviation, n=3 ; within columns, means labeled with different letters indicate a significant difference at the (P<0.05) level. BFST : cookie made from unfermented tiger nut flour ; BFSF24 : cookie made from

tiger nut tuber flour fermented for 24 hours ; BFSF48: cookie made from tiger nut tuber flour fermented for 48 hours; and BFSF72: cookie made from tiger nut tuber flour fermented for 72 hours.

### **Discussion:-**

Analysis of the essential amino acid profile showed that BFSF48 cookies are the richest in these amino acids, with particularly high levels of leucine, isoleucine, lysine, valine, and phenylalanine. This high content is thought to result from proteolytic degradation induced by fermentative microorganisms, which hydrolyze storage proteins into free amino acids, thereby increasing their relative concentration in the final product (Ndiaye, 2020). Leucine, the most abundant essential amino acid in BFSF48 cookies, is thought to play a key role in stimulating muscle protein synthesis and regulating insulin secretion (Chukwuma et al., 2010). Lysine is thought to be involved in collagen formation and calcium absorption, functions that are particularly important for people with diabetes who are at increased risk of bone demineralization (Wu, 2013).

Valine and isoleucine are believed to contribute to energy metabolism and blood glucose regulation (Zanchi et al., 2011), while phenylalanine acts as a precursor to neurotransmitters such as dopamine and adrenaline, thereby contributing to the regulation of mood and metabolism (Fernstrom, 2013). These findings are consistent with the work of Chukwuma et al. (2010) and Ndiaye. (2020), who demonstrated that fermentation improves the protein quality of foods by hydrolyzing proteins into free amino acids. Nonessential amino acids also showed significant variations among the formulations. The BFSF48 cookies had the highest levels, particularly of glutamic acid, arginine, aspartic acid, serine, glycine, proline, and alanine. This high content is thought to result from the hydrolysis of native proteins and the release of nonessential amino acids bound to protein structures by microbial proteases. Arginine is thought to stimulate insulin secretion by pancreatic beta cells, which would confer antidiabetic properties on tiger nut (Ndiaye, 2020 ; Wu et al., 2009). Glutamic acid is thought to play a role in regulating energy metabolism and nerve transmission (Newsholme et al., 2003), while glycine is involved in the synthesis of glutathione, a major endogenous antioxidant that helps combat oxidative stress associated with diabetes (Wheeler et al., 1999). Proline and alanine are thought to play a role in protein structure and energy metabolism (Wu, 2013). Compared to the control non-leavened cookie (BFST), the BFSF48 cookies show a marked improvement in this profile, consistent with the work of Gambo et Da'u. (2014).

Sensory evaluation of cookies made with fermented tiger nut flour revealed that all four (4) formulations received scores above 5/9 for all descriptors, indicating overall acceptability in line with the acceptability criteria defined by Meilgaard et al. (2007). This result is comparable to that of Sharma et al. (2016), who obtained acceptability scores ranging from 6.8 to 7.2/9 for cookies made with sprouted millet, confirming that alternative flours can produce sensorially acceptable cookies. Color and texture were consistent across the formulations ( $p > 0.05$ ), which can be explained by the constant composition of tiger nut flour, eggs, and olive oil common ingredients that determine these visual and structural attributes. In contrast, aroma significantly differentiated the formulations. The non-fermented cookies (BFST : 7.10/9) and those fermented for 24 hours (BFSF24 : 6.85/9) received higher ratings than those fermented for 48 hours (BFSF48 : 6.50/9) and 72 hours (BFSF72 : 6.00/9).

This difference could be explained by changes in the flavor profile during fermentation : Fermentative microorganisms produce volatile compounds with a pronounced fermented odor, the acceptability of which varies among consumers. Contrary to the findings of Sharma et al. (2016) where germination improved the acceptability of the cookies by increasing total protein and phenolic content in this study, prolonged fermentation degrades the aroma, likely due to the production of organic acids (lactic and acetic acids) that alter the olfactory perception. However, Adebisi et al. (2017) showed that biscuits made from fermented millet exhibited varying levels of acceptability depending on the duration of fermentation, with a preference for slightly fermented or unfermented formulations, which corroborates our results. The BFST formulation stood out as the most highly rated overall (7.05/9), reflecting the panel's preference for a neutral taste that enhances the perception of other sensory attributes. These results suggest that the unfermented control provided better sensory acceptability under the conditions of this study. Nevertheless, the panel size ( $n = 20$ ) and the tasters' possible lack of familiarity with fermented products suggest that the study should be expanded to include consumers accustomed to these local ingredients (Meilgaard et al., 2007).

### **Conclusion:-**

The overall objective of this study is to promote the use of a underutilized local food crop, the tiger nut (*Cyperus esculentus* L.), which is currently used primarily as a snack, through the production of cookies with varying

fermentation times. The results of the analyses showed that all biscuit formulations exhibit remarkable nutritional potential, as evidenced by high concentrations of essential and non-essential amino acids. The biscuits produced after 48 hours of fermentation showed high levels of essential and non-essential amino acids (glycine, proline, alanine, and aspartic acid). Sensory attributes such as color, aroma, flavor, taste, texture, juiciness, and tenderness of the BFST, BFST24, BFS48, and BFS72 formulations were positively rated by the majority of tasters. The cookies produced after a 48-hour fermentation period possess good nutritional potential and received favorable sensory evaluations; therefore, they can be recommended for human consumption, specifically for people with diabetes, given their nutritional richness.

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