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Diversity of Traditional Processing of *Tchakpalo*, an Indigenous Beer from Benin

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Abstract Originally associated with the sociocultural groups of Central Benin, *Tchakpalo*, a traditional beninese beer, has gradually spread throughout the country. This study aimed to establish the socio-professional profile of vendors and to document the new production practices of *Tchakpalo*. Hence semi-structured survey combined with direct observations of *Tchakpalo* vendors were carried out in the five municipalities of Southern Benin. The study indicates that this trade is strongly dominated by women (97.52%), aged 35 to 54 (87.60%), mostly educated (64.46%) and married (75.21%). They have at least five years of experience (78.51%). However, some have been working in this field for over 15 years (30.58%) and some practise this activity exclusively (42.97%). Nevertheless, *Tchakpalo* trade allows them to contribute significantly to their families' financial needs (100%). A large diversity of production practices has been registered through the study area. Thus, maize is the most used raw material in *Tchakpalo* production. Five technological variants of *Tchakpalo* production have been identified (DFM: Double-Fermented Maize; MFM: Mono-Fermented Maize; NFM: No-Fermented Maize; MFMS: Mono-Fermented Maize-Sorghum; NFMS: No-Fermented Maize-Sorghum). Each variant presented the same unit operations while the number, sequence, operating conditions, additives, and production equipment differ from a variant to another. The Mono-Fermented Maize (MFM) variant is the most commonly used by producers (37.70%). The results of this study provide a solid scientific database for projects to promote this beer, which is emblematic of Benin's food heritage.

Keywords: *maize, sorghum, gender, technological diagram, traditional processing, diversity*

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1. Introduction

The first inhabitants of the Earth primarily fed themselves with food obtained principally through hunting and gathering [1]. Later, the need to cultivate certain crops arose. Cereal grains were among the first crops to be grown and harvested. Ancient civilizations prospered in part due to their ability to produce, store and distribute these cereal grains: maize in the America before the arrival of Europeans, rice in the great Asian civilizations, and barley in Ethiopia and Northeast Africa. Millennia later, cereals remain staple products in Africa and constitute an important source of energy and micronutrients [2]. They are processed into various food products, both traditional and modern. The types of processing depend on the cereals cultivated and local dietary habits.

In Sub-Saharan African countries, several traditional beers are produced from locally grown cereals, particularly maize (*Zea mays* L.), millet (*Pennisetum typhoideum*) and sorghum (*Sorghum bicolor* (L.) Moench), and they constitute the main alcoholic beverage for savanna populations, meanwhile palm wine is the drink of forest-dwelling populations [3]. These beverages

contribute significantly to the diet of the populations in these countries and possess remarkable socio-economic importance. These beverages play a crucial role in ceremonies and public events and provides important income for women, who mainly produce them [2].

In Benin, *Tchakpalo* is a local and low-alcohol made by malting, brewing, and spontaneously fermentating a wort made from water and germinated maize or sorghum grits, or both [4]. Originally associated with the *Idaatcha* and *Nago* sociocultural groups, located in the municipalities of Glazoué and Dassa-Zoumè in Central Benin [5], this beer has gradually spread throughout the country, particularly in major cities, where it has become very popular [6].

During it migration, the original production process of *Tchakpalo* has undergone regional adaptations. These adaptations affect multiple aspects of the production, including the unit operations and their associated parameters, but also the raw materials, ingredients, and the production and sales equipment. However, the variations in *Tchakpalo* production methods in Southern Benin, are poorly documented and not widely recognised.

A valorization of this traditional beer, which is highly appreciated by the Beninese population, requires standardization of the production process based on the most appreciated sensory attributes. To accomplish this goal, it is essential to gather accurate information about the actors of the value chain and the processing conditions, and the distribution methods involved in the sector. This study aimed to contribute the food security of the population by documenting the processing conditions and distribution methods during *Tchakpalo* production and sale in Benin.

2. Material and Methods

2.1. Study Area

This study was carried out in the five (05) urban municipalities in Southern Benin within the Grand Nokoué area [7]: Cotonou (the economic capital), Porto-Novo (the administrative capital), and Abomey-Calavi, Sèmè-Podji and Ouidah (three residential municipalities) (Figure 1). The selection is justified by the limited documentation on the *Tchakpalo* production in these municipalities, particularly in Ouidah, Sèmè-Podji and Porto-Novo. The few studies on *Tchakpalo* are focused on Central Benin.

2.2. Selection of Survey Participants

For the selection of survey participants, mixed method, combining purposive sampling with the snowball sampling was implemented following Hongbete et al. [8]. Specifically, in each municipality, five (05) districts were randomly selected. Within each district, *Tchakpalo* vendors were chosen either randomly or based on recommendation, depending on their accessibility and availability and consent to participate in the study. In total, two hundred seventy-nine (279) vendors of *Tchakpalo* were interviewed during the survey period.

2.3. Collection of Socio-professional Data of *Tchakpalo* Vendors

The socio-professional profile of *Tchakpalo* vendors in the Grand Nokoué area was documented in French and/or the local language (*Fon*, *Goun*, *Yoruba*, *Nago*, Mahi, etc.), using a semi-structured questionnaire, from January to May 2024. The questionnaire, administered at the *Tchakpalo* sales site (*Tchakpalodrôme*), was structured around two main axes:

- Socio-demographic characteristics of the vendors including name, gender, age, occupation, level of education and/or literacy, ethnicity and marital status.
- Eco-professional characteristics of vendors including the nature of the producer, the type of trade (exclusive or not, primary or secondary), years of experience, method use for sale, financial income and membership in a professional association or organization.

2.4. *Tchakpalo* Production Monitoring

Based on their availability and the possibility of accessing their production units, sixty-one (61) *Tchakpalo* vendors were selected for production monitoring (09 in Ouidah, 16 in Abomey-Calavi, 07 in Cotonou, 08 in Sèmè-Podji and 21 in Porto-Novo). Production of *Tchakpalo* was followed at their respective processing units, in order to establish the flow chart used by each *Tchakpalo* processors. Particular attention was given to the raw materials (type, selection, variety, availability, additives, etc.), the production equipment (type, nature, manufacturing material, use, maintenance, etc.), and the production method (unit operations, operating conditions, packaging, etc.).

2.5. Statistical Analysis of Collected Data

The survey data collected were computed using GraphPad Prism Version 10.5, and descriptive statistics (mean and proportion) were performed to generate various graphs with the same software. Multiple comparison tests were conducted to analyse the differences in proportions among the various modalities of categorical variables (age, gender, etc.) using the prop.test function in R software version 4.4.2. ArcGIS Version 10.8 was used for the geographical representation of the study area.

3. Results and Discussion

3.1. Distribution of *Tchakpalo* Vendors in the Study Area

The Figure 2 shows the distribution of *Tchakpalo* vendor's accross the studied municipalities. In total, two hundred and seventy-nine (279) vendors inequally distributed across the study area (48 in Ouidah, 60 in Abomey-Calavi, 60 in Cotonou, 51 in Sèmè-Podji and 60 in Porto-Novo) were involved in the first phase of this

study. *Tchakpalo* vendors were found in all districts of the investigated municipalities showing the importance of the activity. This large distribution of vendors can be explained by the fact that the traditional beer *Tchakpalo* is well-known and consumed by many people. Over the past decade, it has become very popular, particularly in the major cities of Benin [6] (Konfo et *al*., 2015).

The municipalities of Ouidah and Sèmè-Podji recorded less *Tchakpalo* vendors than the other municipalities. This result can be explained by differences in the demographic profiles of these municipalities. Indeed, the communes of Ouidah and Sèmè-Podji have a low population density (482 and 897 inhabitants/km², respectively) compared to the communes of Abomey-Calavi (1,218 inhabitants/km²), Porto-Novo (5,286 inhabitants/km²), and Cotonou (8,595 inhabitants/km²), according to the INSAE [9] database. It is important to mention that Abomey-Calavi (residential city), Cotonou (economic capital), and Porto-Novo (administrative capital) are among the most cosmopolitan urban centers in Benin. In these municipalities, a cultural diversity can be observed, which is reflected, among other things, in a wide variety of culinary offerings. Therefore, the popularity of the traditional beer *Tchakpalo* in these areas comes as no surprise. This result also suggests that *Tchakpalo* consumers may be more represented in the municipalities of Abomey-Calavi, Porto-Novo, and Cotonou than in those of Ouidah and Sèmè-Podji.

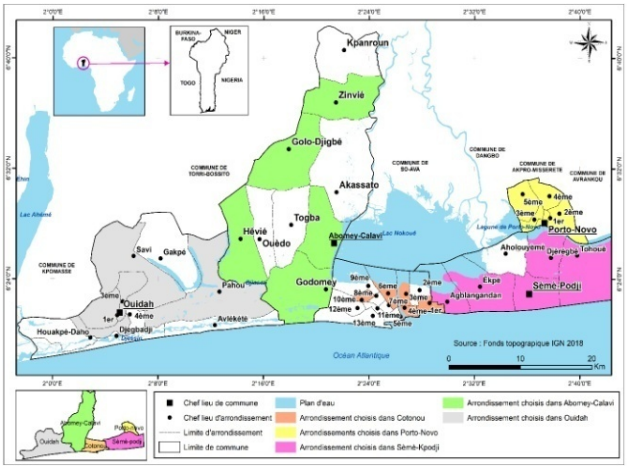


Figure 1. Geographical location of the study area

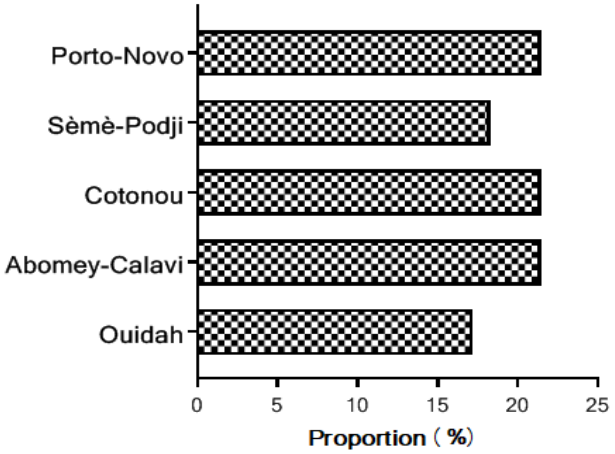


Figure 2. Distribution of *Tchakpalo* vendors according to municipality

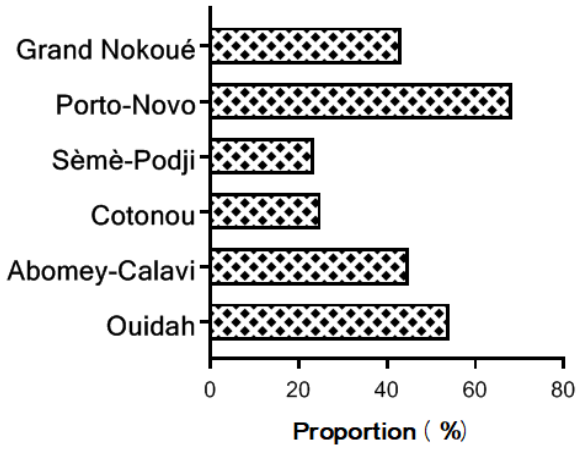


Figure 3. Proportion of genuine *Tchakpalo* vendors by municipality

3.2. Food Fraud Relating to *Tchakpalo*

All *Tchakpalo* vendors surveyed do not actually sell *Tchakpalo*. Indeed, this traditional beer is typically produced from maize, millet, sorghum, or a mixture of these grains. The production process must include three major stages: malting, brewing and fermentation. Unfortunately, only 43.37% of vendors offer the consumers a beverage produced according to the above criteria and with the main attributes of *Tchakpalo* (Figure 3). More specifically, there are more processors/vendors of genuine *Tchakpalo* in the municipalities of Ouidah and Porto-Novo. Conversely, the proportion of vendors of genuine *Tchakpalo* is at least half as low in the municipalities of Cotonou and Sèmè-Podji. Other processors/vendors of *Tchakpalo* are selling to the consumers adulterated *Tchakpalo* (fake *Tchakpalo*), which consists of a fermented or unfermented drink that, from an organoleptic and technological point of view, doesn't present the original attributes of *Tchakpalo*. The raw materials used for these fake *Tchakpalo* drinks are mainly pineapple (*Ananas comosus*) peel and *Guissi* (fermented, soaked maize starch supernatant). These ingredients are cooked to produce a drink to which carbonised sugar syrup is added to obtain the brownish color like the one of genuine *Tchakpalo*. Other chemical products are added to approximate the organoleptic characteristics of the original *Tchakpalo*. This practice, technically classified as food fraud, exposes consumers to significant health risks (biological, chemical, and physical). In fact, food fraud is defined as the act of altering, misrepresenting or substituting one product for another, thereby compromising consumer safety and economic ethics [10]. Primarily motivated by economic gain, food fraud poses serious risks to consumer health due to the introduction of unauthorized substances or allergens and mislabelling of toxic chemicals into food products [11]. The situation is even worse in developing countries such as Benin, where regulatory applications and food control are weak.

3.3. Socio-demographic Profile of *Tchakpalo* Vendors

The Table 1 provides information on the socio-demographic characteristics of *Tchakpalo* vendors in Grand Nokoué. Here only vendors of genuine *Tchakpalo*

(121 individuals) were d considered. A high significant difference ($p < 0.001$) was recorded between the modalities of each socio-demographic parameter. This Table 1 shows that the *Tchakpalo* sale is an activity carried out almost exclusively by women (97.52%) in Grand Nokoué. In fact, the few male *Tchakpalo* vendors encountered do not own the stalls themselves. They co-sell *Tchakpalo* with their wives when the latter are engaged in secondary commercial activities, family activities or other activities. These men, all of whom are labourers, have their workshops right next to the *Tchakpalo* sales site. It would therefore not be wrong to say that the sale of *Tchakpalo* is an activity carried out exclusively by women in Southern Benin. This feminization of *Tchakpalo* sales was also observed by Egounlety et *al*. [5] in the municipality Dassa-Zoumé in Central Benin.

Table 1. Socio-demographic characteristics of *Tchakpalo* vendors

Parameters	Ouidah (n=26)	Abomey-Calavi (n=27)	Cotonou (n=15)	Sèmè-Podji (n=12)	Porto-Novo (n=41)	Grand Nokoué (n=121)	*p-value*
Sex							
Female	25 (96.15%)	27 (100%)	13 (86.67%)	12 (100%)	41 (100%)	118 (97.52%)	< 0.001
Male	01 (3.85%)	0 (00%)	02 (13.33%)	00 (00%)	00 (00%)	03 (2.48%)	
Age							
< 25	01 (3.85%)	02 (7.41%)	00 (00%)	00 (00%)	00 (00%)	03 (2.48%)	
[25-35[	00 (00%)	04 (14.81%)	02 (13.33%)	00 (00%)	02 (4.88%)	08 (6.61%)	
[35-45[	18 (69.23%)	13 (48.15%)	09 (60%)	12 (100)	15 (36.58%)	67 (55.37%)	< 0.001
[45-55[	06 (23.07%)	08 (29.63%)	04 (26.67%)	00 (00%)	21 (51.22%)	39 (32.23%)	
[55-65[	01 (3.85%)	00 (00%)	00 (00%)	00 (00%)	03 (7.32%)	04 (3.31%)	
Ethnic group							
Fon	14 (53.85%)	10 (37.04%)	04 (26.67%)	01 (8.33%)	05 (12.19%)	34 (28.10%)	
Goun	00 (00%)	1 (3.70%)	09 (60%)	06 (50%)	32 (78.05%)	48 (39.67%)	
Nagot	00 (00%)	5 (18.52%)	00 (00%)	00 (00%)	00 (00%)	5 (4.13%)	
Idatcha	02 (7.69%)	5 (18.52%)	02 (13.33%)	00 (00%)	01 (2.44%)	10 (8.26%)	< 0.001
Yoruba	04 (15.38%)	01 (3.70%)	00 (00%)	02 (16.67%)	03 (7.32%)	10 (8.26%)	
Xwla	00 (00%)	00 (00%)	00 (00%)	03 (25%)	00 (00%)	03 (2.48%)	
Houéda	03 (11.54%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	03 (2.48%)	
Others	03 (11.54%)	5 (18.52%)	00 (00%)	00 (00%)	00 (00%)	08 (6.61%)	
Formal level education							
Not enrolled in school	09 (34.62%)	10 (37.04%)	04 (26.67%)	05 (41.67%)	15 (36.59%)	43 (35.54%)	
Primary	13 (50%)	11 (40.74%)	09 (60%)	05 (41.67%)	15 (36.59%)	53 (43.80%)	< 0.001
Secondary	04 (15.38%)	06 (22.22%)	02 (13.33%)	02 (16.66%)	11 (26.82%)	25 (20.66%)	
University	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	
Marital status							
Single	00 (00%)	04 (14.82%)	00 (00%)	00 (00%)	00 (00%)	04 (3.30%)	
Married	22 (84.61%)	16 (59.26%)	14 (93.33%)	10 (83.33%)	29 (70.73%)	91 (75.21%)	< 0.001
Divorce	00 (00%)	06 (22.22%)	00 (00%)	02 (16.67%)	07 (17.07%)	15 (12.40%)	
Widow	04 (15.38%)	01 (3.70%)	01 (6.67%)	00 (00%)	05 (12.20%)	11 (09.09%)	

$p > 0.05$ (No significant) ; $p < 0.05$ (significant) ; $p < 0.01$ (Very significant) ; $p < 0.001$ (Very highly significant).

Our results are consistent with those reported by Kagambega et *al*., [12] which noticed that In Burkina Faso, for example, the production and sale of traditional drink *Zoom-koom* is carried out exclusively by women. In Cameroon, the traditional fermented cereal drink (Kounou) is produced exclusively by women [13]. Other studies have also reported the predominance of women in the preparation and sale of street food (Noumavo et *al*., [14] in Benin; Adeosun et *al*., [15] in Nigeria; Nkosi and Tabil, [16] in South Africa; Ma et *al*., [17] in China and Samapundo et *al*., [18] in Haiti). This predominance of women observed in this study can be explained by the fact that in Africa, most activities involving cooking or food is devolved to women [19]. In addition, they are generally cheerful and more welcoming to customers. According to Konaté et *al*. [20], the predominance of women in the traditional processing of agricultural products results from their dual status as housewives and agricultural workers, often responsible for food preparation.

However, in other parts of the world, with very patriarchal cultures, like Brazil, there's a strong male presence in the street food sector. In fact, research carried out in Brazil by Isoni Auad et *al*. [21] and Cortese et *al*. [22], report that 80% (federal district) and 58% (city of Florianopolis) of street food vendors were men, respectively. In Haiti [18] and Kenya [23], it was reported that street food vendors were predominantly men.

Several factors can influence the gender profile in street food vending. These include: the type of food, the geographical area, cultural considerations, location (city centre or outlying neighbourhoods), etc. Ethnic specialization is sometimes noted. For example, in West Africa, grilling meat is a male specialty while roasted fresh corn is categorised as female activity. The Fulani, Moors and Hausa are the main groups involved in grilling meat as most of time, people belonging to those ethnic group practices animal rearing. Other culinary specialties

(curdled milk, ice cream, etc.) can be made by either men or women.

Except for Porto-Novo city, where *Tchakpalo* vendors registered were very old {[45-55[, 51.22%}, it can be noted that, the majority of *Tchakpalo* vendors of Grand Nokoué belong to the 35-44 age group (55.37 %) or the 45-54 age group (32.23 %). This result is close to the rate 97.5 % (26-65 years old) obtained by Egounlety et *al*. [5] in Central Benin on female vendors of *Tchakpalo* and slightly lower than the 69.4% (aged 35 to 54) obtained by Mahopo et *al*. [24] in South Africa on female street food vendors. Tégblé et *al*. [25] also observed a predominance of female vendors aged 35 to 45 in street food vending in Southern Benin. However, in a study conducted in Cameroon by Bayoï and Danla [26] on *Bili-Bili* and *Cochette*, two traditional beers produced from sorghum and rice respectively, the vendors were much younger (aged 20 to 40). Several factors influence the age of street food vendors (type of food, geographical area, culture, level of development, etc.). However, the 35-45 age group is predominant. This can be explained by the fact that this age corresponds to family settlement for many people and the need of financial resources to support their families is more highlighted in that period. Much more productive, with a strong desire to fulfil themselves, they are open to all types of income-generating activities that do not require large financial resources, such as street food selling.

The marital status of *Tchakpalo* vendors vary slightly from one city to another. The major marital types found include single, married, divorced, and widowed women. However, the majority of *Tchakpalo* vendors are married (75.21%) or divorced (12.40%). Although none of the vendors had received university degree, the majority had attended Primary or secondary school (64.46%), contrary to the results obtained by Egounlety et *al*. [5] (2019) in Central Benin, where the majority of female *Tchakpalo* vendors were illiterate (55%). This difference in the level of education of *Tchakpalo* vendors between Southern and Central Benin can be explained by the difference in the level of school infrastructure. In fact, in the southern municipalities, almost all villages and city neighbourhoods have at least one primary school and junior and senior high schools [27], which is not always the case in the central municipalities. Furthermore, the cities of Abomey-Calavi, Cotonou, and Porto-Novo are among the four cities with special status in the country, characterized by a level of development and urbanization significantly higher than in other cities. The level of education of street food vendors could increase in the coming years, thanks to the efforts of the Beninese government.

Indeed, free access to preschool and primary education, decreed in 2006 by the Beninese government, is now implemented throughout the country. Furthermore, the introduction of free school meals in preschool and primary schools, especially in rural areas, has significantly improved school enrolment rates for girls and boys [28]. When street food vendors are educated, their knowledge of food safety is relatively good and consumers are better protected. In a study conducted by Thanh [29] in Vietnam, a very positive correlation was recorded between street svendors' knowledge of food safety and their level of education and training. Although this remains debatable, education remains an important tool for development, especially in developing countries.

The ethnic groups most represented among *Tchakpalo* vendors in Grand Nokoué are the Fon (28.10%) and the *Goun* (39.67%). The strong representation of these two groups is entirely normal. Indeed, the *Fon-Goun* and related ethnic groups constitute the majority socio-cultural groups in the municipalities involved in this study. They account for 56.7 % of population of Cotonou, 66 % of population of Porto-Novo and 69.8 % of Ouidah population [30]. Although *Tchakpalo* it originated from central Benin, where it is mainly produced by the people from Nago ethnic group, traditional *Tchakpalo* beer has been adopted by ethnic groups in other towns and villages to which it has migrated.

3.4. Sales Practices and Economic Importance of the *Tchakpalo* Trade

The sales practices and economic importance of the *Tchakpalo* trade are presented in Table 2. A highly significant difference ($p < 0.001$) was observed between the modalities of almost all the parameters evaluated. This table shows that *Tchakpalo* production in Grand Nokoué is carried out by the women vendors themselves (100 %). For some, the *Tchakpalo* selling is their only professional activity (42.97 %), as is the case in the municipality of Dassa-Zoumè (Central Benin), where this traditional beer is widely consumed [5] (Egounlety et *al*., 2019). In Grand Nokoué, however, some vendors combine it with other commercial activities (57.02 %). For the majority of those in the latter group (66 %), the *Tchakpalo* selling remains their main commercial activity. The secondary activities they engage in, are periodic, with greater importance during periods of low sales of *Tchakpalo* (rainy seasons, harmattan, major holidays, etc.).

In terms of professional experience, the profile of *Tchakpalo* vendors varies from one city to another. It should be noted that more than half of the *Tchakpalo* vendors (57.85 %) have less than ten (10) years of professional experience. Approximately twenty-six percent (26 %) of vendors have between ten (10) and nineteen (19) years of experience in this activity, while nearly sixteen percent (16%) have been working in this field for more than twenty (20) years. This overall view hides certain subtleties. In fact, in the city of Porto-Novo, nearly half of the vendors (48.78%) have more than fifteen years of experience in *Tchakpalo* production and sales. This observation can be explained by the socio-demographic profile of *Tchakpalo* vendors. It is in this city that we find the oldest vendors (58.54% ≥15 years).

Considering the age profile and the number of years of experience, it can be noted that processors/vendors involved in this activity are generally young girls or young women who have made it their career. They find themselves in this trade mainly either through family inheritance, lack of employment opportunities, or for its average financial income.

Regardless of the municipalities, stationary sales are the most common method used by *Tchakpalo* vendors. More than three-quarters of these vendors use stationary sales (77.69%). Stationary sales refer to a form of marketing in

which the vendor operates from a fixed, stable, and easily identifiable location. In this sale mode, the consumer moves to the place of sale. The opposite of this sale form is itinerant or street selling, in which the vendor moves to offer her products to consumers. In this study, none of the *Tchakpalo* vendors exclusively adopt street vending. However, some vendors adopt a mixed sales method (22.31%) that combines stationary and itinerant sales to reach a larger number of consumers.

Very few vendors receive production orders from individuals in the municipalities of Ouidah and Sèmè-Podji. However, in the municipalities of Abomey-Calavi, Cotonou, and Porto-Novo, nearly half of the *Tchakpalo* vendors receive production orders for special events (weddings, dowries, birthdays, popular celebrations, etc.).

All the vendors report that selling *Tchakpalo* is a financially rewarding activity. The activity could generate significant profits, which enable processors/vendors to contribute significantly to their families' financial needs and to save money. Most of them did not wish to comment on the profits made daily. However, some vendors claim to make up to 9 $ US per day, especially during periods of high heat.

Unfortunately, none of *Tchakpalo* vendors (0 %) belong to a professional association, group or organization. Membership in such structures offers enormous advantages. They organize training for members on various aspects of their profession (economic, technical, marketing, etc.). Negassa et *al*. [31] showed that 95.4% of street food vendors have never had the opportunity to attend training related to food safety and hygiene.

3.5. Different Technological Variants of *Tchakpalo* Production in Grand Nokoué

3.5.1. Raw Materials

The two (02) main raw materials used in *Tchakpalo* production in Grand Nokoué are maize and sorghum. They are used in single production (maize or sorghum alone) or in co-production (maize and sorghum mixture). Each producer adopts one type of raw material and uses another only in the case of a special order. Table 3 shows the distribution of producers according to the type of raw material used daily. It is easy to see that maize in single-crop production is used by nearly three-quarters of producers, followed by a mixture of maize and sorghum. None of the producers use sorghum alone. This is because sorghum is more expensive than maize, which remains the main cereal in southern Benin. Even in central Benin, where *Tchakpalo* originated from, producers claim that combining raw materials for *Tchakpalo* production is very economical [5].

The raw material is purchased from wholesalers or retailers, at the market or in residential areas. According to *Tchakpalo* producers, the main quality criterion used in selecting raw materials is color (white or white-yellow for maize and red for sorghum). Secondarily, the grains must be whole, dry, free of mold, and contain no foreign matter or insect pests.

Table 2. Sales practices and economic importance of *Tchakpalo* trade

Parameters	Ouidah (n=26)	Abomey-Calavi (n=27)	Cotonou (n=15)	Sèmè-Podji (n=12)	Porto-Novo (n=41)	Grand Nokoué (n=121)	*p-value*
Production of *Tchakpalo* by the vendor							
Yes	26 (100%)	27 (100%)	15 (100%)	12 (100%)	41 (100%)	121 (100%)	< 0.001
No	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	
Type of commercial activity							
Exclusive	09 (34.62)	12 (44.44)	05 (33.33)	07 (58.33)	19 (46.34)	52 (42.97%)	0.040
No-exclusive	17 (65.38)	15 (55.56)	10 (66.67)	05 (41.67)	22 (53.66)	69 (57.02%)	
Number of experience years							
[0-5[	04 (15.38%)	09 (33.33%)	04 (26.67%)	02 (16.67%)	07 (17.07%)	26 (21.49%)	< 0.001
[5-10[	08 (30.77)	12 (44.45%)	07 (46.67%)	06 (50%)	11 (26.83%)	44 (36.36%)	
[10-15[	04 (15.38%)	03 (11.11%)	03 (20%)	01 (8.33%)	03 (7.32%)	14 (11.57%)	
[15-20[	06 (23.08%)	01 (3.70%)	00 (00%)	00 (00%)	11 (26.83%)	18 (14.88%)	
[20-25[	03 (11.54%)	02 (7.41%)	01 (6.66%)	00 (00%)	03 (7.32%)	09 (7.44%)	
> 25	01 (3.85%)	00 (00%)	00 (00%)	03 (25%)	6 (14.63%)	10 (8.26%)	
Sales method							
Stationary	17 (65.38%)	21 (7.78%)	10 (66.67%)	10 (83.33%)	36 (87.80%)	94 (77.69%)	< 0.001
Mobile	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	
Mixed	09 (34.62%)	06 (22.22%)	05 (33.33%)	02 (16.67%)	05 (12.20%)	27 (22.31%)	
Oder							
Yes	02 (7.69%)	13 (48.15%)	06 (40%)	02 (16.67%)	19 (46.34%)	42 (34.71%)	< 0.001
No	24 (92.31)	14 (51.85%)	09 (60%)	10 (83.33%)	22 (53.66%)	79 (65.29%)	
Financial income							
Yes	26 (100%)	27 (100%)	15 (100%)	12 (100%)	41 (100%)	121 (100%)	< 0.001
No	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	
Membership in a professional association/organization							
Yes	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	00 (00%)	< 0.001
No	26 (100%)	27 (100%)	15 (100%)	12 (100%)	41 (100%)	121 (100%)	

$p > 0.05$ (No significant) ; $p < 0.05$ (significant) ; $p < 0.01$ (Very significant) ; $p < 0.001$ (Very highly significant).

[A1] Corn seed, [A2] Sorghum seed, [B1-2] Sorting, [B3] Winnowing, [C1-3] Washing, [D1-2] Soaking, [E1-3] Draining, [F1-8] Germination, [G1-3] Drying, [H1-2] Crushing, [I1] 1rst Fermentation, [J1-2] 1rst Fermentation, [K1-3] Cooking, [L1-3] 2nd Fermentation, [M1] Addition of carbonized sugar syrup, [N1-2] Filtration, [O1] Addition of white powdered sugar, [P1-2] Packaging and sale.

Figure 4. Diagram images showing the differents units operations of *Tchakpalo* production process

Table 3. Distribution of vendors according to the raw material used

Raw materials	Vendors Proportion (%) (n = 121)	*p-value*
Maize only	90 (74.38%)	
Sorghum only	00	< 0.001
Mixure Maize-sorghum	31 (25.62%)	

p > 0.05 (No significant) ; p < 0.05 (significant) ; p < 0.01 (Very significant) ; p < 0.001 (Very highly significant).

3.5.2. Technical Production Methods for *Tchakpalo*

Five (05) different technological diagrams have been identified to produce *Tchakpalo* in Grand Nokoué. These include the three (03) crucial and decisive stages in brewing, namely malting, brewing and fermentation.

The various stages of malting process are almost identical among producers. This process begins with cleaning (sorting, winnowing and washing) of the maize or sorghum several times to remove as much rotten grains and foreign materials as possible (moldy or broken maize grains, weevils, sand, stones, etc.) (Figure 4). The clean grains are then soaked in water, often in a closed container, at room temperature for 1 to 2 days. To produce maize-sorghum *Tchakpalo*, the maize and sorghum grains are soaked together. Soaking is widely recognized as the most critical step in malting because, good soaking will result in good germination [32]. Indeed, rehydration of the grains starts cellular metabolism, which leads to the lifting of grain dormancy and their entry into germination [33].

Enzymes such as amylases (α and β), proteases, peptidases and glucanases, which are essential for the germination phase, are synthesized and released during soaking. The soaked cereal grains are then drained, spread out in a basket lined with banana leaves or on a synthetic cloth on the ground, and covered for 3 to 4 days to ensure proper germination. During germination, the grains are sprinkled with water every 24 hours or twice a day (morning and evening) to allow the grains to germinate properly and to limit the risk of fungal contamination. The germinated seeds produce seedlings of relatively uniform size. These seeds are sun dried for an average of 3 days. This step has two advantages: it dries the seeds and stops germination [32].

The brewing process in *Tchakpalo* production essentially consists of grinding the malted grains and cooking the resulting grits. The malted maize or sorghum grains are crushed using a mill or a mortar and pestle. This step releases the important elements as starch polymers and enzymatic equipment, and increases the surface area in contact with water, thus optimizing sugar extraction [32]. The grits obtained after crushing are mixed with tap water and homogenized. This mixture may or may not undergo spontaneous fermentation for 24 to 48 hours at room temperature. This is followed by cooking at 100 °C on a wood or charcoal fire to obtain malted maize or sorghum wort (a sweet solution composed principally of fermentable sugars). The wort obtained in this way, after various additions (carbonized sugar syrup, *Guissi*,

sorghum panicle, lemongrass leaves, etc.) depending on the type of diagram, is filtered and the grains residues are removed. The grains residues obtained are often reused for another preparation. Producers add tap water and/or *Guissi*, then leave the mixture to seattle or ferment, as appropriates, folklore by the other seps described above.

All producers (100%) add caramelized sugar syrup to the mash to obtain or enhance the characteristic brownish color of *Tchakpalo*. In addition to caramelized sugar syrup, some producers (21.49%) add sorghum panicles to give maize *Tchakpalo* its brownish color. In the study conducted by Egounlety et *al*. [5], 50% of producers reported that they add sorghum panicles and/or sorghum leaf sheaths to change the whitish color of maize *Tchakpalo* to a brown color that is highly appreciated by consumers. According to some producers (8.26%), sorghum panicles also have antibacterial properties. Some producers add fermented maize starch supernatant (Guissi) to acidify the medium, making it more conducive to good fermentation. Lemongrass leaves or their infusions are sometimes added during or after cooking for flavouring of the drink.

The filtrate obtained undergoes spontaneous fermentation for 24 hours at room temperature. During this fermentation phase, sugars are converted into alcohol and organoleptic compounds are produced. Although this fermentation is spontaneous, it modifies the content of essential components in the must, such as carbohydrates, proteins, and minerals, reduces anti-nutritional factors, and induces the production of various aromas [34]. To speed up fermentation, some producers add baker's yeast (*Saccharomyces cerevisiae*). It should be noted that all producers (100%) use plastic containers for fermentation. This could be explained by the fact that plastic accumulates heat better, thus creating ideal conditions for the development and proliferation of fermenting microorganisms. In the fermentation processes of traditional fermented beverages, the fermenting microorganisms come mainly from the microflora naturally present in the substrates, additives, utensils, and equipment used [35].

The product of this fermentation, known in brewing technology as bruite beer, green beer, or young beer, is filtered and sweetened by adding powdered white sugar or left unsweetened before being packaged for sale. Depending on the technology used, this produces *Tchakpalo* made from maize, sorghum, or a mixture of maize and sorghum. *Tchakpalo* is generally packaged in calabashes, plastic basins, or 0.5 L, 1.5 L, or 25 L cans. Some consumers add lemon juice to *Tchakpalo* before drinking it. Figure 5 and Figure 6 shows the production diagrams for maize *Tchakpalo* and maize-sorghum *Tchakpalo*, respectively. Basicallly, there are three (03) technological variants for the production of maize *Tchakpalo* and two (02) technological variants for the production of maize-sorghum *Tchakpalo*.

3.5.3. Major Technological Differences Between the Various *Tchakpalo* Production Processes Identified

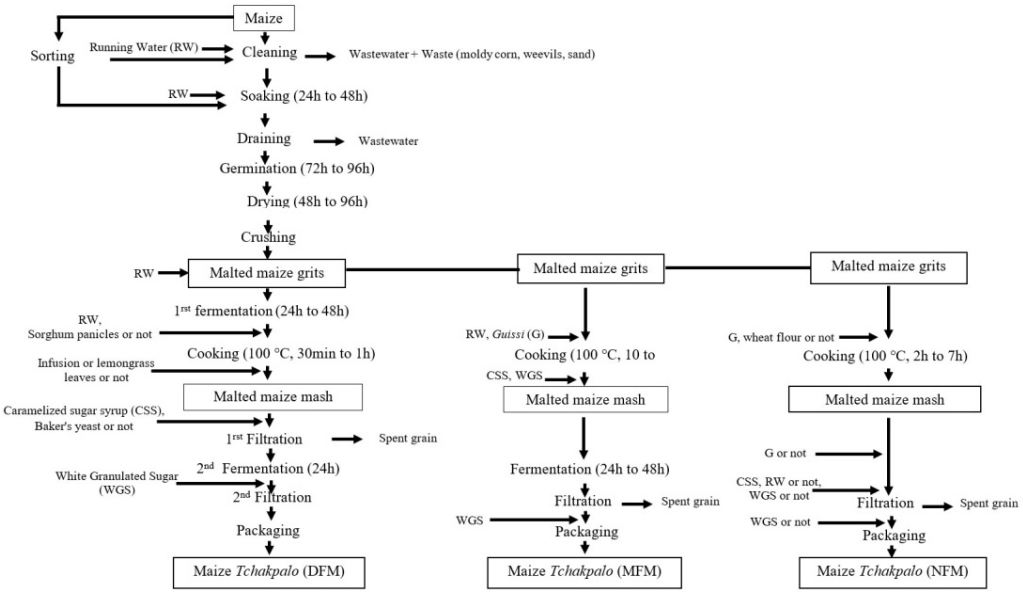
The five (05) different *Tchakpalo* production processes identified in this study contain all practically the same unit operations (sorting, washing, soaking, draining, germination, drying, crushing, cooking, filtration, fermentation and packaging). However, the number, chronology, operating conditions (duration, temperature, etc.), additives and production equipment vary significantly from one process to another. Also, the number of processors varies significantly ($p < 0.001$) from one process to another. This result confirms the observations of some authors who have worked on traditional african beers. Indeed, Coulibaly et *al*. [36] stated that traditional beer production processes in Africa are long, complex and vary depending on the country or region, but are nevertheless based on the same principles. These processes involve three main operations: malting, brewing and fermentation [37,38]. Thus, based on the two raw materials (maize and sorghum) and the number of major technological operations (malting, brewing and fermentation), Table 4 presents a comparative summary of these variants.

The Table 4 shows that the type of raw material and the number of fermentation stages are the most significant criteria differentiating the various *Tchakpalo* production processes in Grand Nokoué. Three (03) variants contain at least one distinct stage of spontaneous fermentation (DFM, MFM and MFMS). In the other two (02) variants, there is no distinct stage of spontaneous fermentation; this has been replaced by the usage of fermented maize starch supernatant (*Guissi*), which acidifies the medium, giving *Tchakpalo* the tangy taste normally obtained after fermentation. *Guissi* is also considered a starter, as it contains fermenting microorganisms. As a reminder, *Guissi* is purchased from *Akassa* producers. It is a traditional fermented paste made from maize starch and consumed in several West African countries, especially Benin [12].

The Table 5 illustrates the distribution of *Tchakpalo* producers according to the type of diagram used. This table shows that the MFM and NFM processes are the most widely used by producers in all the municipalities involved in this study. They are used by 37.70 % and 26.23 % of producers in Grand Nokoué, respectively.

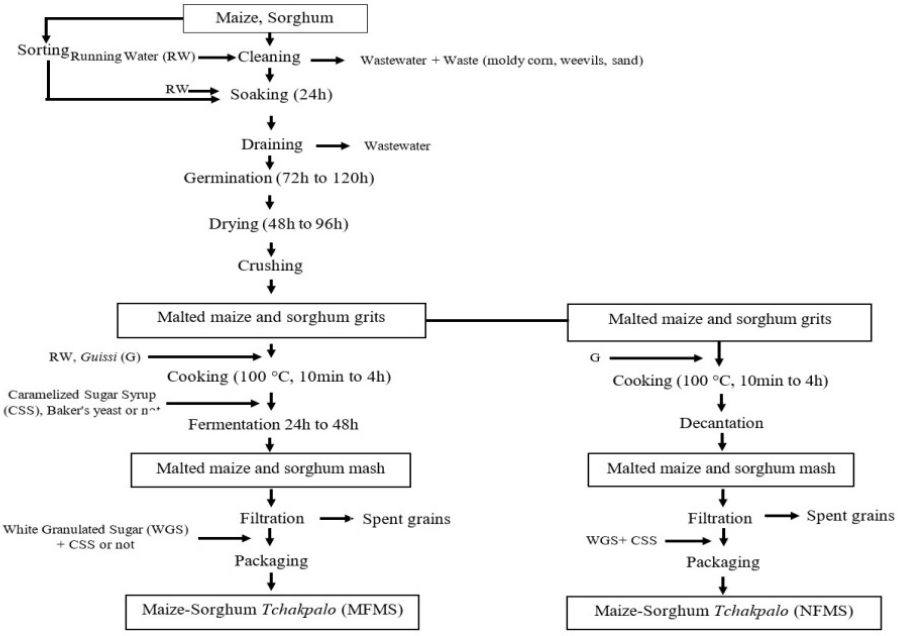
Konfo et *al*. [6] observed that 95 % of women producers of maize *Tchakpalo* in urban areas (Cotonou, Abomey-Calavi and Lokossa) used a production process without a distinct fermentation stage. According to producers using the NFM process, *Guissi* not only reduces the production time of *Tchakpalo*, making it less labor-intensive and more economical, but also gives *Tchakpalo* a distinctive taste and aroma that is highly appreciated by consumers.

In fact, the duration of spontaneous fermentation of a product can be shortened by using another previously fermented product containing specific microorganisms such as yeasts and lactic acid bacteria: this is known as back-slopping inoculation [39]. Back-slopping is a traditional fermentation technique that involves reusing a portion of a previous culture to sow a new production, thus preserving and adapting the microbial flora over successive cycles [40]. This fermentation technique has been widely used for centuries because it is easy to apply and produces high yields, even though it poses significant health risks [41].



DFM: Double Fermented Maize; MFM: Mono Fermented Maize; NFM: No Fermented Maize

Figure 5. Technological variants for the production of maize Tchakpalo in Grand Nokoué



MSMF: Maïs-Sorgho Mono Fermented; MSNF: Maïs-Sorgho No Fermented

Figure 6. Technological variants for the production of maize-sorghum Tchakpalo in Grand Nokoué

Table 4. Comparative summary of the *Tchakpalo* production variants identified

Steps	Unitary operations	*Number*				
		Maize *Tchakpalo*			Maize-sorghum *Tchakpalo*	
		DFM	*MFM*	*NFM*	*MFMS*	*NFMS*
Malting	Soaking	1	1	1	1	1
	Germination	1	1	1	1	1
	Drying	1	1	1	1	1
Brewing	Crushing	1	1	1	1	1
	Cooking	1	1	1	1	1
	Filtration	2	1	1	1	1
Fermentation	Clear fermentation	2	1	0	1	0

DFM: Double Fermented Maize ; MFM: Mono Fermented Maize ; NFM: No Fermented Maize ; MFMS: Mono Fermented Maize-Sorghum ; NFMS: No Fermented Maize-Sorghum.

Table 5. Distribution of female producers according to the type of diagram used

Technologies	Proportion of producers (%)						
	Ouidah (n=09)	Abomey-Calavi (n=16)	Cotonou (n=07)	Sèmè-Podji (n=08)	Porto-Novo (n=21)	Grand Nokoué (n=61)	*p-value*
DFM	00 (00%)	02 (12.5%)	00 (00%)	01 (12.5%)	04 (19.05%)	07 (11.47%)	
MFM	04 (44.44%)	05 (31.25%)	03 (42.86%)	03 (37.5%)	08 (38.09%)	23 (37.70%)	
NFM	02 (22.22%)	04 (25%)	03 (42.86%)	02 (25%)	05 (23.81%)	16 (26.23%)	< 0.001
MFMS	02 (22.22%)	03 (18.75%)	00 (%)	01 (12.5%)	02 (9.52%)	08 (13.11%)	
NFMS	01 (11.11%)	02 (12.5%)	01 (14.28%)	01 (12.5%)	02 (9.52%)	07 (11.47%)	

$p > 0.05$ (No significant) ; $p < 0.05$ (significant) ; $p < 0.01$ (Very significant) ; $p < 0.001$ (Very highly significant).

4. Conclusion

This study focuses on the technological diversity and socio-professional profile of *Tchakpalo* vendors in Grand Nokoué and reveals that the sector is strongly dominated by women aged 35 to 54, educated and married, belong to the *Fon* and *Goun* ethnic groups, and have at least five years of experience. None of them belong to an association, group, or professional organization. Nevertheless, this informal trade allows them to contribute significantly to their families' financial needs. The high degree of heterogeneity in production practices, reflecting the local adaptation of the original process, is an obstacle to the standardization and promotion of this beer, which is emblematic of Benin's food heritage. However, the characterization of the actors and technological variants (DFM, MFM, NFM, MFMS, and NFMS) provides an essential scientific basis for research and development projects aimed at producing safe, consistent quality *Tchakpalo* that can be promoted on a larger scale. Achieving these objectives requires characterization of microbiological, physicochemical, and nutritional properties of the different variants identified, and, far better, identifying the sensory attributes related to the most appreciated *Tchakpalo* by consumers and it related physicochemical qualities attributes.

Styles for table title, table head, and table text are provided. Tables should be set in one column wherever possible and be placed near their first mention in the body. Tables and figures do not need to be placed on separate pages at the back of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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