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# Research Article
# Characterization of Production Processes and Various Uses of Palm Kernel Oil in Benin

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## Abstract

**Background and Objective:** Palm kernel oil, extracted from the kernels of *Elaeis guineensis*, holds substantial economic, cultural and livelihood importance in Benin, particularly for rural communities. Despite its wide-ranging applications across the food, cosmetic and pharmaceutical sectors, comprehensive information on its production systems and consumption patterns in Benin remains limited. This study aimed to characterize the production processes, utilization practices and consumption forms of palm kernel oil in Benin. **Materials and Methods:** A survey was carried out from August 2024 to February 2025 involving 259 stakeholders across the departments of Mono, Couffo, Ouémé, Plateau, Atlantique and Zou. Data collected on knowledge, perceptions, uses and production technologies of palm kernel oil were analyzed using descriptive statistics and analysis of variance (ANOVA), followed by the Student-Newman-Keuls test at a 5% significance level. **Results:** Women represented the majority of participants (87.3%). Three production systems were identified: traditional (12%), semi-traditional (19%) and modern (54%). Traditional oil, typically black in color, is predominantly used for cultural and ritual practices, including purification ceremonies, funerals and traditional healing (8.49%). In contrast, semi-traditional and modern oils are dark brown and yellowish, respectively and are more frequently used in cosmetic applications (49.81%), particularly in the production of local soaps (e.g., Kôtô, soda, cooki). They are also used in food preparation (30.4%) for dishes such as beans, fritters, sauces and fried foods, as well as in toothpaste production (8.1%). **Conclusion:** Production techniques significantly influence the organoleptic characteristics and subsequent uses of palm kernel oil. Despite its functional and nutritional potential, the oil remains underutilized in human diets and warrants enhanced promotion and valorization.

Key words: Benin, nutritional quality, palm kernel oil, production techniques, valorization

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Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Population growth in African countries is contributing to rising global food and nutritional demands. Addressing these needs while improving the quality of agricultural and agro-food production represents a major challenge for developing nations today[1]. In this context, the expansion of local agro-processing industries offers a strategic opportunity to enhance food availability and improve consumer access[2]. Vegetable oils, which are widely used in traditional cuisines across Africa, South America and Asia, also play a critical role in the cosmetics, biofuel and food industries[3]. Among these, palm kernel oil-extracted from the kernels of the oil palm (*Elaeis guineensis*)-holds particular importance in Benin due to its economic significance and its contribution to the livelihoods and cultural practices of rural communities.

The oil palm is an essential crop in southern Benin, both economically and socioculturally[4]. However, current levels of palm kernel oil production remain insufficient to meet the steadily increasing demand driven by rapid population growth[5]. Strengthening the national economy requires diversification and structuring of agricultural value chains, which can enhance export revenues. In a globalized market, the development of the oil palm sector has thus become a strategic priority for Benin to reinforce its competitive positioning[5]. The southern region, the country's main production zone, is characterized by sandy-clay soils underlain by substantial lateritic deposits locally referred to as *terre de barre*[6]. In developing economies endowed with oil palm resources, palm kernel oil production represents a key activity, supporting both local industries and rural communities. It provides substantial employment opportunities and constitutes an important source of household income[7]. This vegetable oil also has numerous industrial applications, including the manufacture of glycerin, candles, margarine, ointments, pharmaceuticals, polishes and oil paints and it can serve as an economical feedstock for biodiesel when produced at large scale[8,9]. In most plantations, mixed oil palm varieties (Dura, Tenera and occasionally Pisifera) are cultivated, harvested and processed collectively .

Oil extraction from oilseeds employs both traditional and modern techniques, including mechanical and chemical processes[10]. Although, artisanal palm kernel oil production remains predominant, industrial initiatives are increasingly emerging, signalling a gradual transformation of the sector. Nonetheless, the value chain continues to face several structural challenges in Benin. The heterogeneity of production methods significantly affects product quality and commercial value. Furthermore, despite the oil's diverse applications in the food, cosmetic and pharmaceutical sectors, comprehensive knowledge of its uses and consumption patterns in Benin remains limited. Yet, this sector holds considerable potential for youth employment, especially in light of the growing demand for higher-quality palm kernel oil.

Given these considerations, in-depth research on the production, marketing and consumption of palm kernel oil in Benin is essential. Such work would contribute to improving public awareness, enhancing value addition and supporting market development. This study was undertaken within this framework, aiming to examine the production process, uses and consumption forms of palm kernel oil produced in Benin.

## MATERIALS AND METHODS

**Study area:** The study was conducted in the Departments of Mono, Couffo, Ouémé, Plateau and Atlantique (Southern Benin), as well as Zou (Central Benin). These areas were selected for their high oil palm productivity, as the Southern and parts of the central regions constitute the primary agroecological zones suitable for oil palm cultivation in Benin[6]. The selection of municipalities was carried out in collaboration with officers from the Territorial Agricultural Development Agencies (ATDA), who served as technical intermediaries during fieldwork. Consequently, the investigation covered the municipalities of Allada and Zè (Atlantique); Aplahoué, Djakotomey, Dogbo, Klouekanmé, Lalo and Toviklin (Couffo); Athiémè, Comè and Lokossa (Mono); Adjarra and Porto-Novo (Ouémé); Kétou, Pobè and Sakété (Plateau); and Abomey, Agbangnizoun, Bohicon, Covè, Djidja, Ouinhi, Zagnanado, Zakpota and Zogbodomey (Zou). In total, 6 departments and 25 municipalities were included. Village selection within these municipalities was based on the confirmed presence of active palm kernel oil production activities. Figure 1 presents the geographic distribution of the surveyed municipalities.

**Sampling:** The number of individuals to be interviewed in each district was determined using the quota sampling method, based on statistical data from the National Institute of Statistics and Demography (INSTaD), formerly the National Institute of Statistics and Economic Analysis[11,12]. A total of 259 stakeholders involved in the production and utilization of palm kernel oil were surveyed, comprising 226 women and 33 men. The distribution of participants by department, municipality and study zone is provided in Table 1.

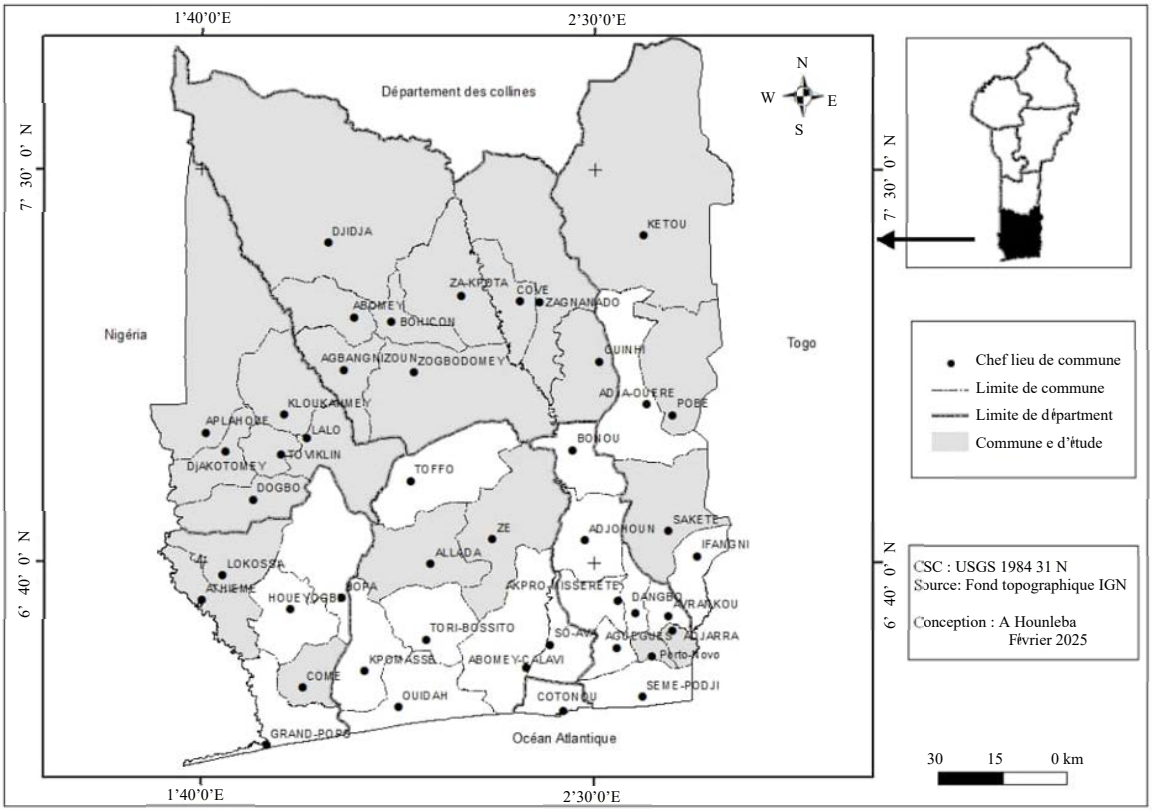


Fig. 1: Geographic location of the surveyed municipalities

Table 1: Number of respondents by department, municipality and region

| Survey areas/departments | Municipalities | No. of respondents |
|---|---|---|
| **South Benin** | | |
| Atlantic (30 respondents) | Allada | 17 |
| | Ze | 7 |
| Couffo (64 respondents) | Aplahoue | 14 |
| | Djakotomey | 19 |
| | Dogbo | 6 |
| | Klouekanme | 9 |
| | Lalo | 7 |
| | Toviklin | 9 |
| Mono (42 respondents) | Athieme | 13 |
| | Come | 15 |
| | Lokossa | 14 |
| Ouémé (21 respondents) | Adjarra | 8 |
| | Porto-Novo | 13 |
| Plateau (37 respondents) | Ketou | 14 |
| | Pobe | 22 |
| | Sakete | 1 |
| **Central Benin** | | |
| Zou (65 respondents) | Abomey | 12 |
| | Agbangnizou | 4 |
| | Bohicon | 10 |
| | Cove | 10 |
| | Djidja | 5 |
| | Ouinhi | 5 |
| | Zagnanado | 4 |
| | Zakpota | 10 |
| | Zogbodomey | 5 |
| **Total number of surveys** | | 259 |

**Data collection:**

**The study was implemented in two consecutive phases:**

- **Phase 1:** Conducted from August to October 2024, this phase consisted of focus group discussions in the 25 selected municipalities. Guided by a structured discussion framework, each focus group comprised 8-12 women and 1-3 men, all of whom were actively engaged in palm kernel oil production or processing
- **Phase 2:** Conducted from November 2024 to February 2025, this phase involved individual interviews using a structured questionnaire. A snowball sampling approach, as described by Gandeho, was applied to recruit respondents[13]. In total, 259 stakeholders-including young adults, adults and elderly individuals of both sexes-participated. Respondents were producers and processors of palm kernel oil. In addition to socio-cultural variables (gender, age, education level, occupation, religion, ethnicity), the questionnaire addressed knowledge and perceptions of palm kernel oil (storage, preservation, organoleptic qualities), its uses and production technologies

**Statistical data analysis:** Collected data were coded and entered into Excel 2016, then analyzed using SPSS (Statistical Package for Social Sciences) version 20.0 to generate descriptive statistics, including frequencies, percentages and means[13]. Quantitative variables were subjected to analysis of variance (ANOVA) using the PROC GLM procedure in SAS (Statistical Analysis System) version 9.2, following the approach described by Balogoun (2014). Post hoc comparisons of means were conducted using the Student-Newman-Keuls test at a 5% significance level.

In African contexts and particularly in Benin-local perceptions of phenomena and practices are strongly shaped by customs and traditions closely tied to sociocultural identity[14]. Accordingly, respondents were classified according to age group (young, adult, elderly), gender (female, male), ethnic group (Adja, Aizo, Fon, Goun, Mina, Nagot, Sahouè, Yoruba) and education level (illiterate, primary, secondary, university). The combination of these variables yielded 48 sociocultural categories (Table 2), compared with the 168 theoretically possible combinations, the difference being attributed to the absence of certain combinations within specific regions. The resulting contingency matrix was analyzed using simple Correspondence Factor Analysis (CFA) in Minitab 19 and the outputs were presented in tables and figures[15]. The number of respondents associated with each of the 48 sociocultural categories is reported in Table 2.

Table 2: Number of respondents associated with the 48 main sociocultural groups studied (N = 259)

| Socio-cultural group codes | | No. |
|---|---|---|
| Adult Adja woman with primary education | AFAP | 3 |
| Adult female Adja with secondary education | AFAS | 1 |
| Adult female Adja, uneducated | AFAA | 20 |
| Adult female Aizo with primary education | AFAiP | 1 |
| Adult Female Aizo with no education | AFAiA | 8 |
| Adult female with primary education | AFFP | 1 |
| Adult Female Secondary level education | AFFS | 1 |
| Adult Female Fon with no education | AFFA | 14 |
| Adult Female Nagot uneducated | AFNA | 18 |
| Adult Female Sahouè, uneducated | AFSA | 3 |
| Adult Female Yoruba, uneducated | AFYA | 1 |
| Adult uneducated Aizo man | AMAiA | 1 |
| Adult Male Goun with university education | AMGU | 1 |
| Young Female Adja at primary school level | JFAP | 11 |
| Young Adja woman at secondary level | JFAS | 2 |
| Young uneducated Adja woman | JFAA | 42 |
| Young Aizo woman with primary education | JFAiP | 1 |
| Young Aizo woman, uneducated | JFAiA | 9 |
| Young Fon woman with primary education | JFFP | 11 |
| Young Fon woman with secondary education | JFFS | 4 |
| Uneducated Fon Young Woman | JFFA | 29 |
| Young Goun woman with primary education | JFGP | 4 |
| Uneducated young Goun woman | JFGA | 9 |
| Young Mina woman with primary education | JFMP | 3 |
| Young Mina woman, uneducated | JFMA | 5 |
| Young uneducated woman Nagot | JFNA | 7 |
| Young Sahouè woman with primary education | JFSP | 1 |
| Young uneducated Sahouè woman | JFSA | 3 |
| Young Yoruba woman with primary education | JFYP | 2 |
| Uneducated young Yoruba woman | JFYA | 4 |
| Young Adja man with primary education | JMAP | 1 |
| Young Adja man at secondary level | JMAS | 1 |
| Young Adja man at university level | JMAU | 1 |
| Young Adja man with no education | YUA | 1 |
| Young Aizo man with primary education | JMAiP | 3 |
| Young Man Fon, primary level | JMFP | 9 |
| Young Fon Man with Secondary Education | JMFS | 5 |
| Young Fon Man with University Education | YUMU | 2 |
| Uneducated Fon Young Man | JMFA | 1 |
| Young Goun man with primary education | JMGP | 1 |
| Young Man Goun at secondary level | JMGS | 1 |
| Young Mina Man of Primary Level | JMMP | 1 |
| Young Mina man, uneducated | JMMA | 1 |
| Young uneducated man Sahouè | JMSA | 1 |
| Old uneducated Adja woman | VFAA | 2 |
| Old uneducated Aizo woman | VFAiA | 3 |
| Old woman Fon uneducated | VFFA | 4 |
| Old Man Aizo with secondary education | VMAiS | 1 |
| Total | | 259 |

## RESULTS

**Sociodemographic characteristics of stakeholders involved in palm kernel oil production in Benin:** Table 3 summarizes the descriptive statistics of the sociodemographic characteristics of respondents across the 6 surveyed departments. The findings indicate that palm kernel oil production is predominantly undertaken by women, who constitute 87.3% of stakeholders, whereas men represent 12.7%. Respondents ranged in age from 20-95 years, with a mean age of 44 years. Results from the analysis of variance (ANOVA), followed by the Student-Newman-Keuls test, show that stakeholders in the Departments of Atlantique, Couffo and Plateau are significantly older ($p<0.05$) than those in Mono, Ouémé and Zou (Fig. 2). Additionally, 68.0% of respondents were between 20 and 50 years of age and were primarily involved as producers and traders of palm kernel oil (96.1%). A high proportion of respondents (71.4%) reported having no formal education.

### Identification of palm kernel oils in Benin

**Presentation of palm kernel oils in Benin:** Plate 1 presents the different forms of palm kernel oil identified in Benin. The characteristics of the oils vary according to the production method, which directly influences their color, odor, taste and applications. Three main production methods were identified. The modern process produces a fluid, yellowish oil with a mild odor and a pleasant taste, primarily used in cosmetics and to

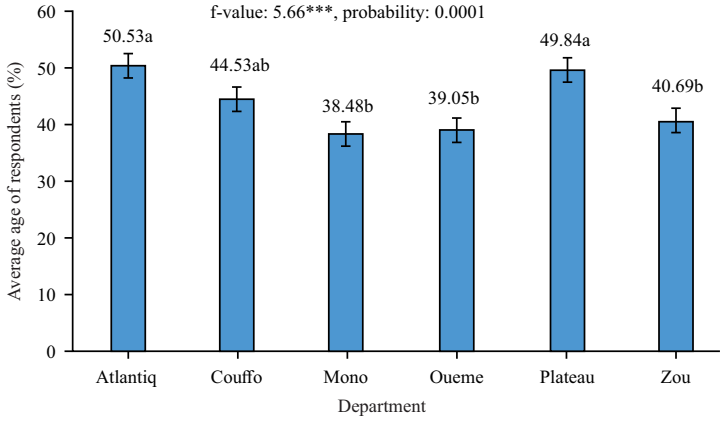


Fig. 2: Quantitative data (mean values±standard errors) on the age of palm kernel oil stakeholders in the two surveys
Error bars followed by the same letters are not significantly different (p>0.05) according to the Student Newman-Keuls test

Table 3: Sociodemographic characteristics of surveyed palm kernel oil stakeholders by study department

| | Percentage of respondents (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Variables/modalities | Atlant (n = 30) | Couffo (n = 64) | Mono (n = 42) | Ouémé (n = 21) | Plateau (n = 37) | Zou (n = 65) | Total (n = 259) |
| **Category of respondent** | | | | | | | |
| Farmer/producer | 0.0 | 0.0 | 0.0 | 0.0 | 13.5 | 0.0 | 1.9 |
| Consumers | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| Producers/traders | 100.0 | 98.4 | 100.0 | 81.0 | 86.5 | 100.0 | 96.1 |
| Traditional practitioners/producers | 0.0 | 0.0 | 0.0 | 19.0 | 0.0 | 0.0 | 1.5 |
| **Age** | | | | | | | |
| 0≤age <50 years | 45.8 | 64.1 | 85.7 | 85.7 | 45.9 | 73.8 | 68.0 |
| 50≤age <70 years | 33.4 | 34.3 | 11.9 | 14.3 | 54.1 | 21.6 | 28.1 |
| 70 years or older | 20.8 | 1.6 | 2.4 | 0.0 | 0.0 | 4.6 | 3.9 |
| **Gender** | | | | | | | |
| Male | 29.2 | 3.1 | 14.3 | 19.0 | 2.7 | 20.0 | 12.7 |
| Female | 70.8 | 96.9 | 85.7 | 81.0 | 97.3 | 80.0 | 87.3 |
| **Ethnicity** | | | | | | | |
| Adja | 0.0 | 100.0 | 50.0 | 0.0 | 0.0 | 0.0 | 32.8 |
| Aizo | 91.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.4 |
| Fon | 8.3 | 0.0 | 7.1 | 28.6 | 10.8 | 100 | 34.9 |
| Goun | 0.0 | 0.0 | 0.0 | 71.4 | 2.7 | 0.0 | 6.2 |
| Mina | 0.0 | 0.0 | 23.8 | 0.0 | 0.0 | 0.0 | 3.9 |
| Nago | 0.0 | 0.0 | 0.0 | 0.0 | 67.6 | 0.0 | 9.7 |
| Sahouè | 0.0 | 0.0 | 19.0 | 0.0 | 0.0 | 0.0 | 3.1 |
| Yoruba | 0.0 | 0.0 | 0.0 | 0.0 | 18.9 | 0.0 | 2.7 |
| **Level of education** | | | | | | | |
| None | 70.9 | 82.8 | 61.9 | 57.1 | 91.9 | 60.0 | 71.4 |
| Primary | 16.6 | 9.3 | 35.7 | 33.3 | 5.4 | 27.6 | 20.5 |
| Secondary | 8.3 | 6.3 | 2.4 | 9.5 | 0.0 | 10.8 | 6.6 |
| Academic | 4.2 | 1.6 | 0.0 | 0.0 | 2.7 | 1.5 | 1.2 |
| **Religion** | | | | | | | |
| Animist | 91.7 | 100.0 | 69.0 | 38.1 | 18.9 | 86.2 | 74.1 |
| Celestial | 0.0 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 1.2 |
| Christian | 8.3 | 0.0 | 31.0 | 33.3 | 54 | 13.8 | 19.7 |
| Muslim | 0 | 0.0 | 0.0 | 14.3 | 27.0 | 0.0 | 5.1 |

n: No. of respondents

a lesser extent in food. The semi-traditional process results in an oil similar in appearance but more aromatic and with a highly pleasant taste, making it more suitable for culinary applications. The traditional process yields a very dark, strongly odorous oil with a bitter taste, commonly used for therapeutic purposes (e.g., treatment of hemorrhoids, itching, chickenpox) and in traditional ceremonies. In general, the darker, more odorous and more bitter the oil, the more traditional the production method, which consequently influences its intended uses.

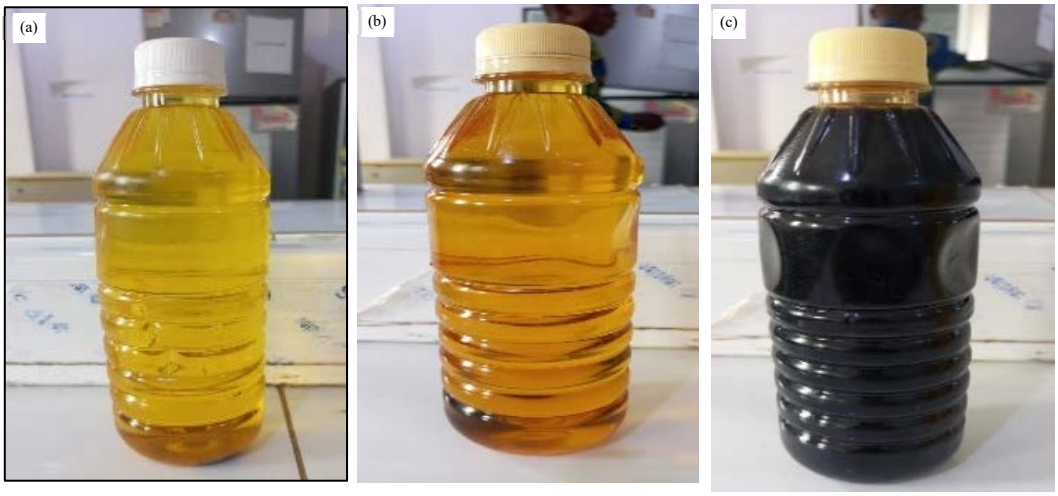


Plate 1(a-c): Different types of palm kernel oil in Benin

(a) **Names:** *Ninmoumi, Adimihoué, Dékimi, Adiagbon*
**Characteristics:** Oil produced using modern methods, fluid, yellowish, less fragrant
**Uses:** Rarely used in food or cosmetics

(b) **Names:** *Ninmi, Dhoutout, Tchotcho, Dékimi, Adiagboum, Adin*
**Characteristics:** Oil produced using a semi-traditional process, fluid, yellowish, fragrant
**Uses:** Food

(c) **Names:** *Tokpli, Tchotchoakou, Aditchotcho, Tchotcho*
**Characteristics:** Oil produced using traditional methods, fluid, very dark, very fragrant
**Uses:** Therapeutic (haemorrhoids, itching, chickenpox, traditional ceremonies)

The nomenclature of these oil types varies across regions. Oil produced by the modern process is known as *Ninmoumi* in Adja and Mina, *êninmoumi* in Sahouè (Mono and Couffo); *Adimihoué* in Fon (Zou), *Dékimi* in Aizo and Fon (Atlantique); and *Adiagbon* in Yoruba and Goun (Plateau and Ouémé). Oil from the semi-traditional process is referred to as *Ninmi*, *êninmi*, or *dhoutoun* in Mono and Couffo; *Tchotcho* in Zou, *Dékimi* in Atlantique; and *Adin* in Ouémé. The traditional oil is called *Tokpli* in Mono and Couffo; *Tchotcho* in Ouémé and Mono, *Tchotchoakou* in Zou; and *Aditchotcho* in Plateau.

**Different palm kernel oil production methods in Benin:** The survey identified 3 primary production methods for palm kernel oil in Benin. These include a modern method with 2 variants distinguished by the thermal processing of kernels (Fig. 3 and 4), as well as two traditional methods, each represented in Fig. 5 and 6.

**Production of different types of palm kernel oil by study department in Benin:** Figure 7 shows the dendrogram of departments involved in palm kernel oil production. Based on production quantities of the different oil types, the Department of Couffo ranked first with 12.5% of total production, followed by Zou (10.0%), Atlantique and Plateau (3%) and Mono and Ouémé (2.5%). Numerical classification data were subjected to ANOVA and the Student-Newman-Keuls test (Table 4) revealed that the modern process is used significantly more frequently in the Departments of Zou and Mono ($p<0.05$). In contrast, the semi-traditional process is more widely adopted in Atlantique ($p<0.05$), whereas traditional production is more prevalent in the Zou Department.

Additionally, responses indicated that in Couffo, some producers combine the modern and semi-traditional methods, while others employ all three methods. In the Departments of Zou and Plateau, producers most commonly combine semi-traditional and traditional methods.

**Palm kernel oil production methods in relation to surveyed stakeholders:** Figure 8 illustrates respondents' adoption rates of the various palm kernel oil production methods. Overall, the results indicate that producers in Benin predominantly

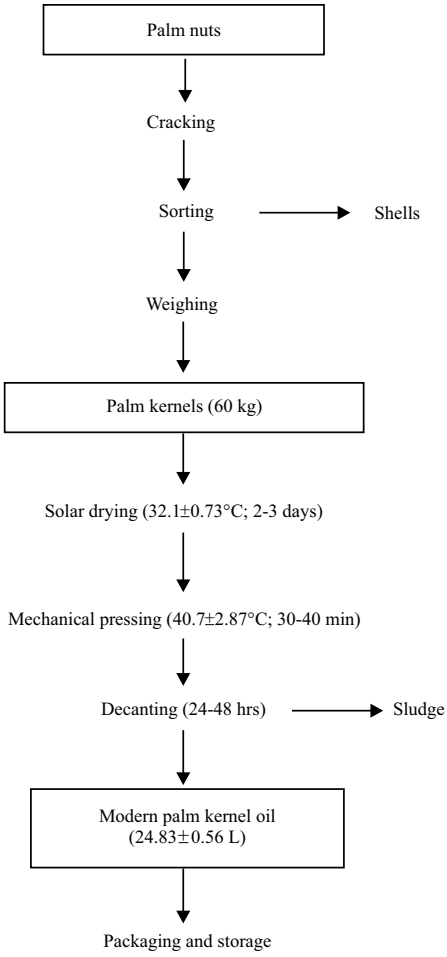


Fig. 3: Technological diagram of modern palm kernel oil production (solar drying of kernels)

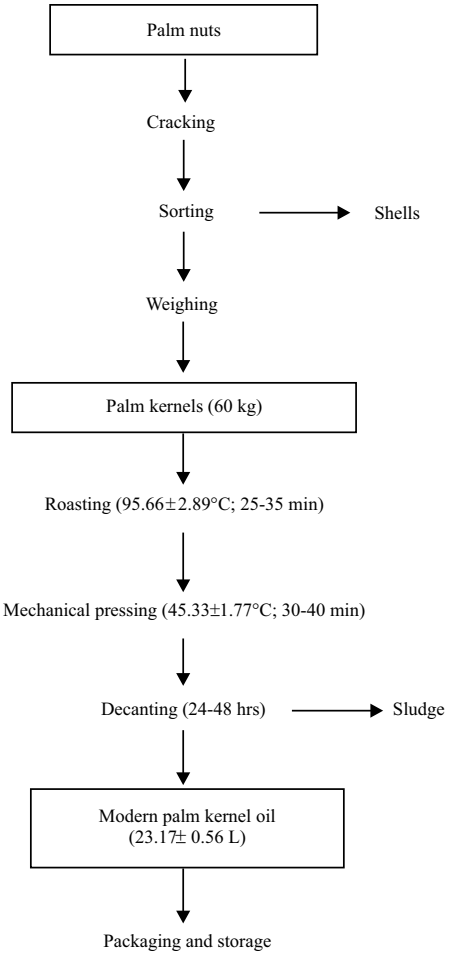


Fig. 4: Technological diagram of modern palm kernel oil production (roasting of kernels)

Table 4: Comparison of mean scores of responses on different palm kernel oil production methods by study department

| | Production processes | | | | | |
|---|---|---|---|---|---|---|
| Study departments | Modern | Modern and Semi-traditional | Semi-traditional | Semi-traditional and Traditional | Semi-traditional and Traditional and modern | Traditional |
| Atlantic | 3.25±0.75$^{b}$ | 5.50±1.50$^{b}$ | 3.25±0.75$^{a}$ | 7.75±2.25$^{bc}$ | 3.25±0.75$^{b}$ | 1.00±0.00$^{b}$ |
| Couffo | 4.00±1.00$^{b}$ | 18.25±5.75a | 1.00±0.00$^{c}$ | 13.75±4.25$^{a\ b}$ | 10.75±3.25$^{a}$ | 1.75±0.25$^{b}$ |
| Mono | 16.75±5.25$^{a}$ | 3.25±0.75$^{b}$ | 1.00±0.00$^{c}$ | 7.75±2.25$^{bc}$ | 0.25±0.25$^{b}$ | 4.00±1.00$^{b}$ |
| Ouémé | 8.50±2.50$^{b}$ | 1.00±0.00$^{b}$ | 1.00±0.00$^{c}$ | 4.75±1.25$^{c}$ | 0.25±0.25$^{b}$ | 1.75±0.25$^{b}$ |
| Plateau | 5.50±1.50$^{b}$ | 1.75±0.25$^{b}$ | 1.75±0.25$^{bc}$ | 16.75±5.25$^{a}$ | 0.25±0.25$^{b}$ | 3.25±0.75$^{b}$ |
| Zou | 19.00±6.00$^{a}$ | 2.50±0.50$^{b}$ | 2.50±0.50$^{ab}$ | 19.00±6.00$^{a}$ | 0.25±0.25$^{b}$ | 7.00±2.00$^{a}$ |
| F-Value | 9.17 | 6.65** | 7.03 | 13.44 | 5.91 | 7.73 |
| Probability | 0.0001 | 0.0009 | 0.0006 | 0.0001 | 0.0016 | 0.0004 |

combine the semi-traditional and traditional methods (72%). Nevertheless, a substantial proportion also employs the modern method (54%) for palm kernel oil production.

Correspondence Factor Analysis (CFA) performed on the data relating production methods to sociocultural groups enabled the characterization of associations between stakeholder profiles and production practices (Fig. 9). The first two axes explained approximately 42.18% of the total variance (Table 5). The analysis revealed that young Goun men with primary or secondary education, Adja men with secondary education, young Sahouè women without formal schooling and Aizo women with primary education primarily engage in traditional and semi-traditional production, packaging their oils in 1 L containers. Young Mina, Adja and Sahouè men with

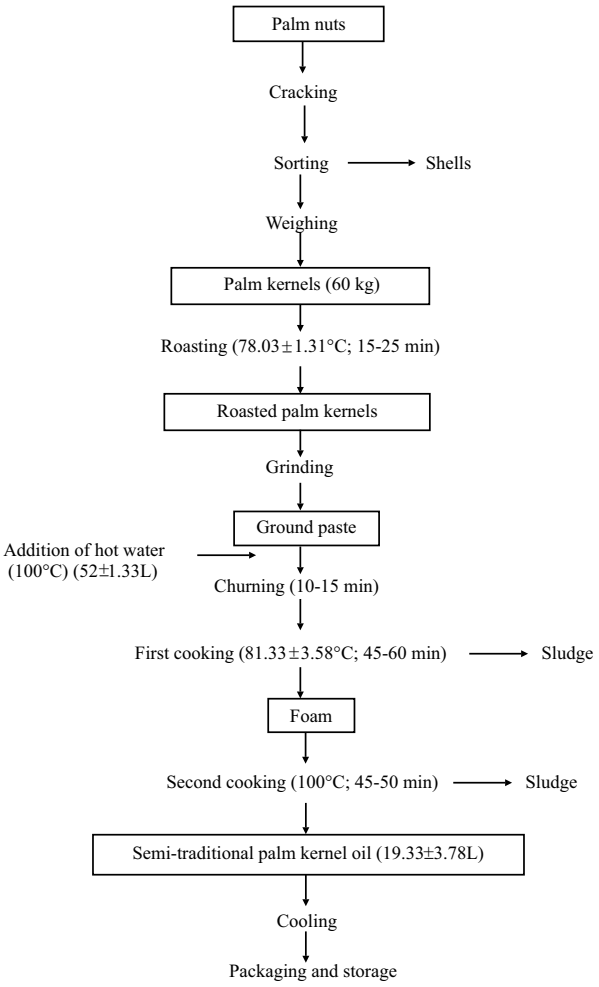


Fig. 5: Technological diagram of semi-traditional palm kernel oil production

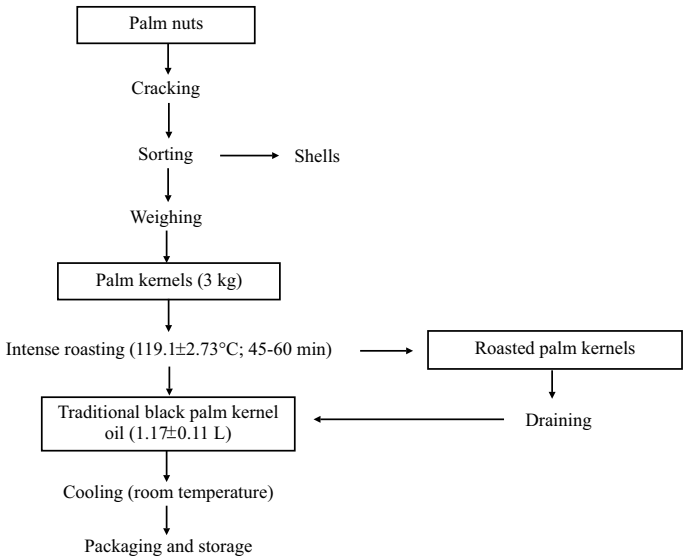


Fig. 6: Technological diagram of traditional palm kernel oil production

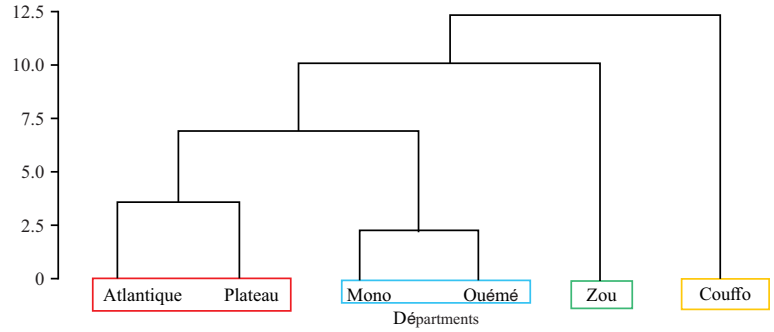


Fig. 7: Dendrogram showing the departments producing palm kernel oil in Benin

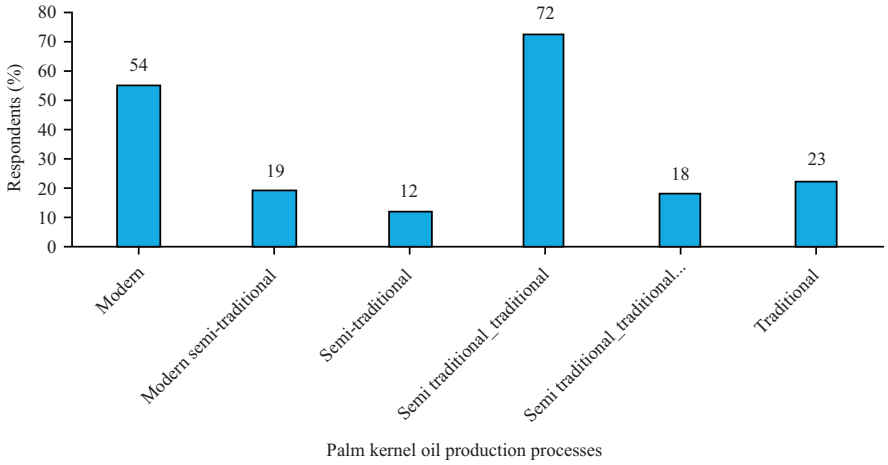


Fig. 8: Palm kernel oil production methods according to respondents

Table 5: Eigenvalues of the first five principal components

| Axis | Inertia | Proportion | Cumulative |
|---|---|---|---|
| 1 | 0.1048 | 0.2244 | 0.2244 |
| 2 | 0.0922 | 0.1974 | 0.4218 |
| 3 | 0.058 | 0.1241 | 0.5459 |
| 4 | 0.0497 | 0.1064 | 0.6524 |
| 5 | 0.0453 | 0.097 | 0.7493 |

no schooling; young Sahouè and Adja men and women with primary education and young Goun men with university education predominantly adopt modern production, storing their oils in drums and barrels. Finally, adult Adja women with secondary education, young Adja men with university education and young and adult Aizo men and women with primary education produce using multiple methods and package their oils in basins.

**Different uses and forms of consumption of palm kernel oil**

**Uses of different types of palm kernel oil produced in Benin:** Figure 10 presents the distribution of respondents' statements regarding the uses of palm kernel oil in Benin. Palm kernel oil is primarily used in the cosmetics sector (49.8%), particularly in the production of local soaps (Kôtô, soda, cooki). It is also used in food preparation (37.06%) for frying and preparing local dishes such as beans, fritters and sauces. Respondents additionally reported its use in traditional practices (8.49%), including rituals, purification ceremonies, funerals and traditional therapies, as well as in toothpaste production (8.1%).

**Assessment of palm kernel oils according to production methods and respondents' justifications:** Figure 11 presents the distribution of respondents' evaluations of palm kernel oil quality according to production method. The results demonstrate considerable variability in perceptions. A majority of respondents described the oils as pleasant (56.75%) and acceptable (57.14%). Conversely, other respondents characterized the oils as unpleasant (42.85%), rejected (42.85%), or prohibited (42.85%).

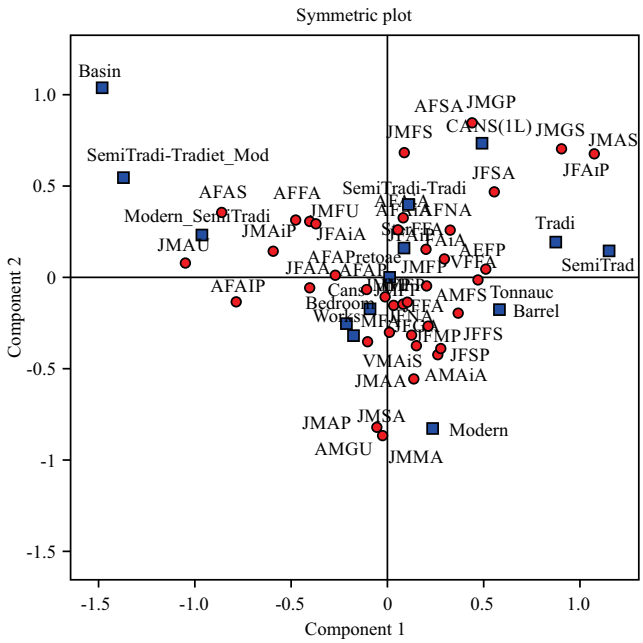


Fig. 9: Responses on palm kernel oil production methods: Projection of sociocultural groups on the factorial system axis following a Correspondence Factor Analysis (CFA)

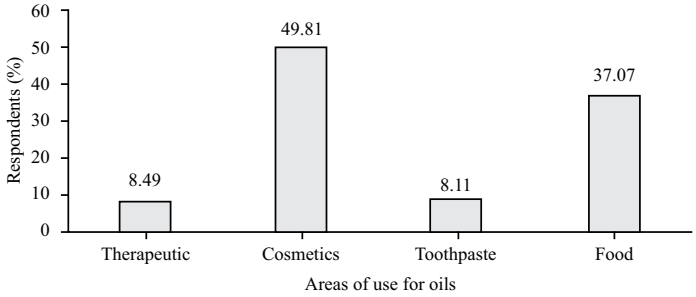


Fig. 10: Histogram showing the different uses of palm kernel oils

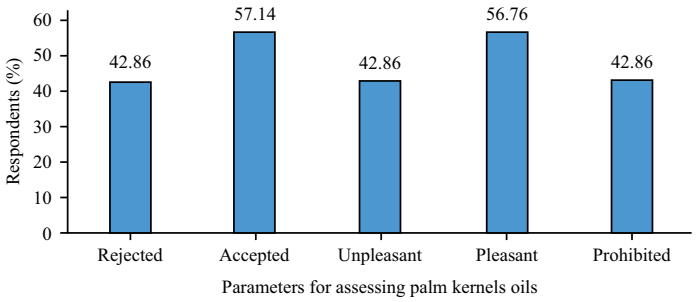


Fig. 11: Histogram showing the assessment of palm kernel oils according to production methods

Principal Component Analysis (PCA) (Table 6) showed that the first two axes accounted for 87.7% of total variability. Oils produced using modern and semi-traditional methods were generally perceived as acceptable due to their pleasant taste, odor and color, particularly among young respondents across ethnic groups and education

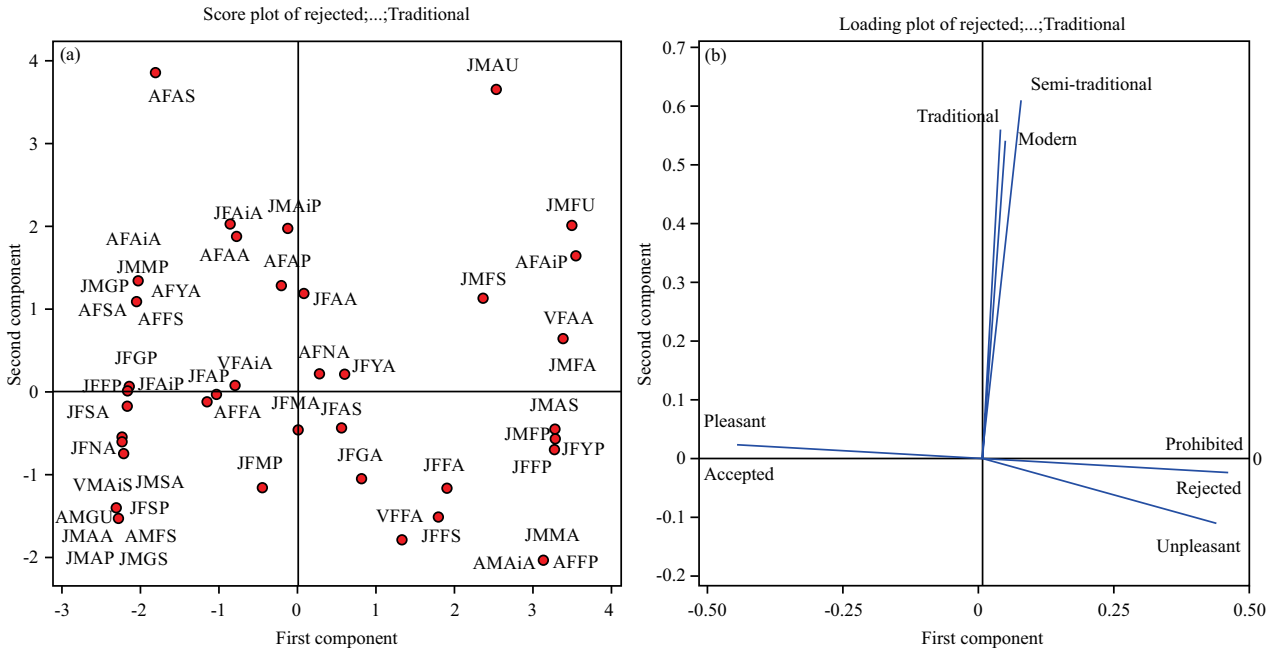


Fig. 12: Overall knowledge of surveyed stakeholders on palm kernel oil production methods and their uses based on Principal Component Analysis (PCA)

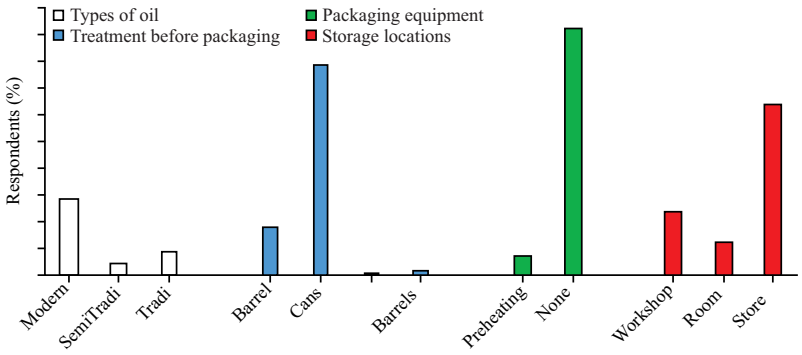


Fig. 13: Packaging and storage of different types of palm kernel oils

Table 6: Eigenvalues of the first five principal components

| Axis | Eigenvalue | Proportion | Cumulative |
|---|---|---|---|
| 1 | 4.9311 | 0.616 | 0.616 |
| 2 | 2.0829 | 0.26 | 0.877 |
| 3 | 0.6069 | 0.076 | 0.953 |
| 4 | 0.315 | 0.039 | 0.992 |
| 5 | 0.0641 | 0.008 | 1 |

levels. In contrast, oils produced traditionally were generally rejected and described as prohibited and unpleasant in taste and odor by older and adult respondents of all sociocultural categories (Fig. 12 and Table 7).

Table 7: Correlations of variables with the principal components

| Variables | PC1 | PC2 | PC3 |
|---|---|---|---|
| Rejected | 0.449* | -0.024ns | -0.032ns |
| Accepted | -0.449* | 0.024ns | 0.032ns |
| Unpleasant | 0.429* | -0.112 ns | 0.115ns |
| Pleasant | -0.449* | 0.023ns | 0.032 ns |
| Prohibited | 0.449* | -0.024ns | -0.032ns |
| Modern | 0.045ns | 0.544* | 0.723* |
| Semi-traditional | 0.075ns | 0.612 | -0.004ns |
| Traditional | 0.035ns | 0.561 | -0.679* |

*Significant correlation at the 30% threshold; ns = non-significant correlation at the 30% threshold

**Packaging and storage of different types of palm kernel oil:** Figure 13 presents the distribution of respondents according

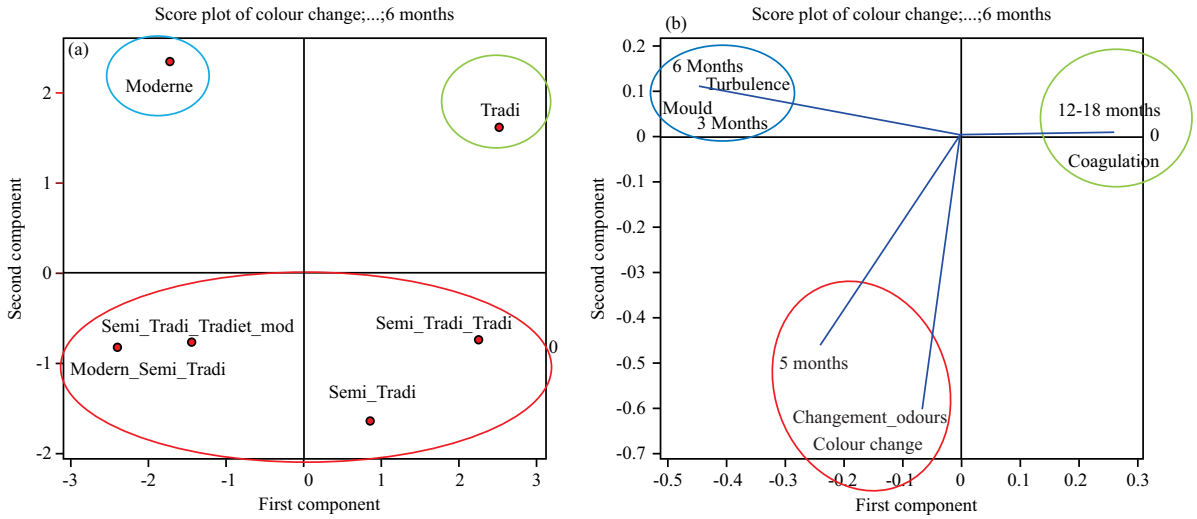


Fig. 14: Overall knowledge of surveyed populations regarding the influence of palm kernel oil production methods on their shelf life, based on Principal Component Analysis (PCA)

to packaging and storage methods used for different types of palm kernel oil. The analysis indicates that oils are either preheated (7.3%) or not (32.7%) before being stored in barrels (18.1%), cans (79.2%), drums (0.4%), or casks (2.3%). Storage locations include workshops (23.6%), rooms (12.4%) and warehouses (64.1%).

In general, producers preheat semi-traditional and traditional oils before packaging them in cans for storage in warehouses. Conversely, modern palm kernel oil typically to packaging and storage methods used for different types of palm kernel oil. The analysis indicates that oils are either preheated (7.3%) or not (32.7%) before being stored in barrels (18.1%), cans (79.2%), drums (0.4%), or casks (2.3%). Storage locations include workshops (23.6%), rooms (12.4%) and warehouses (64.1%).

In general, producers preheat semi-traditional and traditional oils before packaging them in cans for storage in warehouses. Conversely, modern palm kernel oil typically receives no thermal treatment prior to being packaged in cans, drums, or casks and stored in workshops or rooms.

**Shelf life of palm kernel oils:** Shelf-life analysis revealed substantial variation among production methods. Some techniques allowed storage for up to 18 months, whereas others resulted in deterioration within only a few months. PCA results showed that the first two axes explained 88.3% of total variance (Table 8). According to respondents, modern oils have a shelf life of approximately three months and exhibit mold and turbidity beginning at six months. Semi-traditional oils may be stored for up to five months before changes in odor and color occur. Traditional oils can be preserved for up to 12 months before coagulation takes place (Fig. 14 and Table 9).

Table 8: Eigenvalues of the first five principal components

| Axis | Eigenvalue | Proportion | Cumulative |
|---|---|---|---|
| 1 | 6.272 | 0.57 | 0.57 |
| 2 | 3.4429 | 0.313 | 0.883 |
| 3 | 0.8147 | 0.074 | 0.957 |
| 4 | 0.4315 | 0.039 | 0.996 |
| 5 | 0.0388 | 0.004 | 1 |

Table 9: Correlations of variables with the principal components

| Variables | PC1 | PC2 | PC3 |
|---|---|---|---|
| Colour change | -0.066ns | -0.606ns | -0.102* |
| Changement_Odours | -0.066ns | -0.606ns | -0.102* |
| Coagulation | 0.262 | 0.012 | -0.645ns |
| Mould | -0.446ns | 0.111* | -0.189* |
| Turbulence | -0.446ns | 0.111 | -0.189 |
| 12 to 18 months | 0.262 | 0.012 | -0.645 |
| 5 months | -0.242 | -0.464 | 0.053* |
| 3 months | -0.446ns | 0.111* | -0.189* |
| 6 months | -0.446ns | 0.111 | -0.189* |

*Significant correlation at the 30% threshold and ns: Non-significant correlation at the 30% threshold

**Recognition of deterioration signs of palm kernel oil types during storage:** Figure 15 shows the percentages of respondents reporting specific signs of deterioration in palm kernel oil. The most frequently cited changes were alterations in odor and color, followed by coagulation, mold growth and

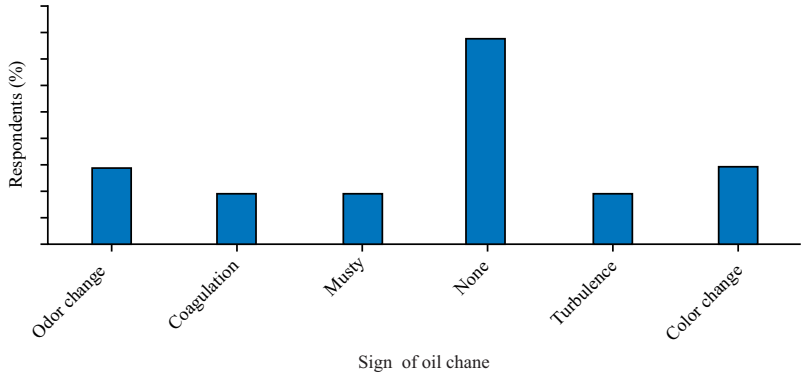


Fig. 15: Histogram showing the signs used to recognize the deterioration of different types of palm kernel oil

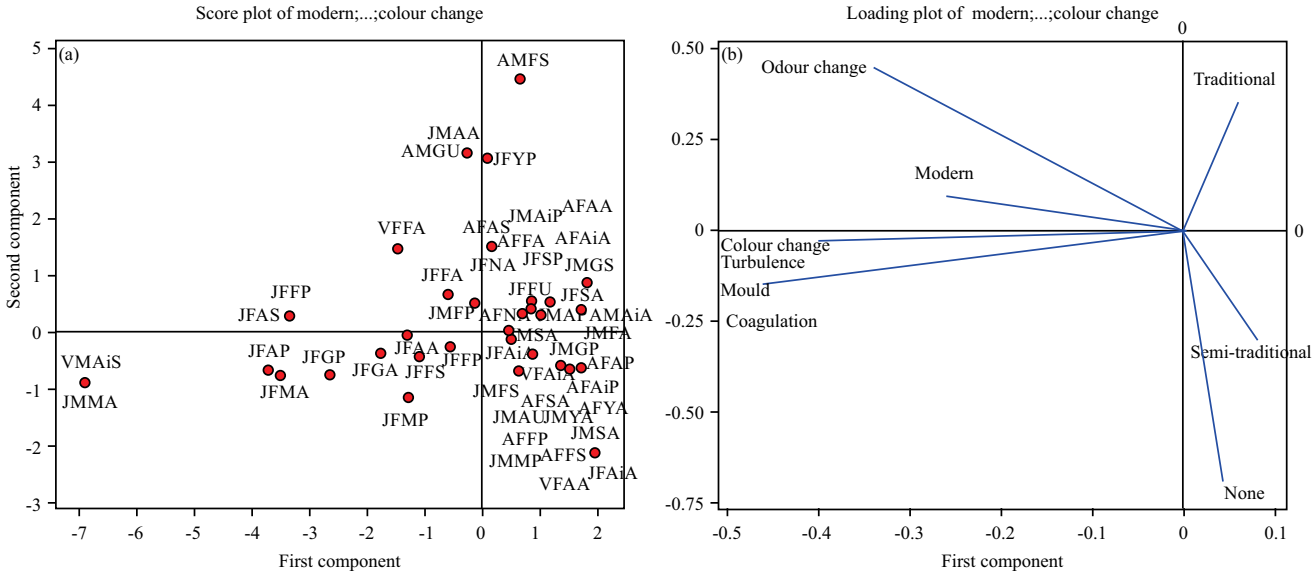


Fig. 16: Histogram showing the signs used to recognize the deterioration of different types of palm kernel oil

Table 10: Eigenvalues of the first five principal components

| Axis | Eigenvalue | Proportion | Cumulative |
|---|---|---|---|
| 1 | 4.3993 | 0.489 | 0.489 |
| 2 | 1.5808 | 0.176 | 0.664 |
| 3 | 1.0653 | 0.118 | 0.783 |
| 4 | 0.9348 | 0.104 | 0.887 |
| 5 | 0.6995 | 0.078 | 0.964 |

Table 11: Correlations of variables with the principal components

| Variable | PC1 | PC2 | PC3 |
|---|---|---|---|
| Modern | -0.257ns | 0.097ns | -0.572* |
| Semi-traditional | 0.079 ns | -0.303* | 0.066ns |
| Traditional | 0.059 ns | 0.361 | 0.76 |
| Odour change | -0.341* | 0.457 | -0.035ns |
| Coagulation | -0.462* | -0.147ns | 0.134ns |
| Mould | -0.463* | -0.147ns | 0.134ns |
| None | 0.044ns | -0.703* | 0.173ns |
| Turbulence | -0.463* | -0.147ns | 0.134ns |
| Colour change | -0.404* | -0.024ns | 0.077ns |

*Significant correlation at the 30% threshold and ns: Non-significant correlation at the 30% threshold

turbidity. However, the majority of respondents (78.0%) reported that they were unable to recognize any indicators of oil deterioration.

PCA results indicated that the first two principal components accounted for 66.4% of total variance (Table 10). Correlation patterns (Table 11), together with Figure 16, show that adult Fon men and young Goun women with secondary education, as well as uneducated young Sahouè women, reported an inability to identify deterioration parameters for traditional oils. Conversely, young and older Mina and Adja men with no schooling or primary/secondary education, along with young women across all ethnicities and education levels, reported that modern oils frequently exhibit changes in color and odor, mold development and coagulation during storage.

## DISCUSSION

**Sociodemographic characteristics of stakeholders involved in palm kernel oil production in Benin:** The findings of this study indicate that women are predominantly engaged in palm kernel oil production in Benin. This gendered distribution may be attributed to the division of labor within oil palm-producing households, where men typically oversee plantation management, including maintenance, felling and harvesting of fruit bunches. Women, who are more frequently responsible for food preparation, generally undertake the processing of palm fruits into palm oil and the extraction of palm kernel oil. The predominance of individuals aged $0 \leq age < 50$ years, combined with a mean producer age of 44 years, suggests that palm kernel oil production requires a relatively young and physically active workforce, given the labor-intensive nature of the operations involved. Adults and older persons often provide supervisory roles and transmit technical expertise to younger producers, underscoring the importance of intergenerational knowledge transfer. These observations are consistent with those reported by Bokossa *et al.*[5], who emphasized that agro-food processing represents an important income-generating activity for women, contributing substantially to household economic stability and children's education.

The study further revealed that most palm kernel oil producers have no formal education. This finding suggests that the activity relies primarily on indigenous technical knowledge and is accessible to individuals regardless of sociocultural attributes, including gender, age group, religion, or educational level. These results align with Gandeho *et al.*[13], who demonstrated that local adaptive strategies are not strictly determined by age or gender but rather by agricultural experience and household access to financial and market resources.

**Identification of palm kernel oils in Benin:** The quality of palm kernel oil in Benin varies considerably depending on the production method employed. Processing techniques influence the color, odor and taste of the oils, thereby shaping their potential uses. These methods also determine the local nomenclature assigned to the oils by different sociolinguistic groups. For instance, the term *Ninmoumi* (Ninmou = fresh kernels, mi/ami = oil) used among the Adja in southern Benin refers to an oil produced from kernels subjected to minimal thermal treatment using the modern extraction method. Conversely, *Tchotchoakou* (Tchotcho = palm kernel oil, akou = pure) used by the Fon in central Benin indicates that no water is added during traditional extraction. Thus, processing technology directly influences the naming of products derived from the same raw material. Such linguistic variability reflects the deep cultural significance and functional adaptation of palm kernel oil to specific dietary, cosmetic, or therapeutic needs, consistent with the findings of Yapi *et al.*[16] in Côte d'Ivoire.

Marked variability in processing methods across departments was also observed. Several factors may explain these disparities. In departments such as Zou and Mono, the presence of more advanced processing units facilitates the adoption of modern, mechanized extraction techniques. In contrast, in Atlantique and Couffo, producers more frequently rely on semi-traditional or mixed methods, likely due to financial limitations, restricted access to modern equipment, or a desire to maintain artisanal heritage. Statistical analyses confirmed significant interdepartmental differences in the adoption of production methods. In Couffo, where many producers combine multiple extraction techniques, the pattern suggests a transitional phase toward technological modernization, driven by evolving market demands or strategies to optimize yields. Similar trends have been documented by Bakri *et al.*[10] in their work on the development of palm kernel processing technologies and by Sam *et al.*[9], who demonstrated the relevance of modeling approaches to improving production efficiency.

Overall, while modern extraction methods dominate palm kernel oil production in Benin, the persistence of traditional and semi-traditional techniques reflects a combination of economic constraints, equipment availability and strong cultural attachment to ancestral practices. Factorial analyses revealed that sociocultural group membership plays an important role in shaping extraction choices. Individuals with higher education levels generally favor modern methods, whereas those with little or no formal education tend to rely on traditional practices. This pattern supports the findings of Yapi *et al.*[16], who indicated that knowledge and practices surrounding palm kernel oil partly depend on educational attainment and of Konnon *et al.*[17], who underscored the influence of access to training and financial means on the adoption of modern processing methods.

**Different uses and forms of consumption of palm kernel oil:** The analysis of palm kernel oil utilization in Benin reveals a strong influence of sociocultural dynamics on its various applications. The predominant use of palm kernel oil in cosmetic formulations can be attributed to both its economic accessibility and its intrinsic physicochemical properties, particularly its high saponification value, which enables the production of soaps with effective cleansing capacity. Paulin

and Irène[18] reported that the fatty acid profile and relative oxidative stability of palm kernel oil make it particularly suitable for soap manufacturing and other cosmetic products. Additionally, in several communities, traditional knowledge passed down across generations continues to reinforce the medicinal and cosmetic value attributed to this oil. While rural populations often favor medicinal or culinary applications, urban consumers increasingly prioritize cosmetic uses, especially those aligned with industrial standards. Economic status further influences consumption choices: individuals with lower income levels tend to rely on locally produced palm kernel oil, whereas higher-income groups may opt for imported or processed alternatives. This pattern reflects the observations of Goggin and Murphy[19], who noted that consumer choices regarding vegetable oils are largely shaped by purchasing power and product availability.

Perceptions of palm kernel oil quality vary across production methods and sociocultural contexts. Oils produced through modern and semi-traditional techniques are generally more appreciated, while those obtained via traditional methods are more frequently rejected. This divergence may be explained by the fact that traditionally extracted oils often exhibit stronger odors and darker coloration, sensory attributes that differ from the expectations associated with oils intended for culinary use. Beyond sensory characteristics, however, cultural beliefs also influence acceptance. Traditional oils may be valued for their medicinal or spiritual properties, leading to non-culinary uses. As highlighted by Yonti *et al.*[20], the distinction between oils considered "pleasant" and those perceived as "prohibited" or "unpleasant" underscores the significant role of sociocultural norms and local belief systems in shaping consumption patterns.

Packaging and storage practices for palm kernel oil also vary according to sociocultural group and production method. Modern oils are typically stored without prior heating, reflecting confidence in standardized extraction and processing conditions. The choice of container-such as cans, barrels, or drums-and storage location (warehouses, rooms, or workshops) appears to depend on whether the oil is intended for household consumption (smaller containers) or commercial distribution (larger storage units). These storage practices can directly affect oil quality and longevity. According to Louis *et al.*[7], storage conditions significantly influence the physicochemical characteristics of palm kernel oil, particularly its susceptibility to oxidation and its overall stability, thereby affecting both nutritional quality and shelf life.

Shelf-life analysis indicates substantial variability among the different production methods. These disparities can be attributed to the treatments applied during processing, which affect chemical composition and resistance to oxidative rancidity. Exposure to oxygen and the specific fatty acid composition of the oil are critical determinants of oxidative stability. Habibiasr *et al.*[21] demonstrated that both drying conditions and chemical composition exert significant effects on oil longevity. Respondents reported that modern oils deteriorate more rapidly than semi-traditional and traditional oils, often developing mold during storage. This tendency may be linked to differences in moisture content: Traditional oils, which typically undergo minimal thermal treatment, may have higher moisture levels, influencing their rate of deterioration. Habibiasr *et al.*[21] also showed that moisture content directly affects the chemical and physical properties of palm kernel oil, potentially reducing its stability and limiting storage duration.

The ability of stakeholders to recognize signs of oil deterioration during storage varies according to cultural experience and educational background. Communities with strong culinary traditions may be more adept at identifying spoilage indicators such as color changes, unusual odors, or coagulation, based on observational knowledge passed down through generations. Conversely, low levels of formal education may reduce awareness of oxidation processes, rancidity risks and microbial contamination, potentially compromising safe consumption practices. As emphasized by Louis *et al.*[7], appropriate storage techniques and adequate knowledge of preservation risks are essential for maintaining palm kernel oil quality and ensuring its safe utilization.

## CONCLUSION

This study provides a comprehensive analysis of palm kernel oil production practices in Benin, revealing a sector largely sustained by women with limited formal education who perpetuate knowledge and techniques inherited across generations. The findings demonstrate considerable variability in production methods among departments. Modern processing techniques are more prevalent in regions such as Zou and Mono, whereas semi-traditional and traditional methods remain dominant in other areas. This heterogeneity reflects underlying economic and cultural factors, as well as disparities in access to modern processing equipment across production zones. In terms of quality, traditionally produced oils appear to exhibit greater stability, while oils derived from modern methods tend to deteriorate more rapidly. These observations highlight the importance of selecting production methods that balance efficiency, product quality and consumer preferences, while also accounting for the practical constraints faced by producers. Overall, the study underscores

the need to improve and optimize palm kernel oil production technologies in Benin to enhance both the quality and shelf life of the oils produced. Strengthening modernization efforts-particularly through targeted training, capacity building and improved access to appropriate processing equipment-would contribute to increased productivity and improved product quality. Such advancements are essential for supporting a sector that holds significant economic, social and cultural importance within the country.

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