

Date	Submitted	Accepted	Published
	25 th November 2025	10 th March 2026	9 th April 2026

PHYSICOCHEMICAL, MICROBIOLOGICAL AND HEDONIC CHARACTERIZATION OF A SMOKED MEAT-BASED FOOD (*TOUTOU*) OF THE MBOUM PEOPLE IN THE ADAMAOUA REGION OF CAMEROON

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ABSTRACT

Toutou is a snack food made from smoked meat seasoned with a mixture of ingredients in a matrix made of peanut paste. It is, therefore, one of the traditional methods of preserving meat used by the *Mboums*, an indigenous people in the Adamaoua region of Cameroon. This food, highly prized for its organoleptic qualities, has not been the subject to scientific and technical study like *kilishi*. However, the artisanal nature of its production system is limited by various constraints, resulting in significant organoleptic and hygienic variability. This study describes local manufacturing practices in relation to the implementation of innovative unit operations for the operator (drying and cooking) and evaluates the relationship between meat types (Eye of round and Rib eye), primary meat processing, and the type of spice mixture used and the physicochemical, hygienic, and hedonic qualities of *toutous*. The diagnosis of technical practices highlights an exclusively female and ethnic activity. The processing capabilities of the two muscles (Eye of round, Rib eye) show a better techno-functional predisposition: WC (73.37 ± 0.49 - $75.6 \pm 0.52\%$), pH (6.56 ± 0.05 - 6.57 ± 0.05), Water Retention Capacity (WRC) (13.67 ± 1.15 - $19.33 \pm 0.57\%$), trimming yield (50.59 ± 0.49 - $72.11 \pm 0.16\%$), slicing rate (3.55 ± 0.23 - $4.12 \pm 0.1 \text{ kg} \cdot \text{min}^{-1}$), trimming flow rate (0.53 ± 0.1 - $0.8 \pm 0.1 \text{ kg} \cdot \text{min}^{-1}$). The oxidation level of the *toutous* at production scale, represented by the thiobarbituric acid index (TBAr), is within an acceptable range (0.40 ± 0.02 to $0.97 \pm 0.01 \text{ mg Malondialdehyde (MDA)/kg}$). The hygienic quality of *toutous* shows the following microbial loads: Total Aerobic Mesophilic Flora (TAMF), ($0.3 \times 10^6 \pm 0.82$ - $2.73 \times 10^6 \pm 0.47 \text{ CFU/g}$), fecal coliforms (0 - $0.70 \times 10^3 \pm 1.63 \text{ CFU/g}$), *Staphylococcus aureus* ($0.09 \times 10^3 \pm 0.47$ - $2.56 \times 10^3 \pm 0.82 \text{ CFU/g}$), *Clostridium perfringens* (0 - $0.43.33 \times 10^3 \text{ CFU/g}$), Molds and yeasts (0 - $43 \times 10^2 \pm 0.47 \text{ CFU/g}$), Xerophilic molds ($0.3 \times 10^2 \pm 1.25$ - $0.04 \times 10^2 \pm 0.47 \text{ CFU/g}$). These microbial loads obtained exceed the maximum values permitted by the microbiological criteria (ANOR) for cooked meat products. This requires the implementation of good hygiene and manufacturing practices at production sites. In terms of overall acceptability, all the *toutous* were appreciated and ranked in order of preference, with the preeminence of Eye of round cooked with *kilishi* spices, followed by the Rib eye cooked with *toutou* spices as the most appreciated under the technical production conditions of the northern savannahs of Cameroon. This study opens up significant prospects for the technological and technical study of the meat processing system used to make *toutou*, with opportunities for scientific and technical optimization, particularly in terms of shelf life.

Key words: *toutou*, constraints, muscles, eye of round, rib eye, spices, technological and hygienic quality, *Mboum*

Citation: Ndihi AC1, Kundje FPAB and A Goudoum Physicochemical, Microbiological and Hedonic Characterization of a Smoked Meat-based Food (*Toutou*) of the Mboum People in the Adamaoua Region of Cameroon. *Afr. J. Food Agric. Nutr. Dev.* 2026; **26**(3): 29054-29073. <https://doi.org/10.18697/ajfand.150.26620>



INTRODUCTION

The food craft industry, consisting of small-scale food production, processing and distribution structures, is the main source of food in African urban centers [1]. These structures draw on the potential offered by the diversity of exploitable agricultural resources and rapidly growing consumer demand due to rapid population growth and urbanization [2, 3]. As a result, artisanal food production activities can be considered a driver of agricultural sector development and a means of reducing urban food insecurity [4]. Cameroon's cattle herd has continued to grow, reaching approximately 10.2 million head in 2010, according to data from the French Review of Economics and Management. The herd increase, estimated at around 16% between 2018 and 2023, was accompanied by a rise in beef production, which rose from 126,512 tons in 2022 to 130,169 tons in 2023, an increase of 3% [5]. The northern savannah regions of Cameroon are the main locus for cattle farming and meat processing. They alone account for more than 81.85% of the total cattle farming [6]. Three-quarters of the 18,931 tons of regional meat production in the Far North is sold entirely for domestic consumption. The remaining quarter is processed into various secondary products (*kilishi*, *soya*, *tsiré*, steak, smoked meat), most of which are traditional practices of the predominantly Hausa populations [7, 8, 9]. While soya, *tsiré* and steak are intended for direct consumption, *kilishi* and seasoned smoked meat (*toutou*) are not only a form of direct consumption but also a form of meat preservation [10].

Kilishi is a meat drying practice believed to have been introduced in the 12th century by the Arabs to the nomadic Hausa people, according to medieval Arab sources. *Kilishi* is a snack food made from strips of meat seasoned with a cocktail of ingredients in a matrix made of peanut paste, dried and/or grilled, and represents one of the traditional forms of meat preservation practiced in the savannah areas of Africa. By contrast *toutou* is a smoked seasoned meat product, a representative component of the food and cultural heritage of the Mboum people. It is little known by other populations and, in this respect, has not yet benefited from any scientific, technological, or market appeal. Its preservation function also justifies interest in it in the same way as *kilishi*, a centuries-old product that is part of the culture and identity of the Hausa people [11].

Research on the technological and quality characteristics of *toutou* for the markets is therefore justified and based on an understanding of the raw material-process-quality relationship. Due to its central role in the *toutou* manufacturing process, smoked meat appears to be a critical factor in determining product quality. Therefore, to address this issue, this study aims to contribute to the promotion of *toutou*'s market potential through its physicochemical, microbiological and hedonic characterization.

MATERIALS AND METHODS

Monitoring the production of *toutou* in Ngaoundere in the Belaka neighborhood

Ten female producers aged 40-60 years in a Mboum's quarter namely Belaka in Ngaoundere I subdivision in Cameroon were selected based on their reputation in the local *toutou* production system and their willingness to participate in the transfer of know-how for laboratory-level production.

Source and preparation of animal and plant material

Two muscles: Eye of round (ER) and Rib eye (RE) from the categorical cut of a 4-year-old Goudali zebu carcass, slaughtered under controlled conditions (Table 2) at the municipal slaughterhouse in the city of Maroua, were used to make the *toutou*. The two muscles were divided into three batches. The first batch was smoked (S), the second dried (D) and the third cooked (C). Three types of ingredients were used: *Toutou* (T), Sausage (S) and *Kilishi* (K) spices. These were used without a specific recipe and are summarized in Table 3.

Muscle processing and monitoring of *toutou* production

The meat was trimmed and the *toutou* manufacturing processes were carried out at the Bioscience Laboratory of the National Advanced School of Engineering. The processes were monitored from start to finish in line with local practice. Finished products were sampled, weighed, and sealed in sterile double-density polyethylene plastic bags for analysis.

Physical analyses

Gravimetric measurements of samples

The weight of the samples taken during each stage of the process was determined using a Camry digital scale model EK5350 with an accuracy of 0.01g. The core temperature of the samples was determined using a TP 3001 digital thermometer. The duration of each unit operation was determined using a digital stopwatch. The mass data collected during each unit of operation was used to determine the production yields at the various intermediate and final stages, as follows:

- i) *Trimming Yield (TY): percentage of mass relative to the initial fresh meat mass (Eq. 1):*

$$TY = \frac{(M_1 - M_2)}{M_1} \times 100 \quad (1)$$

With: M_1 : Mass in grams of meat to be trimmed; M_2 : Mass in grams of trimming losses

- ii) *Trimming Rate (TR): mass of meat trimmed per unit of time (Eq. 2)*



$$TR = \frac{M}{t} \text{ (kg. min}^{-1}\text{)} \quad (2)$$

With: M: Mass in kilograms of meat to be rolled out; t: Time taken (min) to roll out the mass M of meat

iii) *Slicing rate (SR): mass of meat sliced into strips per unit of time (Eq. 3)*

$$SR = \frac{M}{t} \text{ (kg. min}^{-1}\text{)} \quad (3)$$

With: M: Mass in kilograms of meat to be sliced out; t: Time taken (min) to slice out mass M of meat

Physicochemical analyses

Water Content (WC) and Dry Matter (DM)

The water content of meat samples and *toutous* was determined by drying a 5 g sample in an oven at 105°C until a constant weight was reached. The total dry residue or dry matter, denoted as DM, was expressed as a percentage of the fresh matter. (Eq. 4):

$$\% MS = \frac{(M_2 - M_0)}{(M_1 - M_0)} \times 100 \quad (4)$$

Where: M_0 = mass (g) of the empty capsule; M_1 = mass (g) of the capsule containing the test sample before drying; M_2 = mass (g) of the capsule containing the dried test sample. The water and volatile matter content, denoted H was deduced from the dry matter content (Eq. 5): $\%H = 100 - \%DM$ (5).

pH measurement

pH measurements of meat and meat products were taken from 10g of fresh meat or meat product. The measurements were taken on the homogenate obtained using an electrode (Bluelab Combo Meter).

Water retention capacity (WRC) of muscles

Water retention capacity (WRC) is assessed by quantifying the volume of juice extracted (expressible juice) from a meat sample under given conditions. This quantity depends on the method used and must therefore be determined using a standardized method. In this regard, a combined approach based on the Hamm method and the Touratier measurement approach was adopted [12, 13]. A 1g sample of raw muscle, approximately 2cm long and 1cm wide, was placed between two sheets of Whatman No. 114 filter paper, previously weighed, and pressed between two flat glass plates for 20 minutes under a 1kg weight. The weight gain of the filter paper relative to the initial weight of the meat defines the WRC of the meat.

Thiobarbituric Acid Index (TBArS)

The TBArS (thiobarbituric acid reactive substances) are by-products formed during the peroxidation of unsaturated fatty acids (omega-3 fatty acids and omega-6 polyunsaturated fatty acids) [14]. Determining their levels allows the oxidation status of samples to be quantified.

Trichloroacetic acid and phosphoric acid were used to extract thiobarbituric acid reactive substances from the samples according to the protocol described by Pegg [15]. A 20 g test sample of *toutou* was suspended in 50 mL of extractive solution (20% trichloroacetic acid in 2M phosphoric acid at 4°C) and homogenized for 1.5 min. This volume was made up to 100 mL with distilled water and the whole mixture was homogenized using a stirrer (Oscill 12; Prolabo) for 1 min. The solution was filtered, 50 mL of the mixture through Watman No. 1 filter paper. The 5 mL of the filtrate was transferred to a test tube (15x200mm) containing 5 mL of TBA (0.005M in distilled water). The tubes were closed, and the solutions mixed using a vortex mixer (Jencons-PLS; VX 100). The tubes were kept in the dark at room temperature (20°C) for 15 hours. The color obtained after this time was measured using a UV/Visible spectrophotometer (Rayleigh vis-723N) at 530 nm.

The TBA value is obtained by multiplying the absorbance by 5.2 [16]. It is expressed in mg of malonic aldehyde per kg of *toutou* sample. There are no TBArS index threshold values in the literature; however, a product containing less than 1 mg MDA equivalent/kg is generally accepted as being unoxidized [14].

Microbiological analyses

The stock suspension is the first dilution prepared from each sample of *toutou*. The 25 g of each *toutou* is ground aseptically between two Bunsen beakers in a Robot-cop Blender GT 550, Switzerland sterile in the presence of 225 ml of autoclaved Maximum Recovery Diluant (MRD). This homogeneous solution is the 10⁻¹ stock suspension. The various dilutions are made from the stock solution in accordance with ISO 6887-2 (ISO, 2004).

a) Total Aerobic Mesophilic Flora (TAMF)

The total germ count indicates the overall bacterial contamination of the sampled site, thus allowing an assessment of its general safety. The total mesophilic aerobic germ count was performed on Plate Count Agar (PCA) (Oxoid CM463) (ISO 4833:1991) from decimal dilutions seeded in Petri dishes and incubated at 37°C for 72 hours. The results are expressed in colony-forming units per gram (CFU/g) [17, 18, 19].

b) *Escherichia coli* (fecal coliforms)

Fecal coliforms are heat resistant. They are counted in accordance with Standard NF V08-01, 1992, on a selective Violet Red Bile Lactose Agar (VRBL) agar medium, with the inoculated Petri dishes incubated at 44°C for 24 to 48 hours. Purple colonies with a diameter of at least 0.5 mm were retained [20].

c) *Staphylococcus aureus*

Staphylococcus aureus was counted on Baird Parker Oxoid CM 275 agar. The medium was seeded on the surface with the various dilutions and the Petri dishes were incubated at 37°C for 48 hours. Colonies measuring 1 to 2 mm in diameter were counted.

d) *Clostridium perfringens*

Presumptive identification and enumeration of *Clostridium perfringens* was performed on Shahidi-Ferguson *Perfringens* (S.F.P. Agar, Oxoid CM 587), made selective by aseptically adding 25 mL of a telluric egg yolk emulsion (SR47) to 500 mL of medium, and a selective supplement of *Perfringens* (TSC, SR88) or Oxoid SFP, at a rate of 1 mL per 100 mL of medium. The 1 mL of the inoculum and its decimal dilutions were seeded in a double layer and the Petri dishes were incubated in an anaerobic jar for (20±2) hours at 37°C in the presence of a gas mixture of hydrogen and carbon dioxide. Microorganisms (sulfite-reducing) reduce sodium sulfite to sulfide, causing ferric citrate to form a black precipitate of iron sulfide around the colonies, allowing for their presumptive identification.

e) Molds and Yeasts

Molds and yeasts were counted on Dichloran Rose Bengal Chloramphenicol Oxoid CM 727 agar, made more selective against bacterial flora after adding 0.1 mg/mL chloramphenicol to the agar, following the horizontal method recommended by ISO 21527-2: 2008. The different dilutions were seeded on the surface of Petri dishes and incubated at 30°C for 72 hours.

f) Xerophilic molds

The xerophilic mold count was performed on Dichloran-Glycerol (DG18) Base Oxoid CM729 agar, made more selective against bacterial flora after adding 0.1 mg/mL of chloramphenicol to the agar and 110 mL of glycerol/500 mL of agar. Seeding was performed on the surface and the petri dishes were incubated at 37°C for 48 hours.

Hedonic analysis of *toutous*

The *toutous* obtained were subjected to a hedonic test by a panel of 30 regular *toutou* consumers. The samples were presented in identical containers, coded with random three-digit numbers. Each sample had a distinct number. All samples were

presented at the same time to each taster, accompanied by drinking water to rinse the mouth between samples.

Each taster was asked to rate the samples on a scale of 1 to 9, ranging from “Extremely unpleasant” (1) to “Extremely pleasant” (9) [21]. The parameters evaluated were the color, taste, tenderness, and overall acceptability of the samples. The overall duration of the test did not exceed 30 minutes for each taster (3 rounds in total).

Data analysis

All measurements were taken in triplicate and the results were expressed as mean $\pm$ standard deviation. Analysis of variance (ANOVA) of the means was used to evaluate the effect of the different factors, and Duncan's test was used to rank the significantly different means at a probability threshold of $p < 0.05$. Statgraphics 5.0 software was used for this purpose.

RESULTS AND DISCUSSION

The *toutou* manufacturing process

Monitoring the *toutou* manufacturing processes in the city of Ngaoundéré in the Bélaka district among 10 Mboum producers highlighted that *toutou* manufacturing was exclusively female, with an average age of 55 years among owner-producers, of whom the majority had at least primary education (Table 1). This contrasts with the perception of *kilishi*, which was made exclusively by men, mainly from the Hausa ethnic group [11]. The manufacturing process was similar for all producers and has been summarized in figure 1, revealing some variability in the type of raw material used (smoked meat, charred meat, bush meat).

The involvement of women in *toutou* production was mainly driven by its family nature, with market potential coming second. As a result, the acquisition of know-how was based on technical transfer from mother to daughter, with learning resulting from the fact that the woman has grown up and lived in the *toutou* production environment.

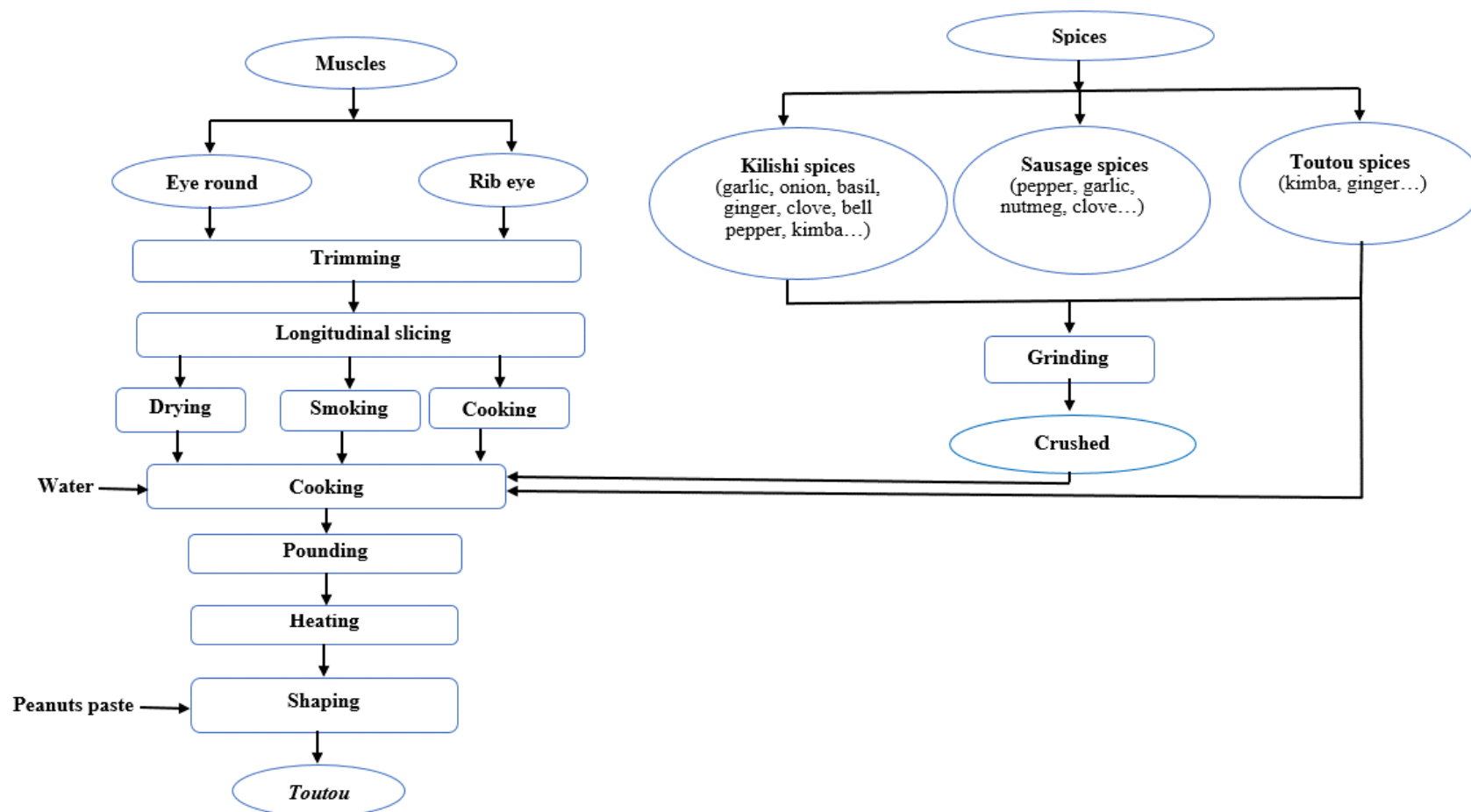


Figure 1: Flow sheet of *Toutou*'s processing

Muscle processing suitability

Table 4 presents three physicochemical characteristics and three processing suitability ratings for the Eye of round and Rib eye cuts. The WC and pH indicators for the Eye of round and Rib eye muscles showed values within a range compatible with those commonly observed at the end of rigor mortis in bovine muscles [22-24]. At the start of aging stage, both muscles had a WC of around 75% and a pH of around 6.57.

The post-mortem evolution of the muscles resulted in a gradual decrease in WC (from 75% to 70%) and pH (from 6.8 to 5.6). This decrease was attributable to the biochemical phenomena occurring in the muscles when the animal was slaughtered. There was therefore a significant difference between the two muscles in terms of the parameters of WC, WRC, trimming yield (TY), and trimming rate (TR), respectively for the Rib eye (73.37 ± 0.49^a %; 13.67 ± 1.15^a %; 50.59 ± 0.49^a %; 0.53 ± 0.1^a Kg.min⁻¹) and the Eye of round (75.6 ± 0.52^b %; 19.33 ± 0.57^b %; 72.11 ± 0.16^b %; 0.8 ± 0.1^b Kg.min⁻¹). This reflects a difference in the tenderness of the two muscles, with the Eye of round muscle appearing to contain less collagen. Its cylindrical shape and alveolar structure suggest a high WRC, and therefore a high WC and easier trimming, as reported by Ndihi *et al.* [10]. The mass recovery rates at the trimming stage did not exceed 73%, which contrasts with the 85% recovery rate reported by Ndihi *et al.* [10] and Yacouba [25]. pH, WC and WRC data were among the main determinants of meat quality, due to their regulatory action on proteolytic enzyme activity and water movement within the muscle.

Physicochemical characterization of *toutous*

Toutous produced using the process shown in Figure 1 and packaged in black low-density polyethylene bags were subjected to the physicochemical analyses summarized in Table 5. The pH, an indicator of acidity and microbiological stability, combined with the WC, which reflected the moisture content and is implicitly correlated with preservation, were combined with the TBARS, an indicator of lipid oxidation, to give an idea of the preservability of the different *toutous*.

pH

The pH values ranged from 5.93 ± 0.03 to 6.46 ± 0.04 , indicating low overall acidification, which suggested mild fermentation. However, the RES-TS and RES-KS samples of *toutou* have the lowest pH values (5.93-5.96), indicating better acidification and therefore better microbiological stability, as reported by Jurie and Listrat [23]. On the other hand, the highest pH values (6.46 ± 0.04 for REC-TS and ERD-TS) indicated slower acidification or fermentation activity. A lower pH (≈ 5.9) was favorable for preservation because it limited the growth of spoilage microorganisms. Thus, the RES batches could be the most stable from a

microbiological standpoint. The spices might have played an important role in toutou's acidification.

Water Content

Water content ranged from $18.2 \pm 0.43\%$ to $36.13 \pm 0.81\%$. The low WC, ERS-SS ($18.2 \pm 0.43\%$) and ERS-TS ($18.9 \pm 0.36\%$), means better drying, and therefore better shelf life, although some samples had high WC, for example RED-SS ($43.46 \pm 0.9\%$), indicating high residual moisture and therefore more limited shelf life, as indicated by Ndihi *et al.* [10].

The Eye of round smoked (ERS) products were more dehydrated, therefore last better, due to a lack of free water for microorganisms. This suggested better physical and microbiological stability of these batches.

TBAs (Thiobarbituric Acid Reactive Substances)

The rupture of myofibrillar cells during slicing and cutting, coupled with successive treatments (drying, cooking, and smoking), releases fat from the muscle and exposes it to oxidation, along with the fat added by the coating.

Overall, the level of oxidation of the *toutous* (Table 5), represented by the thiobarbituric acid index (TBAs), was within a tolerable range (0.40 ± 0.02 to 0.97 ± 0.01 mg MDA/kg) in so far as all TBAs index measured are below 1 mg MDA/kg, which is a threshold for none oxidation product reported by Jeuge *et al.* [14]. This could suggest the presence of natural antioxidants in *toutou*. This antioxidant activity is attributed to spices such as ginger, *xylopia aethiopica*, clove, garlic and onion.

Some values ≥ 1 mg TBAs in *kilishi* coated with a matrix made from peanut paste are reported by Ndihi *et al.* [10]. This means that the lowest oxidation rates were observed for ERC-SS (0.40 ± 0.02) and ERC-TS (0.51 ± 0.01), indicating better oxidative stability due to the fact that the Eye of round is a lean muscle compared to the Rib eye. The highest values ($\approx 0.97 \pm 0.01$ for RED-KS) indicate a high susceptibility to rancidity and therefore poorer preservation. The low TBAs values observed in the ERC and ERS batches suggest the possible presence of natural antioxidants or better control of the technical drying conditions.

The RED batches, with high TBAs, are more sensitive to lipid oxidation, which can alter sensory quality (smell, rancid taste). A triangulation of the parameters (pH, WC, TBAs) suggests that the ERC and ERS batches have the best storage properties with moderate pH, low WC, and low TBAs. The RES batches had a good pH but intermediate oxidation, while the RED and REC batches had higher WC and TBAs, and therefore lower stability. These results highlight the fact that the preservation of *toutou*'s quality depends heavily on controlling drying and lipid oxidation, which will

subsequently influence the final sensory quality of the *toutou*. Similarly, moderate acidification combined with effective dehydration could promote product stability.

V.4. Assessment of the microbiological quality of *toutous*

Table 6 shows the level of contamination in different *toutous* according to the type of treatment. At the microbiological level, as other authors have pointed out, there is a problem with the hygienic quality of artisanal meat products in the northern savannas of Cameroon [26, 27, 28, 29].

When looking at the overall hygienic quality of *toutous*, it was realized that, although this is a widespread problem, there are significant differences ($p < 0.05$) in contamination levels between products with the same microbial load, suggesting cross-contamination between the raw material, the process, the environment and the actor. *Toutous* have microbial loads (T.A.M.F; fecal coliforms, *Staphylococcus aureus*, *Clostridium perfringens*, molds and yeasts, and xerophilic molds) (Table 6) that are mostly higher than the maximum values allowed by the microbiological criteria that cooked meat products must meet in order to be officially recognized as fit for consumption. Total microbial load especially for *S. aureus* and *C. perfringens* suggest non-compliance with good hygiene practices and post-production contamination during handling with peanut paste or during manual drying, smoking, pounding and distribution.

Analysis of the Total Aerobic Mesophilic Flora (TAMF), (Table 6) (contamination germs) in *toutous* suggests that the level of contamination in certain products is acceptable. Basically, the levels of contamination by other microflora are mostly higher than the maximum permitted values, as is the case for thermotolerant coliforms (fecal), which are indicators of recent or constant contamination of human or animal fecal origin with significantly different levels of contamination ($p < 0.05$), suggesting cross-contamination [30]. The levels of contamination by *Staphylococcus aureus* and *Clostridium perfringens* differed significantly ($p < 0.05$) between the different products and follow the same trend, confirming non-compliance with good hygiene and manufacturing practices.

The levels of contamination by molds and yeasts, and xerophilic molds differed significantly ($p < 0.05$) between *toutous*. The high contamination levels reflect and corroborate those obtained on *kilishi* and other artisanal meat products [26-29].

Hedonic Analyses

The hedonic results for the different *toutous* are shown in Figure 2. The integrated analysis of sensory indicators (tenderness, color, taste, overall acceptability) (Figure 2) highlights the unique textural characteristics of Eye round cooked with *toutou* spices (ERC-TS) and Rib eye cooked with sausage spices (REC-SS). In terms of

overall acceptability, ERC-KS (Eye round cooked with *kilishi* spices) ranked first, followed by REC-TS (Rib eye cooked with *toutou* spices) under the technical production conditions of the northern savannahs of Cameroon. This highlights the influence of muscle type and technological processes on organoleptic qualities.

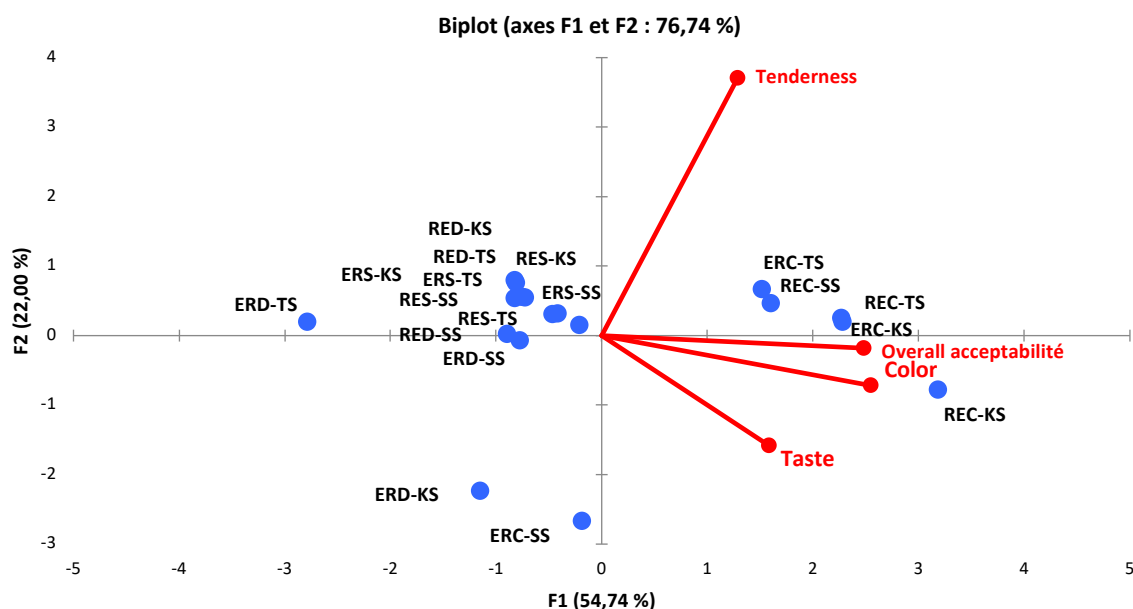


Figure 2: Integrated hedonic analysis of *toutou*'s descriptors

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This study revealed that the technical practice of manufacturing *toutou* is an exclusively female and ethnic activity, carried out mainly by the Mboums. The technological suitability (pH, WC, WRC) of the Eye of round and Rib eye muscles used in the production of *toutou* is within a range compatible with that of meat of good technological quality. The Eye of round, which has a low connective tissue content and a cellular and cylindrical structure, is more suitable for trimming and slicing. Overall, *toutous* produced with three-spice cocktail formulations (*toutou*, *kilishi*, sausage), integrated into a peanut paste matrix, showed low susceptibility to oxidation. However, their hygienic quality remains poor in terms of the microbiological criteria that cooked meat products must meet in order to be officially recognized as fit for consumption, and therefore warrants the implementation of good hygiene and manufacturing practices. The integrated analysis of hedonic indicators highlights the appreciation of all *toutous* to varying degrees, with unique and preeminent characteristics for the Eye of round cooked with *kilishi* spices and the Rib eye cooked with *toutou* spices compared to other *toutous*. This confirms that the innovation implemented in terms of 3 types of spice mixtures and 3 heat treatments used in the processing of *toutou* was effective and contributed to the

overall organoleptic quality of the final products, while safety remains a critical barrier for small and medium size enterprises (SME) development.

Improving hygiene and removing technological constraints are the primary barrier to this market entry to allow the opening of Very Small and Small Medium Size Enterprises to tackle this meat product business opportunity. This innovation opens a significant perspective for improving the productivity of the *toutou* meat processing system, with opportunities for scientific and technical optimization, in particular, in terms of processing and storability of *toutou*.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to this paper and this manuscript has not been submitted to any other journal.

ACKNOWLEDGEMENTS

The authors would like to acknowledge technical support of Halal Food Processing Consulting Building and Trade in Maroua-Cameroon. The authors are also extremely indebted to the National Advanced School of Engineering (NASE) for field logistics and support.

Table 1: Toutou'actors

Age (years)	Workshops number	Gender	Education level			Years in the activity	Professional status
			Non educated	Primary	Secondary		
40	1	Female	0	0	1	15	Owner
50	3		0	1	2	25	
60	6		3	3	0	40	

Table 2: Conditions for obtaining meat for the production of *toutou*

Parameters	
Time between slaughter and arrival at the workshop for processing into <i>toutou</i> (h)	3h 30
Ambient temperature in the laboratory	34.3 ±1°C
Core temperature of the meat	33 ±0.51°C
pH of the meat at the start of trimming	6.56±0.01

Table 3: Ingredients of *toutou*

Ingredients	Sausage Spices (SS) (g)	Kilishi spices (KS) (g)	Toutou Spices (TS) (g)
Peanuts	80	80	80
Salt	2	2	2
Garlic	16	16	0
Onion	0	16	0
Basil	0	5	0
Bouillon cube	2.8	2.8	2.8
Kimba	0.26	0	0.26
Cloves	0.14	0.14	0
Bell pepper	0	3	0
Ginger	0	30	30
Nutmeg	0.26	0	0
Pepper	0.26	2	0
Water	500	500	500

Table 4: Physicochemical characterization and processing suitability of muscles

Muscles	WC (%)	pH	WRC (%)	TY (%)	ing rate (Kg.min ⁻¹)	TR (Kg.min ⁻¹)
Rib eye	73.37±0.49 ^a	6.57±0.05 ^a	13.67±1.15 ^a	50.59±0.49 ^a	3.55±0.23 ^a	0.53±0.1 ^a
Eye of round	75.6±0.52 ^b	6.56±0.05 ^a	19.33±0.57 ^b	72.11±0.16 ^b	4.12±0.1 ^a	0.8±0.1 ^b

N.B.: Values with the same letters do not differ significantly at the probability threshold ($p < 0.05$).

Table 5: Physicochemical characterization of *toutous*

<i>Toutous</i>	pH	WC (%)	TBArs (MDA/kg)
RED-TS	6.23± 0.04 ^{de}	22.83± 0.62 ^e	0.94±0.02 ^k
RED-KS	6.06± 0.05 ^{bc}	30.66± 0.94 ^{fg}	0.97± 0.01 ^l
RED-SS	6.16± 0.03 ^{cd}	33.46± 0.9 ⁱ	0.88±0.02 ^j
REC-TS	6.46± 0.02 ^f	31.86± 0.81 ^g	0.82±0.02 ^h
REC-KS	6.33 ± 0.04 ^{ef}	36.13± 0.81 ^j	0.73±0.02 ^g
REC-SS	6.33 ± 0.05 ^{ef}	30.5± 0.43 ^a	0.62±0.03 ^d
RES-TS	5.93± 0.03 ^a	32± 0.02 ^j	0.53±0.02 ^b
RES-KS	5.96± 0.04 ^{ab}	30.4± 0.71 ^f	0.74±0.02 ^g
RES-SS	6.43± 0.12 ^f	30.5± 0.49 ^f	0.7±0.02 ^f
ERD-TS	6.46± 0.04 ^f	21.9± 0.67 ^{de}	0.76±0.01 ^g
ERD -KS	6.23± 0.06 ^{de}	30.26± 0.25 ^f	0.86±0.01 ⁱ
ERD -SS	6.23± 0.04 ^{de}	33.2± 0.16 ⁱ	0.67±0.02 ^{ef}
ERC-TS	6.43± 0.05 ^f	20.73± 0.9 ^{cd}	0.51±0.01 ^b
ERC-KS	6.23± 0.04 ^{de}	36.13± 0.81 ^j	0.66±0.01 ^e
ERC-SS	6.3± 0.04 ^{ef}	18.2± 0.43 ^a	0.4±0.02 ^a
ERS-TS	6.26± 0.04 ^{de}	18.9± 0.36 ^{ab}	0.56±0.01 ^c
ERS-KS	6.23± 0.06 ^{de}	19.7± 0.37 ^{bc}	0.68±0.01 ^{ef}
ERS-SS	6.1± 0.05 ^{cd}	36± 0.3 ^j	0.52±0.02 ^b

N.B.: Values with the same letters do not differ significantly at the probability threshold ($p < 0.05$).

REC-KS: Rib eye cooked with kilishi spices; REC-SS: Rib eye cooked with sausage spices; REC-TS: Rib eye cooked with toutou spices; RES-KS: Rib eye smoked with kilishi spices; RES-SS: Rib eye smoked with sausage spices; RES-TS: Rib eye smoked with toutou spices; RED-KS: Rib eye dried with kilishi spices; RED-SS: Rib eye dried with Sausage spices; RED-TS: Rib eye dried with toutou spices; ERC-KS: Eye round cooked with kilishi spices; ERC-SS: Eye round cooked with sausage spices; ERC-TS: Eye round cooked with toutou spices; ERS-KS: Eye round smoked with kilishi spices; ERS-SS: Eye round smoked with sausage spices; ERS-TS: Eye round smoked with toutou spices; ERD-KS: Eye round dried with kilishi spices; ERD-SS: Eye round dried with sausage Spices; ERD-TS: Eye round dried with toutou spices.

Table 6: Contamination levels in *toutous* (CFU/g)

<i>Types of toutou</i>	T.A.M.F.	Fecal coliforms	<i>Staphylococcus aureus</i>	<i>Clostridium perfringens</i>	Molds & yeasts	Xerophilic molds
ERD-TS	0.77x10 ⁶ ±1.25 ^c	0.46 x10 ³ ±0.47 ^j	2.56 x10 ³ ±0.82 ^l	0.15 x10 ³ ±0.47 ^b	0.15 x10 ² ±0.47 ^d	0.26 x10 ² ±0.82 ⁱ
ERD-KS	2.73x10 ⁶ ±0.47 ^k	0.29 x10 ³ ±1.25 ^d	1.86 x10 ³ ±0.47 ^j	0.33 x10 ³ ±0.47 ⁱ	0.32 x10 ² ±0.82 ^g	0.08x10 ² ±0.47 ^b
ERD-SS	0.79 x10 ⁶ ±0.47 ^c	0.17 x10 ³ ±1.70 ^b	0.22 x10 ³ ±0.94 ^c	0.16 x10 ³ ±1.25 ^{bc}	0.12 x10 ² ±0.82 ^c	0.08x10 ² ±0.94 ^b
RED-TS	0.17 x10 ⁶ ±0.47 ^a	0.70 x10 ³ ±1.63 ⁿ	2.21 x10 ³ ±0.94 ^k	0.43 x10 ³ ±0.47 ^k	1.29 x10 ² ±1.63 ^k	0.30x10 ² ±0.94 ^j
RED-KS	0.89 x10 ⁶ ±0.47 ^e	0	0.09 x10 ³ ±0.47 ^a	0.31 x10 ³ ±0.47 ^{gh}	0.20 x10 ² ±0.47 ^e	0.19x10 ² ±0.82 ^f
RED-DS	0.79 x10 ⁶ ±1.70 ^c	0.64x10 ³ ±0.82 ^m	0.15 x10 ³ ±0.47 ^c	0.4 x10 ³ ±0.82 ^j	1.21 x10 ² ±0.94 ^j	0.09x10 ² ±0.82 ^{bc}
ERS-TS	0.86 x10 ⁶ ±0.82 ^d	0.18 x10 ³ ±0.82 ^b	0.23 x10 ³ ±0.47 ^c	0.15 x10 ³ ±0.47 ^b	0.16 x10 ² ±0.82 ^d	0.19x10 ² ±1.25 ^{fg}
ERS-KS	2.69 x10 ⁶ ±0.82 ^j	0.46 x10 ³ ±0.94 ⁱ	0.44 x10 ³ ±1.41 ^g	0.32 x10 ³ ±0.94 ^{hi}	0.45 x10 ² ±0.00 ^h	0.14x10 ² ±0.47 ^d
ERS-SS	0.3 x10 ⁶ ±0.82 ^b	0.22 x10 ³ ±0.82 ^c	0.31 x10 ³ ±0.82 ^f	0.16 x10 ³ ±1.25 ^{bc}	0.22 x10 ² ±0.47 ^f	0.16 x10 ² ±0.47 ^e
RES-TS	1.74 x10 ⁶ ±0.47 ^g	0.41 x10 ³ ±0.47 ^g	0.16 x10 ³ ±0.94 ^c	0.17 x10 ³ ±0.47 ^c	0.44 x10 ² ±0.47 ^h	0.19x10 ² ±1.63 ^f
RES-KS	0.86 x10 ⁶ ±0.47 ^d	0.43 x10 ³ ±0.47 ^h	1.42 x10 ³ ±0.47 ⁱ	0.3 x10 ³ ±0.82 ^f	0.32 x10 ² ±0.82 ^g	0.21 x10 ² ±0.82 ^{gh}
RES-SS	0.79 x10 ⁶ ±0.82 ^{bc}	0.35 x10 ³ ±0.94 ^e	0.2 x10 ³ ±0.82 ^d	0.2 x10 ³ ±0.47 ^d	0	0.16x10 ² ±0.94 ^{de}
ERC-TS	2 x10 ⁶ ±1.25 ^g	0.29 x10 ³ ±1.70 ^d	0.16 x10 ³ ±0.47 ^c	0	0.05 x10 ² ±0.47 ^b	0.3 x10 ² ±1.25 ^k
ERC-KS	0.9 x10 ⁶ ±0.82 ^e	0.6 x10 ³ ±1.25 ^l	0.44 x10 ³ ±0.47 ^g	0	0.21 x10 ² ±0.94 ^{ef}	0.1 x10 ² ±0.94 ^c
ERC-SS	1.01 x10 ⁶ ±0.82 ^f	0.55 x10 ³ ±0.82 ^k	0.19 x10 ³ ±0.47 ^d	0	0.31 x10 ² ±0.94 ^g	0.22 x10 ² ±0.94 ^h
REC-TS	2.44 x10 ⁶ ±0.82 ⁱ	0.37 x10 ³ ±0.47 ^{ef}	0.19 x10 ³ ±0.47 ^d	0.3 x10 ³ ±0.94 ^{fg}	0.31 x10 ² ±0.47 ^g	0.16 x10 ² ±0.47 ^{de}
REC-KS	0.88 x10 ⁶ ±1.25 ^{de}	0.39x10 ³ ±0.47 ^f	0.14 x10 ³ ±0.82 ^b	0.22 x10 ³ ±0.94 ^e	1.43 x10 ² ±0.47 ^l	0.04 x10 ² ±0.47 ^a
REC-SS	0.87 x10 ⁶ ±0.94 ^{cd}	0.37 x10 ³ ±0.47 ^{ef}	1.32 x10 ³ ±1.25 ^h	0.15 x10 ³ ±0.47 ^b	0.64 x10 ² ±0.82 ⁱ	0.22 x10 ² ±0.82 ^h
Standards (UFC/g)	3 x 10⁵	10³	10²	30	10²	10²

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