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Production technology and microbiological quality of *kilichi* produced in five locations in Burkina Faso

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Abstract

Kilichi, a dried meat product originating in Niger, is increasingly consumed in Burkina Faso. However, the hygienic quality of this product raises many questions among consumers. The objective of this study was to determine the production technology and hygienic quality of *kilichi* produced in five locations in Burkina Faso. Information on production technology was collected using a questionnaire. Hygienic quality was assessed by testing for indicator bacteria of contamination. Total mesophilic aerobic flora, total coliforms, thermotolerant coliforms, yeasts and molds, spore-forming flora, staphylococci, *Salmonella*, and *Shigella* were tested using standard microbiological analysis methods. A total of 13 *kilichi* producers were interviewed. Thirty-two *kilichi* samples were collected for microbiological analysis. The survey revealed three types of *kilichi* produced. All producers are male. The production process involves five main stages, from cutting to smoking the meat. Total mesophilic aerobic flora, total coliforms, staphylococci, spore-forming flora, and yeasts and molds ranged from $3x10^2$ CFU/g to 10^5 CFU/g, <10 to $3.70x10^3$ CFU/g, <10 to $6.20x10^3$ CFU/g, <10 to $1.67x10^5$ CFU/g, and <10 to $4x10^2$ CFU/g, respectively. Compliance with and application of good hygiene practices during the production and sale of this popular food would improve the sanitary quality of *kilichi* and prevent health risks to consumers.

Keywords : Meat; Production technology; *Kilichi*; Microbiological quality; Burkina Faso

1. Introduction

Meat is a source of animal protein thanks to its high content of essential amino acids (leucine, isoleucine, valine, etc.), iron, zinc, and vitamins (A, B12, B6, D, and E) (*Kimassoum et al.,* 2017; Hissein et al., 2023). Consumed in sauces, grilled or fried, meat contributes to nutritional balance. Its sale helps to combat poverty in developing countries. *Halagarda and Wojciak* (2021) reported that meat consumption has been steadily increasing since 1960. This consumption represents more than 58% of the global protein intake. In most developing countries, meat is considered a food of choice by households. However, this food of choice can often be unfit for human consumption. This is due to a failure to comply with hygiene rules at various stages, from evisceration to cutting. Similarly, poor storage conditions can lead to a deterioration in its organoleptic and nutritional quality. However, meat can be a source of transmission of animal zoonoses to humans. This transmission is a major and recurring public health problem in sub-Saharan Africa (*Kimassoum et al.,* 2017). To mitigate the problems of meat loss, people use several techniques such as fermentation,

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drying, and smoking. The latter two techniques are ways of transforming fresh meat into long-life meat products. In rural areas, they are an alternative means of preserving meat. In these areas, the most common meat product is *kilichi*. It is a ready-to-eat product, traditionally made with fresh beef, camel, sheep, or even goat meat (*Boubacar et al.,* 2019). It is used by local populations as a flavor enhancer in sauces and in other dishes. It is often eaten with bread and used in ceremonies (baptisms, weddings, etc.) as an appetizer. It can also be eaten on its own as a food during travel (*Idowu et al.,* 2010). Nowadays, *kilichi* production has intensified in various areas of West Africa, such as Burkina Faso, Mali, and Niger. This activity is an important source of income for producers. In Burkina Faso, *kilichi* production is still in its infancy. It is produced using traditional methods. Numerous studies have been conducted on *kilichi* and the potentially pathogenic microorganisms that may be found in it (*Mbawala et al.,* 2010; *FAO*, 2014; *Seini et al.,* 2018). However, little data exists on the production technology and microbiological characteristics of *kilichi* in Burkina Faso. Hence the interest of this study, whose overall objective was to assess the sanitary quality of *kilichi* produced in five production areas in Burkina Faso.

2. Materials and methods

2.1. Study site

The study was conducted in five areas spread across three provinces of Burkina Faso : Kadiogo (Ouagadougou), Yatenga (Ouahigouya), and Kouritenga (Sapaga, Koupéla, and Pouytenga) (Figure 1).

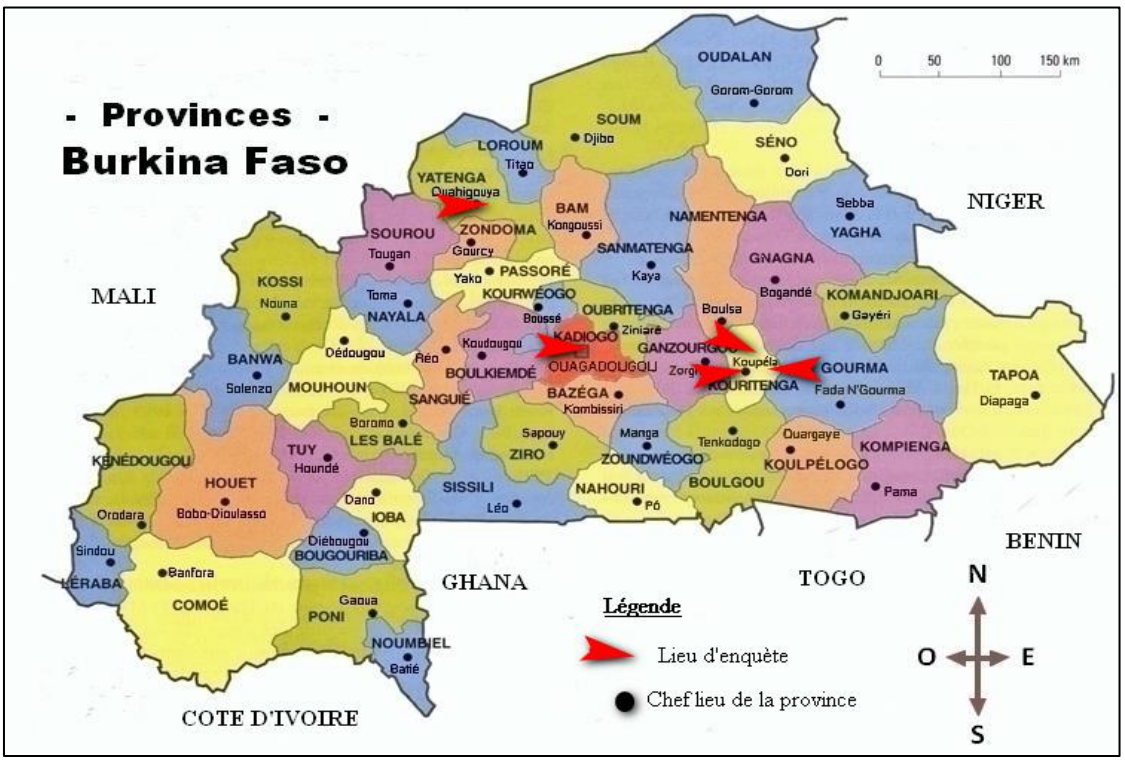

Figure 1 Study site

2.2. Sampling

Samples were taken at random from *kilichi* production and sales sites. For each sample, we took two 40- or 50-gram bags of the same type of *kilichi* from the same production site. Sampling was carried out at production and sales sites in Ouagadougou, Ouahigouya, Sapaga, Koupéla, and Ouahigouya. A total of 32 *kilichi* samples were collected under normal production and sales conditions. All samples collected were packaged in sterile stomacher bags, labeled, placed in coolers containing melting ice, and transported to the Laboratory for microbiological analysis.

2.3. Collection of data on *kilichi* production

An investigation was carried out at the *kilichi* production sites. This investigation was conducted unannounced and consisted of two parts: the first was an oral interview with thirteen *kilichi* producers based on a questionnaire contained

in a survey form. The questions on the survey form focused first on the identity of the producer, then on the technology used to produce *kilichi*, and finally on compliance with good hygiene practices.

The second part consisted of direct observation of the entire production process: the meat used, the production site, the equipment used, the production methods, the staff, and the products obtained. All the information was recorded in a notebook for future use.

2.4. Determination of *kilichi* production technology

The process of implementing production technology was carried out thanks to the collaboration of *kilichi* producers in Ouahigouya, Ouagadougou, and Koupéla. To do this, during our investigations, we made appointments with producers to fully monitor the production technology from fresh meat to the finished product. As we were unable to verify this with all producers, we selected one producer in Ouahigouya and another in Koupéla. At these two producers' facilities, we monitored unit operations, took photos, and asked questions to ensure our understanding. It should be noted that we also asked questions about *kilichi* unit operations at all other producers surveyed.

2.5. Assessment of the sanitary quality of *kilichi*

The analyses focused on counting various microbial flora in *kilichi* in order to assess the hygienic quality of the product. The flora investigated were: total mesophilic aerobic flora, total coliforms, thermotolerant coliforms, yeasts and molds, staphylococci, spore-forming flora, *Salmonella*, and *Shigella* (Table 1).

Table 1 Microorganisms researched or counted and methodologies used

Targeted germs	References	Culture media used	Incubation
Total mesophilic aerobic flora	*ISO 4833-1 (2014)*	Plate Count Agar	37°C during 24H
Total coliforms	*ISO 21528-2. (2017)*	Violet-Red Bile Lactose Agar	37°C during 48H
Thermotolerant coliforms	*ISO 21528-2. (2017)*	Violet-Red Bile Lactose Agar	44°C during 48H
Staphylococci	*ISO 6888-1. (2021).*	Chapman Stone Agar	37°C during 24H
Spore-forming flora	*ISO 4833-1 (2014)*	Plate Count Agar	37°C during 24H
Yeasts and molds	*ISO 21527-2. (2008)*	Sabouraud chloramphenicol	30°C during 72H
Salmonella and *Shigella*	*ISO 6579-1 (2017)*	*Salmonella-Shigella* Agar	37°C during 24H

The results of microbiological analyses were interpreted using a three-class or two-class plan. For salmonella and *Shigella*, the two-class plan was used, which involved searching for these microorganisms in 25 g of *kilichi*. If present, sample would be deemed unsatisfactory, and if absent, it would be deemed satisfactory. For mesophilic aerobic flora, total and thermotolerant coliforms, yeasts, molds, and staphylococci, the three-class plan was used according to criteria m (Table 2).

Table 2 Microbiological criteria used for interpreting results

Microorganisms	Norms (m)	References
Total mesophilic aerobic flora	3.10^5 UFC/g	*Luxembourg Ministry of Health* (2015)
Total coliforms	10^3 UFC/g	*Luxembourg Ministry of Health* (2015)
Thermotolerant coliforms	10^2 UFC/g	*Luxembourg Ministry of Health* (2015)
Staphylococcus aureus	10^2 UFC/g	*Luxembourg Ministry of Health* (2015)
Salmonella-Shigella	Absence/25g	*Luxembourg Ministry of Health* (2015)
Yeasts and molds	10^4 UFC/g	*Luxembourg Ministry of Health* (2015)

2.6. Statistical data processing and analysis

Excel 2013 was used for data entry and to create tables and graphs of microbiological data, and XL Stat 2016 software was used for statistical analyses at a significance level of 0.05%.

3. Results and discussion

3.1. Sociodemographic characteristics of *kilichi* producers

Table 3 presents the sociodemographic characteristics of the respondents. The field survey conducted among *kilichi* producers gathered as much information as possible about the producers themselves and the technology used to produce *kilichi*. The survey revealed that the largest *kilichi* production area in Burkina Faso is Koupéla, which accounts for nearly 46% of the country's producers (Table 3). This could be explained by the fact that *kilichi* originated in Niger and the largest commercial area in Burkina Faso that is close to this country is Koupéla. *Kilichi* and its production technology were likely to have been quickly passed on to the inhabitants of this area by Nigeriens and traffickers.

This study also revealed that *kilichi* producers are men (Table 3). This could indicate the cultural aspect of *kilichi* production, which does not encourage women to take an interest in it. Indeed, it is rare to see women working with raw meat in Burkina Faso. These results differ from those of *Bambara* (2008), who reported that women were more involved in *kilichi* production than men. Since 2008, these women have reportedly withdrawn from *kilichi* production to devote themselves to other activities considered more feminine. This could explain their absence from the production of this commodity in 2020.

The survey also shows that 36% of *kilichi* producers in the area visited are Nigeriens (Table 3). They reportedly brought the production technology with them and decided to engage in this activity to support their families in Burkina Faso and also in their country of origin. In addition, 92% of *kilichi* producers are married and therefore have family responsibilities. If we add to this the *kilichi* sellers and resellers throughout Burkina Faso, we can say that *kilichi* production is an activity that deserves close monitoring by the authorities, as it contributes to the well-being of a large part of the Burkinabe population.

This study also showed that 85% of the *kilichi* producers interviewed had no formal education (Table 3). This could mean that the *kilichi* sector has been taken over by people who did not have the opportunity to receive a good education. The low level of education among producers could result in poor product hygiene and even difficulty in understanding new production technologies. This result is similar to that reported by Hissein *et al.* (2023) in Chad, which states that 87% of charmout producers in Chad have no formal education.

This survey found that more than 77% of *kilichi* producers have more than 10 years of experience (Table 3). This could mean that knowledge about *kilichi* production is passed down from father to son. This has an advantage in terms of *kilichi* quality, as the saying goes: experience is better than science. However, training should not be overlooked, as mistakes can also be passed down over many years.

The survey revealed that more than 77% of producers purchase their meat from slaughterhouses (Table 3). This could be due to the quality and quantity of meat sought from the animals. In fact, producers only use the two legs and two shoulders of the animal. Therefore, most producers believe that purchasing an entire animal for only these parts would be wasteful. The 23% of producers who buy animals for slaughter are butchers or work in collaboration with butchers to facilitate the sale of the rest of the production. This result corroborates that reported by *Seini et al.* (2018) in Niger, who state that the meat used for *kilichi* production is mainly purchased at the slaughterhouse.

This survey also shows that more than 92% of *kilichi* producers prefer beef (Table 3). This is because beef is easier to cut into strips and is less fatty. It therefore facilitates the production of *kilichi*, as cutting the meat into strips is the most labor-intensive part of the process. In addition, beef is cheaper than other meats used in production. This is why other researchers such as *Seini et al.* (2018) define *kilichi* as dried and spiced beef.

The surveys conducted as part of this study showed that more than 40% of the samples were either too tough to chew or too fatty (Table 3). *Kilichi* is a product that must undergo certain processing steps, including the removal of fat and tough parts during trimming. These parts were found in the products inspected. We also noticed that most of the fatty or tough samples were in the batch of coated *kilichi*. The presence of fat and tough parts in *kilichi* shows that certain steps (consisting of removing these parts) during processing have been neglected. These types of *kilichi* are common among processors who have less experience in the field. Some of these producers may think that removing these parts

is a waste of meat, and therefore a reduction in their income. These producers may have taken advantage of the coating to hide non-compliant strips.

Good food hygiene practices are a set of conditions and rules that enable food safety to be monitored and ensured from its origin to its arrival on our plates. The survey shows that more than 54% of *kilichi* producers have never received training in good hygiene practices (Table 3). Most of those who have received training say they received it in Niger or in other contexts. This could indicate a lack of support for the *kilichi* production sector by the authorities, as training in good hygiene practices should be among the first things to learn before starting to produce a food as sensitive as *kilichi*. This result could have a negative effect on the quality of *kilichi* produced in the country. This result corroborates that reported by *Halagarda and Wojciak* (2021), who stated that more than 30% of traditional meat product producers in Serbia have received no education or training in food safety and hygiene.

Table 3 Sociodemographic characteristics of respondents

Variable	**Characteristics**	**Number**	**Percentage**
Sex	Male	13	100%
	Female	0	0%
Nationality	Burkinabè	8	61.54%
	Nigerian	5	38.46%
Localities	Koupéla	6	46.15%
	Ouagadougou	1	07.69%
	Ouahigouya	2	15.38%
	Pouytenga	3	23.07%
	Sapaga	1	07.69%
Marital status	Married	12	92.13%
	Singles	1	07.69%
Level of education	Not enrolled in school	11	84.61%
	Primary	2	15.38%
	Secondary	0	0%
	Superior	0	0%
Years of experience	Less than 10 years	3	23.07
	More than 10 years	10	76.92%
Training in good hygiene practices	Yes	6	46.15%
	No	7	53.85%
Meat origin	Purchase (slaughterhouse)	10	76.92%
	Slaughter (slaughterhouse)	3	23.07%
Favorite type of animal	Beef	12	92.30%
	Sheep or goat	1	07.69%
Technological quality of the samples analyzed	Hard or too greasy	13/32	40.63%
	Good	19/32	59.36%

3.2. Diversity and production technology of *kilichi*

3.2.1. Diversity of kilichi

Three types of *kilichi* are produced according to the techniques used by producers in the areas surveyed. These are : regular *kilichi*, peanut paste *kilichi*, and ginger *kilichi*. Peanut paste *kilichi* (Figure 2) is produced using a peanut paste sauce in which it is immersed for a period of time before being removed and dried. There are two types of peanut paste *kilich*i: the first type, which is generally the most widely produced, has a reddish color. It is produced by adding a coloring agent (*Bixa orellana*) to the peanut paste (Figure 2a). The second type has a yellowish color (Figure 2b). It is produced without coloring agents. Peanut paste *kilichi* may or may not be spicy.

Figure 2 Peanut paste *kilichi*

Ginger *kilichi* is produced, as its name suggests, with a ginger-based sauce. It has a yellowish color and is always spicy (Figure 3a). Regular *kilichi* is produced without sauce. The dried meat is simply coated with a thin layer of oil. The product therefore retains its brown color. It may or may not be spicy (Figure 3b).

Figure 3 Ginger and regular *kilichi*

This result differs from that reported by *Bambara* (2008) in Burkina Faso and that reported by *Yacouba* (2009) in Niger, who only counted plain *kilichi* and *kilichi* with peanut paste. Ginger *kilichi* was not detected in these studies because this product or its technology is unknown or less developed.

3.2.2. Kilichi production technology

The processes developed for the production of the three types of *kilichi* have similarities and differences depending on the producer. Figure 4 shows the *kilichi* production diagram established after interviews with producers.

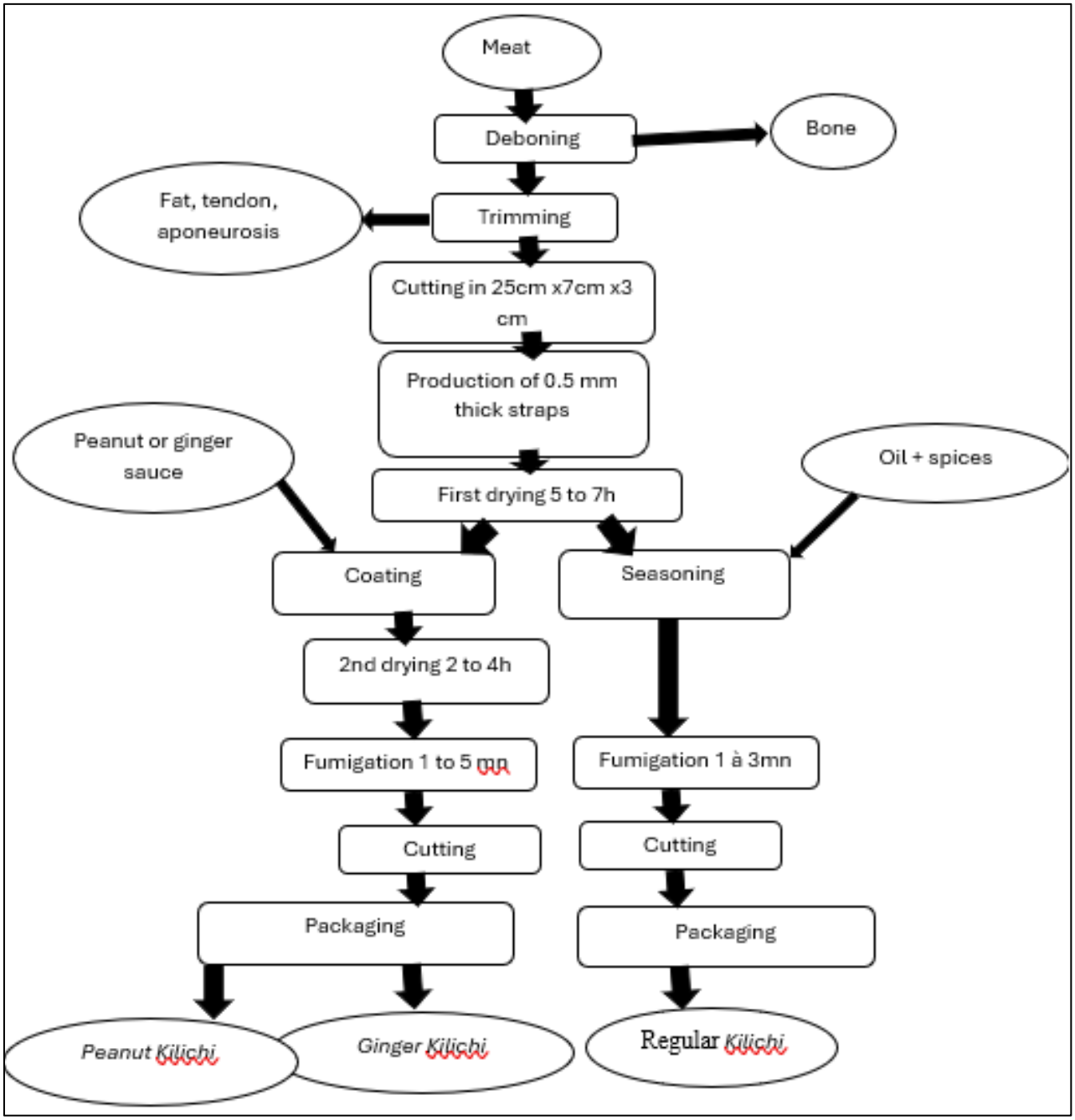

Figure 4 Technological diagram of *Kilichi* production

This diagram differs from that reported by *Bambara* (2008) in Burkina Faso, who stated that there is a washing stage after cutting into strips. This difference could be due to a modification of the production diagram by these producers. Indeed, these producers would see that washing the meat is in a way moistening it, and wetting food that one wants to dry would seem pointless. This diagram also differs from the one reported by *Yacouba* (2009) in Niger, who noted that there are two types of *kilichi*: "Maiyagi" *kilichi* (*kilichi* coated with peanut paste) and "Dan kalambé" *kilichi* (plain *kilichi*). The diagram for ginger *kilichi* was not presented. This type of *kilichi* was unknown in Niger at the time of the study.

3.2.3. Sanitary quality of the kilichi produced

Tables 4, 5, and 6 shows the microorganism load in CFU/g of the *kilichi* samples collected .

Table 4 Microorganism load in peanut-coated *kilichi* samples

Samples	TMAF	TC	TTC	*S. aureus*	SF	YM	SS
2YA	$1x10^3$	<10	<10	<10	<10	<10	Absence
3KA	$1x10^3$	<10	<10	<10	<10	<10	Absence
4KA	$3x10^2$	<10	<10	<10	<10	<10	Absence
6SA	$1.9x10^3$	<10	<10	<10	<10	<10	Absence
7KA	$1.3x\ 10^4$	<10	<10	<10	<10	<10	Absence
8KA	$2.8x10^4$	<10	<10	<10	<10	10^2	Absence
9KA	$5x10^4$	<10	<10	<10	<10	<10	Absence
10KA	$5x10^2$	<10	<10	<10	<10	<10	Absence
11KA	$1.5x10^4$	<10	<10	<10	<10	<10	Absence
12KA	$2.9x10^4$	<10	<10	<10	<10	<10	Absence
14OA	$3x10^3$	<10	<10	$1,5x10^3$	<10	10^2	Absence
15KA	$1x10^4$	<10	<10	<10	$2x10^2$	10^2	Absence
17KA	$6.73x10^4$	<10	<10	<10	$3.9x10^4$	$2x10^2$	Absence
18KA	$4.2x10^4$	<10	<10	<10	<10	$2x10^2$	Absence
33KA	$1x10^3$	<10	<10	$6x10^2$	<10	<10	Absence
Average	$1.75x10^4$	-	-	-	-	-	Absence

Legend : TMAF: Total Mesophilic Aerobic Flora; TC: Total Coliforms; TTC: Thermotolerant coliforms; *S. aureus* : *Staphylococcus aureus*; SF: Sporulating Flora; YM: Yeasts and Molds; SS: *Salmonella-Shigella*

Table 5 Microorganism load in uncoated *kilichi* samples

Samples	TMAF	TC	TTC	*S. aureus*	SF	YM	SS
13KS	$5x10^3$	<10	<10	$3x10^2$	$2,9x10^3$	<10	Absence
19OS	$4x10^4$	$2x10^2$	<10	<10	<10	<10	Absence
20KS	$1,5x10^4$	<10	<10	$2x10^2$	$6x10^4$	$4x10^2$	Absence
21KS	$2,9x10^4$	<10	<10	<10	<10	10^2	Absence
22SS	$2,2x10^3$	<10	<10	$1,5x10^3$	<10	<10	Absence
23SS	10^3	<10	<10	<10	<10	<10	Absence
24KS	$4,73x10^4$	<10	<10	$6,2x10^3$	<10	$2x10^2$	Absence
25SS	$6x10^3$	<10	<10	<10	<10	10^2	Absence
26KS	$2,2x10^4$	$1,2x10^3$	<10	<10	$7,5x10^4$	$3x10^2$	Absence
27KS	$7,6x10^4$	$1,1x10^3$	<10	10^2	$1.67x10^5$	$5x10^2$	Absence
28KS	$4,8x10^3$	<10	<10	<10	$1,5x10^3$	<10	Absence
29KS	$3,9x10^3$	$3,7x10^3$	<10	$1,3x10^3$	<10	$2x10^2$	Absence
30KS	$7x10^2$	10^2	<10	$7x10^2$	<10	<10	Absence

32KS	$2x10^3$	$1,8x10^3$	<10	$2x10^2$	10^3	<10	Absence
34SS	$2x10^3$	<10	<10	10^2	<10	<10	Absence
Average	$1,71x10^4$	-	-	-	-	-	Absence

Legend : TMAF: Total Mesophilic Aerobic Flora; TC: Total Coliforms; TTC: Thermotolerant coliforms; *S. aureus* : *Staphylococcus aureus*; SF: Sporulating Flora; YM: Yeasts and Molds; SS: *Salmonella-Shigella*

Table 6 Microorganism load in ginger-coated *kilichi* samples

Samples	**TMAF**	**TC**	**TTC**	***S. aureus***	**SF**	**YM**	**SS**
5KG	$2,5x10^3$	<10	<10	<10	$1.4x10^4$	<10	Absence
31KG	10^5	<10	<10	<10	$4x10^3$	<10	Absence
Average	$5,13x10^4$	-	-	-	$9x10^3$	-	Absence

Legend : TMAF: Total Mesophilic Aerobic Flora; TC: Total Coliforms; TTC: Thermotolerant coliforms; *S. aureus* : *Staphylococcus aureus*; SF: Sporulating Flora; YM: Yeasts and Molds; SS: *Salmonella-Shigella*

The results showed that the average TMAF (Total Mesophilic Aerobic Flora) load of peanut-coated *kilichi* was $1.74x10^4$ CFU/g, that of ginger-coated *kilichi* was $5.13x10^4$ CFU/g, and that of plain *kilichi* was $1.71x10^4$ CFU/g. The average TMAF load of the coated kilichi samples is higher than that of plain kilichi. This is likely due to the ingredients used in the production of this food product. The production of coated *kilichi* requires the use of a coating sauce, which can always have an effect on the microbiological quality of the final product. In addition to the ingredients used in the production of the sauce, failure to comply with hygiene rules in the production chain promotes the proliferation of bacterial flora. If the production of this sauce is not carried out in accordance with hygiene rules, the final product may be contaminated. Also, the average bacterial load of ginger-coated *kilichi* samples is higher than that of other types of *kilichi* studied. This could be explained by the fact that ginger *kilichi* is a less developed product than the other types of *kilichi* studied. In fact, this type of *kilichi* was produced by only two of the 13 producers surveyed. It is a type of *kilichi* that is unfamiliar to most producers. As a result, those who have started producing this product may not fully understand the hygiene rules that must be applied to the ginger paste to prevent contamination. Producers are therefore not as proficient in its production technology as they are in that of other types of *kilichi*. The same findings were also made by *Boubacar et al.* (2019) in Niger, who reported a higher load of coated *kilichi* than plain *kilichi*. Yacouba (2009) also reported that "Maiyagi" *kilichi*, which was equivalent to coated *kilichi*, had a higher TMAF content than "Dan kalambé" *kilichi*, which was equivalent to plain *kilichi*. With regard to total mesophilic aerobic flora, these analyses yielded CFU/g values below the limit recommended by the *Luxembourg Ministry of Health* (2015) for cooked meat products, which is 3×10^5 CFU/g for total mesophilic aerobic flora. All samples (100%) were therefore deemed satisfactory for this flora. The lower load of this total mesophilic aerobic flora could be due to the fact that the study was conducted during a very hot period. This would have allowed the meat to dry quickly, minimizing product contamination and exposing the existing flora to sunlight, which has a bactericidal effect. These results are similar to those reported by *Tiendrebeogo et al.* (2016), who also found values below the limit recommended by the same ministry.

In this study, the total coliform and thermotolerant coliform counts were consistently below 10 in the coated samples analyzed. This could be due to the spices used in the production of coated *kilichi*. Indeed, some spices used in the production of *kilichi* sauce have been reported by certain authors to have an antibacterial effect. *Sawadogo et al.* (2021) reported that chili peppers, garlic, ginger, and mint have antibacterial properties. According to these researchers, these spices and aromatic plants can even be used to eliminate total and thermotolerant coliforms in peanut paste. The same observations were also made by *Mbawala et al.* (2010), who reported that non-spicy *kilichi* is subject to more contamination than spicy *kilichi*. Our results corroborate those found by *Yacouba* (2009), who also found no coliforms in his samples analyzed in Niger. *Yacouba* (2009) also stated that spices, in addition to their contribution to flavoring, also have antioxidant, antifungal, and, above all, antiseptic properties.

With regard to total coliforms, the *Luxembourg Ministry of Health* (2015) recommends a limit of 10^3 CFU/g for cooked meat products. On this basis, only 4 of the 32 samples analyzed were deemed acceptable. This represents a rate of 12.5%. The other samples (87.5%) were deemed satisfactory. With regard to thermotolerant coliforms, formerly known as fecal coliforms, the *Luxembourg Ministry of Health* (2015) recommends a limit of 10^2 CFU/g for this germ in cooked meat products. In this study, given that the number of thermotolerant coliforms in the samples analyzed was always less than 10, we can say that all samples are considered satisfactory with regard to this germ.

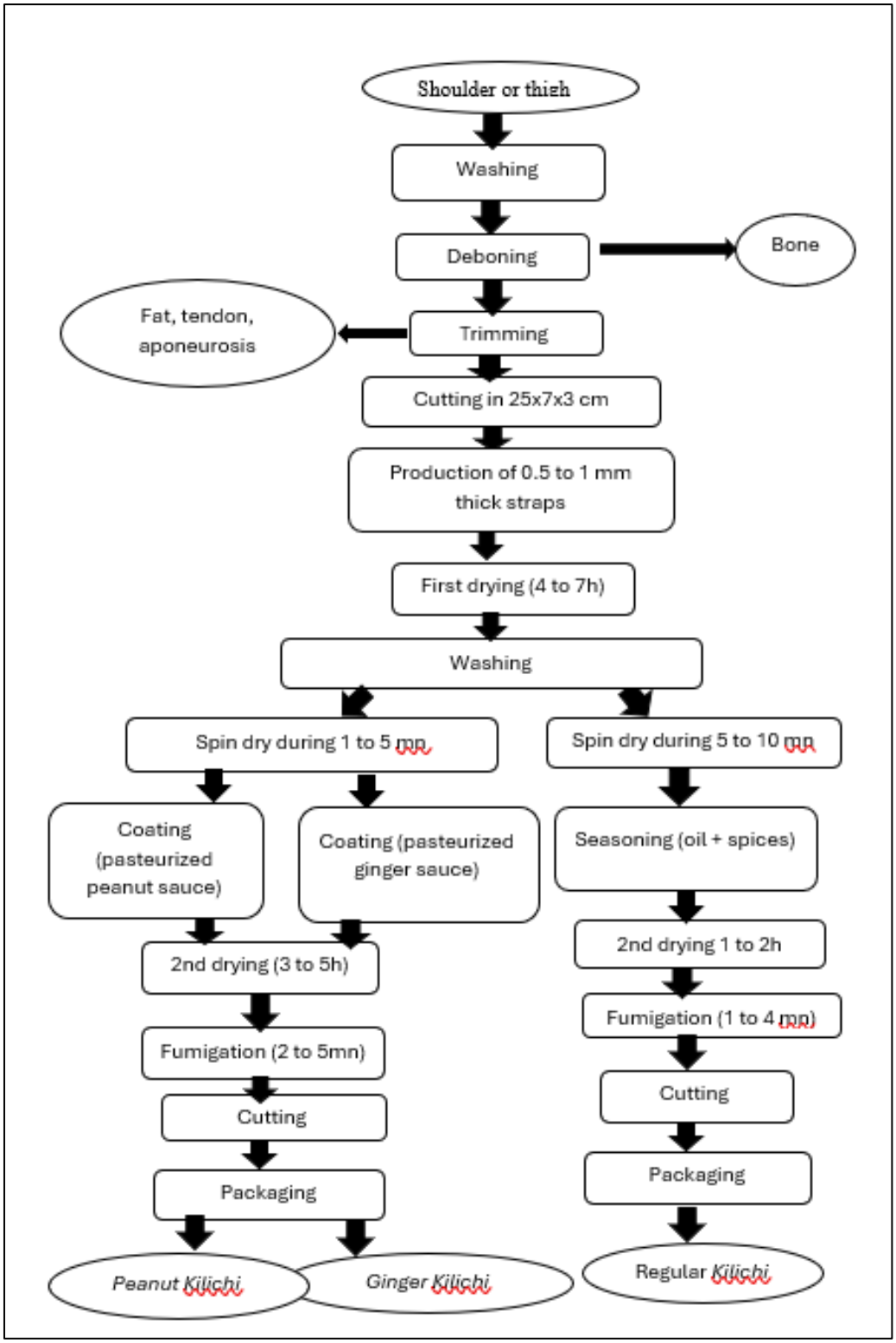

Figure 5 Improved technological diagram for *kilichi* production

Suspicions of *Staphylococcus aureus* were found in coated and plain *kilichi*. *Staphylococcus aureus* is a highly toxinogenic species which, if ingested, can produce toxins with toxic and antigenic properties. This contamination could be explained by the quality of the meat used to prepare the *kilichi* and also by the various handling operations during and after production of the product. *Staphylococcus aureus* are commensal bacteria found in humans and animals, which can be present in the nostrils and other mucous membranes. Contamination by these microorganisms therefore occurs from fresh meat or when hygiene rules are not followed during the production of *kilichi*. A review reports that the total

prevalence of *Staphylococcus aureus* in meat products in Africa was 24.5% (*Thwala et al.,* 2021). These results are also similar to those reported by *Mbawala et al.* (2010) in Cameroon and by *Tiendrebeogo et al.* (2016) in Burkina Faso, who also found suspected *Staphylococcus aureus* in the *kilichi* samples analyzed. For *Staphylococcus aureus*, the *Luxembourg Ministry of Health* (2015) recommends a limit of 10^2 CFU/g of *Staphylococcus aureus* for cooked meat products. Based on this standard, 1 sample was deemed acceptable (3.13%), 4 samples were deemed unsatisfactory (12.50%), and 27 samples were therefore deemed satisfactory (84.4%).

Spore-forming flora were found in all types of *kilichi* analyzed. This indicates the presence of a number of bacteria in these products, including *Bacillus*, *Sporosarcina*, and *Clostridium*. Since these spores are resistant to smoking, hygiene rules must be followed to prevent contamination of the meat by these bacteria before and after cooking.

Yeast and mold were found in 12 samples of *kilichi* analyzed. This could be explained by the fact that dried meat is stored in humid places and sometimes without significant protection. As Burkina Faso is a hot country, these microorganisms easily reach their optimal temperature for growth. With regard to the presence of Salmonella and *Shigella* strains in food products, the *Luxembourg Ministry of Health* (2015) recommends that they should not be present in 25g of cooked meat products. In this study, none of these germs were found in a 25g sample of *kilichi*. All samples (100%) were therefore deemed satisfactory with regard to these germs.

We suggest the diagram in Figure 5 above to producers for the production of an improved quality product.

4. Conclusion

Ultimately, we can say that *kilichi* is a food whose production involves several stages that can be summarized as meat selection, cutting into strips, drying, coating, and smoking. Three types of *kilichi* are produced in our country : regular *kilichi*, ginger-coated *kilichi*, and peanut-coated *kilichi*. From a microbiological point of view, we noticed that coated *kilichi* were more contaminated with total mesophilic aerobic flora than regular *kilichi*. However, the latter was more contaminated with total coliforms, *Staphylococcus aureus*, and yeast and mold than coated *kilichi*. The microbiological quality of *kilichi* produced in Burkina Faso is acceptable. Of the 32 samples analyzed, only four were of unsatisfactory quality due to a high level of suspected *Staphylococcus aureus*. It is necessary to provide regular training in good hygiene practices for producers, most of whom have not had the opportunity to attend school. It is also necessary to consider the use of gas dryers for perfect, rapid drying in all seasons and in complete safety.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no competing interests.

Authors' contributions

CH and OI analysed the data and wrote the manuscript. ZO, DAO reviewed the manuscript. SA contributed to the discussion and reviewed the manuscript. SA managed the project and reviewed the manuscript.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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