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Full Length Research Paper

Isolation of *Escherichia coli* 0157:H7 from selected food samples sold in local markets in Nigeria

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Food borne illnesses have major social and economic impacts. *Escherichia coli* O157:H7 is associated with food borne illness in human beings. It has been an important food borne pathogen that causes food borne diseases such as diarrhea, hemolytic uremic syndrome and hemorrhagic colitis. This study was conducted to detect the presence of *E. coli* O157: H7 in different food samples sold in Nigerian local markets. A total of 60 different food samples (3 each of meat, fufu, waterleaf, pumpkin, carrot, tomatoes, meat pie, yoghurt, watermelon, cucumber, groundnut, cabbage, garden egg, bread, okra, apple, chicken, unpasteurized milk, salad and pawpaw) were collected randomly from different markets in Calabar, Nigeria. The samples were analyzed using standard microbiological techniques. Isolation was carried out using pour plate technique on sorbitol MacConkey agar. The isolates were identified by morphological and biochemical tests. Out of the 60 samples investigated, 36 (60%) were found to be contaminated with *E. coli* O157:H7 while 24 (40%) were negative by conventional methods. All the isolates obtained from the samples were subjected to various biochemical tests and were all confirmed to be *E. coli* O157:H7. The occurrence of *E. coli* O157:H7 serotype in these food products indicates that there may be a potential risk for public health from consuming these foods. This study clearly indicated the need for proper handling and processing of food products especially ready to eat food products. It is also important that at household level proper hygienic measures should be taken to avoid cross contamination.

Key words: *Escherichia coli* O157:H7, diarrhea, food borne illnesses, food samples, hemorrhagic colitis.

INTRODUCTION

Escherichia coli are large and diverse group of bacteria. It is the type of the genus *Escherichia* that contained mostly motile Gram negative bacilli that fall within the family Enterobacteriaceae. It is the predominant facultative anaerobe of the human colonic flora. The organism typically colonizes the infant gastrointestinal tract within hours of life, and thereafter *E. coli* and the host derive mutual benefit for decades (Kaper et al., 2004). *E. coli* is a bacterium that normally lives in the intestines of human and animals, the growth and survival of *E. coli* depends

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on the number of environmental factors such as temperature, pH, water activity, composition of the food, carriage by cattle and contamination of surface water (Center for Disease Control, 2001). The temperature range of growth of *E. coli* is 7 to 8 to 46°C, with an optimum temperature of 35 to 40°C. Although most serotypes of *E. coli* are harmless, several produce toxins that cause illness. Some strains of *E. coli* including *E. coli* O157:H7, produce toxins known as shiga toxins and are called shiga toxin producing *E. coli* (STEC). Their virulence characteristics suggest that they may have significant impact on public health (Perera et al., 2015).

During the past two decades, disease caused by *E*. *coli* O157:H7 has been increasing (Mean et al., 2015). Currently, the Centers for Disease Control and Prevention (CDC) estimated that *E*. *coli* O157:H7 caused an average of 500 outbreaks that affect >73,000 persons and result in >61 deaths each year in the United States (Charatan, 2014). The epidemiology of *E*. *coli* O157:H7 has become an important research topic as manure harboring *E. coli* O157:H7 is dispersed, and soil, food, and water are cross-contaminated with feces containing *E*. *coli* O157:H7 (CDC, 2001; Nakazawa and Akiba, 2001; Mean et al., 2015).

E. coli O157:H7 is an important emerging human pathogen causing haemmorhagic colitis (HC), haemolytic uraemic syndrome (HUS) and thrombotic thrombocytopaenic purpura (TTP) (Amani et al., 2015; Fan et al., 2019). *E. coli* O157:H7 serotypes are identified as enterohaemorrhagic *E. coli* (Oksuz et al., 2004). The infections by *E. coli* O157:H7 have been reported of increasing frequency from all parts of the world in the form of food poisoning outbreaks (Jo et al., 2004; CDC, 2018). Because of the severity of these illnesses and the apparent low infective dose (<10 cells) (Bach et al., 2002), *E. coli* O157:H7 is considered one of the most serious of known foodborne pathogens (Blanco et al., 2003).

Enterohemorrhagic *E. coli* O157:H7 is an important food borne pathogen a causative agent of HC and HUS. Globally, STEC caused 2,801,000 acute illnesses annually, with an incidence rate of 43.1 cases per 100,000 persons per year. This burden led to 3890 cases of HUS and 230 deaths (Lupindu, 2017). Large outbreaks of EHEC infection were reported throughout the world. *E. coli* O157:H7 is the most commonly recognized STEC in the United States, however, many other STEC serogroups including O26, O103, O111, and O145, have been associated with outbreaks and sporadic cases of HC and HUS worldwide (Essendoubi et al., 2019). One of the largest *E. coli* O157:H7 (one of the serotypes of EHEC) outbreaks associated with food consumption occurred in Sakai City, Japan in 1996. About a quarter of African countries have reported isolation of STEC 0157:H7 either from humans, animals, food or the environment (Lupindu, 2017; Yusuf et al., 2018).

The overall aim of this study was to investigate the presence of *E. coli* O157:H7 in different food samples sold in Calabar Metropolis, Nigeria and to determine its incidence rate.

MATERIALS AND METHODS

Sample collection

A total of 60 different food samples (3 each of meat, fufu, waterleaf, pumpkin, carrot, tomatoes, meat pie, yoghurt, watermelon, cucumber, groundnut, cabbage, garden egg, bread, okra, apple, chicken, unpasteurized milk, salad and pawpaw) were collected randomly from different markets in Calabar, Nigeria. All the samples were collected aseptically in sterile universal containers and polyethylene bags and immediately placed in pre-cooled containers containing ice packs and then transported to the laboratory for analyses.

Preparation of samples

About 25 g of food samples was taken and homogenized with 225 ml of buffered peptone water 0.1% in a stomacher for 15 min, after which the homogenate was used for the isolation.

Isolation of *E. coli* 0157:H7

Isolation was carried out after pre-enrichment of the samples by selective plating as described by Kim et al. (2005). One milliliter of the homogenate was used for ten-fold serial dilution after which 0.1 ml of 10^3 dilution factor was inoculated on Sorbitol MacConkey agar (SMAC) supplemented with cefixime (0.05 mg/l) and potassium tellurite (2.5 mg/l) in triplicate. The plates were then incubated at 28°C for 18 to 24 h. After the incubation period, the plates were observed for the growth of *E. coli* 0157:H7 colonies.

Purification and maintenance of isolates

Each discrete colony on a Petri dish was transferred using a sterile inoculating loop into plates containing freshly prepared Nutrient agar (NA) and were incubated at 37°C for 24 to 48 h, respectively. The isolates were then preserved on NA slants stored in the refrigerator at 4°C.

Biochemical confirmation of isolates

The suspected colonies of *E. coli* 0157:H7 were subjected to various tests and confirmed based on the biochemical characteristics. The individual colonies of EHEC from CT-SMAC agar were transferred to tryptic soy broth (TSB) and incubated at 37°C for 24 h. Primary identification tests like Gram's staining, catalase test and oxidase test were performed. Secondary identification tests like indole production, methyl red (MR) reaction, voges proskauer (VP) reaction, citrate utilization test, urease activity, and carbohydrate utilization test were carried out as per the standard procedures.

RESULTS AND DISCUSSION

The percentage of *E. coli* O157:H7 in the food samples analyzed is shown in Figure 1 where the highest rate of

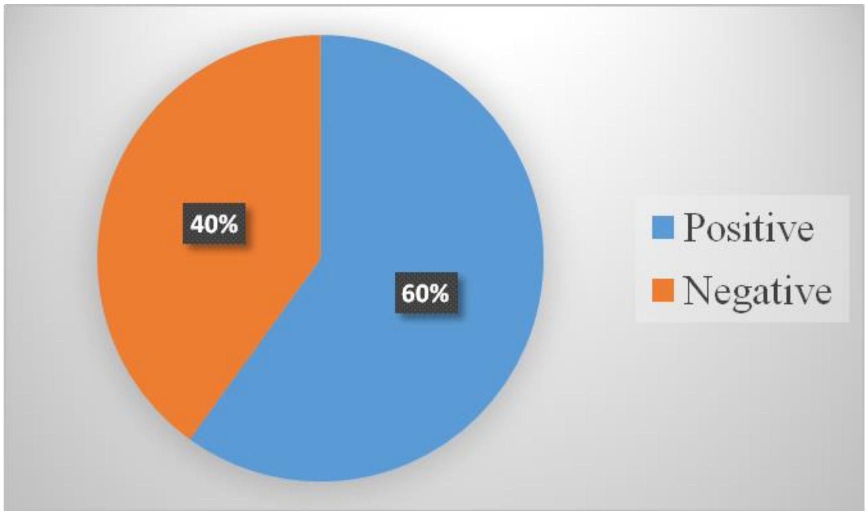

Figure 1. Incidence rate of *E. coli* O157:H7 in selected food samples.

Table 1. Microbial loads of *E. coli* O157:H7 in selected food samples.

S/N	Food sample	Mean count (CFU/g or ml)
1	Meat	3.8×10^2
2	Fufu	1.13×10^2
3	Pumpkin	2.04×10^2
4	Meat pie	2.9×10^2
5	Yoghurt	2.2×10^2
6	Cucumber	1.27×10^2
7	Cabbage	1.43×10^2
8	Garden egg	1.16×10^2
9	Okra	1.52×10^2
10	Salad	2.42×10^2
11	Unpasteurized milk	1.86×10^2
12	Chicken	2.7×10^2

occurrence of *E. coli* 0157:H7 was observed to be 60% with 40% representing negative occurrence. The results of the microbial load of *E. coli* O157:H7 in food samples analyzed are shown in Table 1. The highest *E. coli* O157:H7 load was recorded of meat sample with a mean load of 3.89×10^2 CFU/g while the least load was observed in fufu (1.13×10^2 CFU/g) sample.

All these isolates were positive for catalase test, motility, indole production, MR, triple sugar iron agar reaction and Lysine decarboxylase. These isolates were negative for oxidase, VP, citrate utilization, urease and sodium chloride tolerance test. The results of these tests clearly indicated that they belonged to the category of enterohaemorragic *E. coli*. These isolates were then subjected to carbohydrate utilization tests for identification of species. The results suggested that all the 16 isolates were showing reaction similar to that of *E. coli* O157:H7 shown in Table 2.

The results from the study revealed an overall incidence of *E. coli* O157:H7 as 60% (12/20) in all the collected food samples from different locations in Calabar, Nigeria. Kumar et al. (2004) found that 100% of different beef samples positive for *E. coli* O157:H7 in a study conducted in Mangalore, India. The United States Department of Agriculture (USDA, 2007) reported that the Food Safety and Inspection Service (FSIS) identified more than 75% of the ground beef and vegetable samples were positive for the presence of *E. coli* 0157:H7. Grant et al. (2011) reported that the prevalence of non 0157 EHEC in raw beef as 2.4 to 49.6% in Canada and United States it ranged from 5.7 to 26.2%. These suggested that foods, particularly beef are an important source of *E. coli* 0157:H7 infections. In the present study also, the highest mean load was observed

Table 2. Biochemical characteristics and identification of *E. coli* O157:H7.

S/N	Biochemical test and sugar fermentation	Meat			Fufu		Meatpie			Yoghurt			Cabbage		Cucumber		Okra	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Gram's reaction	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Shape	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod
2	Catalase	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	Oxidase	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Motility	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	Indole production	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Methyl red	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
7	Sucrose	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	Lactose	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	D-Glucose	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10	Citrate utilization	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

in meat sample. This may be due to the fact that the gastro intestinal tract of the cattle is the most important predilection site of the organism (Vijayan et al., 2017). The range of food samples positive in this study for *E. coli* 0157:H7 is of concern to consumers and food processors. More of concern is the fresh vegetables that are eaten raw especially in salads and the already prepared foods.

The occurrence of *E. coli* O157:H7 of the present study was comparatively lower than a study done by Zahraa et al. (2016). They got a prevalence of 82% (135/164) from different food samples. Almost similar result was found in other studies conducted by Vinothkumar et al. (2014) in Puducherry, India who observed 84% prevalence in food samples. Momtaz and Jamshidi (2013) in Iran found 71.2% of the food samples were positive for *E. coli* 0157:H7. These findings suggested that cross-contamination of these food samples may occur in retail food shops and markets with higher prevalence in animals. Cattle act as a reservoir host for EHEC O157:H7 resulting in higher food contamination (Bindu and Krishnaiah, 2010). This is a serious health issue that the public health department of any government to take off. It is important that the regulatory agencies put up an enlightenment campaign to educate consumers on how to control or eliminate cross contamination by cooking meat properly, drinking pasteurize milk and juice, wash produce thoroughly, wash utensils very well, keep raw foods separate and to wash hands thoroughly after handling raw meats.

Similar study carried out in Iraq, from 100 samples of meat only two isolates and from 98 dairy product samples were detected as *E. coli* O157:H7 (Dhaher et al., 2010). In Iran, another study proved that, from 130 bulk tanks of milk just one isolate was *E. coli* 0157:H7 (Brenjchi et al., 2011). While, in another study, from 125 samples of soft cheese prepared from raw milk, found 5 isolates of *E. coli* 0157:H7 (Najand and Khalilli, 2007). Out of 50 ground beef samples, 7 strains of *E. coli* 0157:H7 were detected, while none was isolated from chicken drumsticks in Turkey (Fatma and Murat, 2000).

In Turkey, studies conducted to detect *E. coli* O157 and/or *E. coli* O157:H7 revealed that *E. coli* 0157 have been isolated from different food products with an occurrence varying from 0 to 55% (Elmali et al., 2005). Few studies, however on the isolation of *E. coli* 0157:H7 from ground beef and vegetable products in Turkey have revealed negative results (Siriken and Pamuk, 2004; Siriken et al., 2004). Likewise, there is also no report of any outbreaks due to *E. coli* 0157:H7 in Turkey (Agaoglu et al., 2000). It is likely that these kinds of cases have not been reported or the causative agents of food poisonings have not been identified. Lack of direct link between isolates from humans and other sources makes it difficult to point out incident specific determinants and direction of transmission (Lupindu, 2017). But, it seems that incidences found in this study seem to be higher than those previous studies for other food products. Vegetables, milk and water have also been implicated in *E. coli* 0157:H7 poisoning outbreaks (Kayisoglu et al., 2003).

In Africa, a study carried out in Gwagwalada, Federal Capital Territory, Nigeria, among children between the ages of 0 to 24 months found 31.1% positive for STEC (Onanuga et al., 2014), which could be as a result of the mothers hygienic status.

Conclusion

The findings from this study suggested that most raw foods are contaminated with *E. coli* 0157:H7. This is a serious health issue. Cross-contamination of foods may be occurring in retail meat shops because studies have indicated higher prevalence of *E. coli* 0157:H7 in animals. Cattle act as a reservoir host for EHEC 0157:H7 resulting in higher food contamination. Mainly in the beef retail shops, beef carcasses were not hoisted but kept on the tables or the floor for dressing. More precautions are therefore needed processing and handling of meat to avoid cross contamination of foods. This study has also highlighted the contaminated levels of the various food products. The hygienic environments and handling could have contributed immensely to the cross contamination of other food products not prone to contamination by *E. coli* 0157:H7. Undocumented frequent food borne disease outbreaks in this part of the country could be attributed to *E. coli* 0157H:7.

Efforts should therefore be made to control this bacterium in Nigerian food products in order to avert any sickness or death resulting from eating food contaminated with *E. coli* 0157:H7.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Production technique, safety and quality of *soumbala*, a local food condiment sold and consumed in Burkina Faso

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Exploitation of Non-Wood Forest Products (NWFP) is after agriculture and breeding the third source of income in Burkina Faso. *Soumbala,* made from alkaline fermentation of *Parkia biglobosa* seeds, is one of the most popular indigenous foods condiments very prized by the Burkinabes. This study aimed to assess the process practices and safety measures to ensures good quality along the production chain of *soumbala*. A literature survey followed by investigations was performed. Sphinx Millennium V4.5 software was used for data processing and analysis. The results showed that *soumbala* production is essentially a women activity with *Mossi* and *Lobi* the most active ethnic groups in *soumbala* manufacture. The organoleptic and nutritional qualities as well as safety and stability of *soumbala* depend on the production conditions. The production and sale conditions, the ignorance of rules of hygiene, the lack of training in quality management system or concept of good manufacturing practice (GMP) and the non-compliance practices of processors induced sanitary risks for consumers. Results of this study confirmed the needs to set up training program for GMP, environmental sanitation and personal hygiene both for processor-sellers to improve the safety of *soumbala*.

Key words: Technology of production, food safety, food quality, *Soumbala*, good manufacturing practice (GMP).

INTRODUCTION

Leguminous oil seeds are cultivated in large quantities in many regions of West Africa. The seeds are fermented to produce highly priced traditional condiments, used as seasoning for soup and sauces as well as a source of

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plant proteins to supplement the dietary intake (Oguntoyinbo, 2012). *Soumbala*, along with other African fermented food condiments, is one of the popular food seasonings produced from alkaline fermentation of African locust bean (*Parkia biglobosa* (Jacq.) G. Don) seeds in many West African countries (Savadogo et al., 2011; Ouoba, 2017; Akanda et al., 2018). The fermented seeds had various names according to the country where it is produced and is commonly called *soumbala* in Burkina Faso and Mali (Diawara et al.,1992). *Soumbara*, *iru*, *netetu*, *afitin* or *sonru*, *Dawadawa and Kinda* all also refer to the same product, in Côte d'Ivoire (Fatoumata et al., 2016), in Nigeria (Sanni et al., 2000), Senegal (Ndir et al., 1994), Benin (Azokpota et al., 2006), in Nigeria and Ghana (Akanda et al., 2018) and Serria Leone (Savadogo et al., 2011), respectively. *Soumbala* contained 30-47% proteins, 20-43% lipids and 13-17% carbohydrates, and constituted a great source of energy (464-546 Kcal/100 g), and is a rich source of essential amino and fatty acids (Parkouda et al., 2009). It is also rich in vitamins, especially vitamins of the B group (thiamine, riboflavin and niacin) (Ndir et al., 2000), and also in minerals such as calcium, iron and phosphorus. It has a characteristic strong flavor and odor attributed to the production of components such as ammonia, pyrazines, esters, acids and ketones during the fermentation and production technique (Ouoba, 2017). The diversified components, of *soumbala* contributed to add essential nutrients to monotonous carbohydrate-dominated diets of the rural populations. It is usually added generously as seasoning into the preparation of various dishes such as sauces, soups, "*riz gras au soumbala*", "*Poulet au soumbala*", "*couscous*", etc. widely consumed in Burkina Faso (Somda et al., 2014). *Soumbala* served as a low-cost meat substitute for poorer sections of the community (Campbell-Platt, 1980) due to its content of protein and fat. Beside its flavoring attributes, *soumbala* played an important health maintaining role (Akanda et al., 2018) since, with its diverse components, it is believed to contribute to the regulation of arterial tension, to fight against cardiovascular illness and to contain beneficial bioactive compound-producing *Bacillus* strains that acted as probiotics in the human gastro-intestinal tract. It also played socio-economic and cultural role for the local Burkinabe population (Cheyns and Bricas, 2003; Millogo, 2008).

In Burkina Faso, the traditional processing and fermentation of African locust bean seeds into *soumbala* comprised the following mains steps: boiling of the seeds during 24-40 h, dehulling, second parboiling for 1-3 h, fermentation for 48-72 h (25-30°C), air drying and molding into balls of various sizes (Ouoba, 2017). This artisanal process relied on the know-how of small producers who make *soumbala*, in small manufacturing units, originally destined for house consumption. This technology is non-compliant in terms of both safety and quality of the final product (Somda et al., 2014; Ouoba, 2017). However, today, the production of *soumbala* is growing due to gradually increasing demand and the income generated by this activity for its main actors (Millogo, 2008). A semi-modern technology called ALTECH has been developed, by the Department of Food Technology of the National Research Centre (DTA/IRSAT/CNRST) (Millogo, 2008) and adopted in Ghana (Akanda et al., 2018) and Nigeria (Isu and Ofuya, 2000), for normalization and control of production of standard *soumbala*. Unfortunately, this semi-modern manufacturing unit did not produce enough *soumbala* and both technology and product are judged very-cost effective by producers and consumers, respectively (Millogo, 2008). As a consequence, the artisanal technology is still the main process for production of *soumbala* whose sale enhanced the economic empowerment of rural dwellers, and thus, contributed to poverty alleviation in Burkina Faso (Ouoba et al., 2003; Somda et al., 2014).

The uncontrolled process, based on the know-how of small producers, without application of a quality management system or understanding of the concept of good manufacturing practice (GMP) and plan hygiene (PH), together with the non-compliant sale practices of the product, lead to doubts in terms of hygienic and sanitary qualities of *soumbala* (Cheyns and Bricas, 2003; Ouoba, 2017). The characterization of microbial diversity of *soumbala,* have shown *Bacillus subtilis* as dominant bacteria (Oguntoyinbo et al., 2010; Ouoba, 2017). It is important to note that rudimentary equipment is used, the spontaneous fermentation process and the sale practices are potential sources for the development of spoilage and/or foodborne pathogenic bacteria such as *Bacillus cereus, Listeria monocytogenes*, *Staphylococcus aureus*, etc. responsible for the highest risk of foodborne diseases (Somda et al., 2014; Glover et al., 2018).

Therefore, it is important to evaluate the sanitary risks associated with processors' practices in the production and sale of *soumbala* to inform those involved about corrective measures to be applied for improvement of safety of *soumbala* respecting the standard production norms and consumers' needs (Cheyns and Bricas, 2003; Millogo, 2008; Ouoba, 2017). The methods used to carry out this study were used of a participatory risk analysis process associated with the practices of the actors and evaluating risks for the contamination of *soumbala* along the food chain. The exploitation of different practices of the producers-sellers can make it possible to meet the requirement for safety of *soumbala* produced in Burkina Faso, which led to the following questions: What are the quality and safety risky in the practices of the actors from the production to sale of *soumbala*? What are consumers' opinions on the hygiene and sanitary qualities of the *soumbala* sold in Burkina Faso?

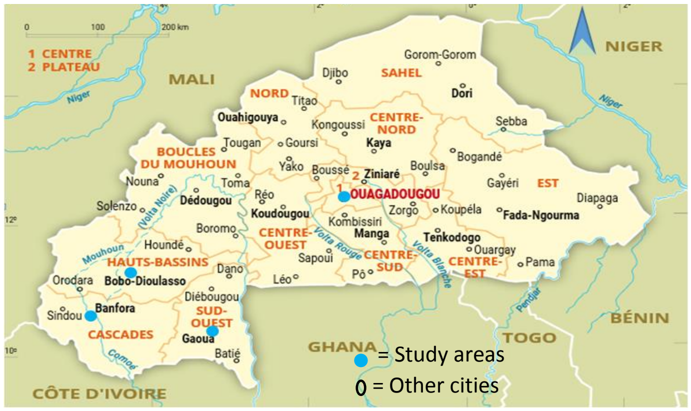

Figure. 1. Location of study areas
(Source: https://www.universalis.fr/atlas/afrique/burkina-faso/#AT003203).

Consequently, this study aimed to update information on the technology practices' of *soumbala* production, the consumers' opinion on its quality and the risk factors associated with it along the food chain.

MATERIALS AND METHODS

Literature research

A literature search was conducted to better understand what has been studied both on the theoretical and practical aspects of *soumbala* production and consumption.

Study areas and period

This study was conducted from March to June 2017 in the cities of four regions of Burkina Faso: Banfora (10°24'26.2"N; 4°33'44.7"W) in *Cascades* region, Bobo-Dioulasso (11°79'27" N; 4°12'11.90"W) in *Hauts-Bassins* region, Gaoua (10°19'50"N; 3°10'46"W) in *Sud-Ouest* region and Ouagadougou (12°22'44"N; -1°29'52"W) in *Centre* region. The studied areas are shown in Figure 1 (colored in Blue circles). These cities have been chosen based on their cosmopolitan character, the large production volume of *soumbala* in these regions and the income generated for local population, the interest given to the current consumption of *soumbala* in various diets linked to the high density of their population (particularly in Ouagadougou and Bobo-Dioulasso) and the socio-cultural diversity influencing the diet of people.

Investigation

A pre-investigation was used to test the questionnaires with *soumbala* actors (producer-sellers and consumers) speaking different local dialects. This made it possible to adapt the questionnaire to the sociological realities. The questionnaires were given individually to the producer-sellers and consumers. A total of 160 persons, chosen randomly were investigated, this included 80 producer-sellers and 80 consumers (20 per city and category). The information requested in the questionnaires serving as a guide to score the sociodemographic status of the respondents, to describe the technological aspects of *soumbala* production, consumer's assessment of quality, and health risks linked to their different practices.

Statistical analysis

Sphinx Millennium V4.5 software (Le sphinx Développement 7450 Chavanod, France) was used for survey data processing and a Chi^2 test was used for analysis of variance at a significance threshold of $p<0.05$.

RESULTS

Overview of the socio-economic importance of *soumbala,* a non-wood product derived from exploitation of *P. Biglobosa* seeds in Burkina Faso

A Non Wood Forest Product (NWFP) can be defined as welfare and services, others than work woods, resulting from renewable forest resources such as forest, wooded lands and outside forest trees (Lamien and Bamba, 2008). It exploitation allowed the populations to support their essential needs (Foods, health, construction, handicraft and socio-cultural) and served as economical source for local communities. NWFPs constituted the third place after agriculture and breeding as sources of income and they represented 23% of the global income for the population in Burkina Faso (Sama and Koukou-Tchamba, 2010). NWFPs employed 10% of the labor force, 80% of households are involved and contributed around 10% of the Gross Domestic Product (PIB) and represented around 10% of the country total experts. It contributed about 16 to 27% in the income of women in *Sud-Ouest* region (Ministère de l'Environnement et du Cadre de Vie (MECV), 2010).

Three regions harbor the majority of Burkina Faso's NWFPs, particularly the production of *P. biglobosa* seeds. These regions are the *Cascades*, *Haut-basins,* and *Sud-Ouest,* which are recognized as centers of the production of African locust bean seeds (Cheyns and Bricas, 2003; Sama and Koukou-Tchamba, 2010). According to the annual statistics report (Agence de Promotion des Produits Forestiers Non Ligneux (APFNL), 2013) elaborated in 2012, around 214 tons of *P. biglobosa* seeds and 48 tons of *soumbala* have been commercialized in Burkina Faso, generating incomes of 6.14 and 7.20 billon FCFA (Currency coins of the Central African CFA franc), respectively. The income generated from *soumbala* constitutes a major component of the gross income of those involved (Millogo, 2008).

The increasing demand of consumers for natural, local and safe foods seasonings have promoted further development of artisanal production of *soumbala.* To be able to meet this need, the DTA/IRSAT/CNRST has developed a semi-modern technology ALTECH for industrialization of *soumbala* production process (Millogo, 2008). It is presumed that valorization and promotion of *soumbala* would be contributed to food security and sustainable development (Millogo, 2008) with poverty alleviation to the local population in Burkina Faso (Millogo, 2008; Ouoba, 2017; Somda et al., 2014).

Socio-cultural characteristics of producer-sellers and consumers of *soumbala*

Table 1 presents the socio-cultural characteristics of the participated population which constituted 20% men and 80% women. The results from the investigations showed that the production and sale of *soumbala* are done by women (100%). The producer-sellers were regrouped in four age groups: the first group constituted of 3.75% of the respondents younger than 25 years, the second group contained 2.50% and are those from 26 to 30 years, the third group comprised 8.75% of the respondents and are 31 to 35 years while the last group included 85.5 % of the respondents and are held than 35 years with high significant difference (Chi^2=187.30, P=0.0001).

The educational background had the following distribution: 68.80% of producers-sellers were illiterates, 2.50% have received local language training, 22.5% went to primary school, and 6.30% had secondary level education with high significant difference (Chi^2=88.90, P<0.0001). Consumers were composed of 46.30% men and 53.80% women, and for the four age groups: the first group held 25.50% of the respondents, the second groups represented 17.5%, and the third group formed 12.65%, while the last group included 45.00% of the respondents. The difference in distribution of age of respondent's population is very significant (Chi^2= 62.75, P<0.0001). Total of 25.00% of consumers were illiterates, 8.80% received local language training, 1.30% have Franco-Arab instruction, 32.5% went to primary school, 16.30% have secondary level education and 16.30% have university education with high significant difference (Chi^2= 29.80, P<0.0001).

The surveyed population included 14 socio-ethnic groups. The main participants were *Mossi* composed of 32.5% producer-saleswomen and 23.8% of consumers, and *Lobi* constituted 17.5% producer-saleswomen and 26.3% of consumers with a high significance (Chi^2= 95.14, P<0.0001). In terms of religion, the surveyed population was formed of 43.70% Muslim, 41.25% Christian and 15.0% Animist.

Socio-economic characteristics of the actors in *soumbala* production-sale

The production of *soumbala* is dominated by women (Table 2). These actors are found in the peri-urban and urban zones and produced *soumbala* individually (100%) in their homes. The producers attested to know the full flow diagram of the *soumbala* processing and 77.60% had more than 10 years' experience. They buy the African locust bean seeds from collectors-sellers (100%) but sometime some are self-suppliers of seeds (5%). They produced *soumbala* all the seasons for socio-cultural (42.5%) and/or economic (97.5%) reasons with high significance (Chi^2=17.29, P=0.0002).

The processors are wholesalers (73.80%) and/or retailers (98.80%) of *soumbala* in local market places (100%) and at their home place (60%). They reported being able to sale the totality (80%) or the half (32%) of their product per week at the unitary prize of 25 F CFA/*soumbala* ball. The majority of producer-sellers (91.5%) reported profitability of their activity, and the income generated used to maintain their economic activity and various household costs (100%).

Practices in the production of *soumbala*

Production technique of soumbala and its distribution chain

In Burkina, *soumbala* is mainly produced by traditional technology. The main steps of traditional process for *soumbala* production are summarized in Figure 2, and in Table 2 it is shown that this technique is still the main process used by processors (100%) in the survey study areas. The *soumbala* is made manually in a familial place (Kitchen) involving a restricted workforce of 1-3 workers (91.3%) or 4-6 persons (7.5%) able to transform 10 (3.8%), 20 (25%) or 30 kg (72.5%) of seeds per month with high significant difference (Chi^2 =58.74, P<0.0001). Aluminum pot (100%) or canaries (17.5%) are used for woods-boiling of seeds during almost 24 h with addition of potassium (alkaline ash) (17.5%) to allow the softening of seeds. The softened seeds are then pounded in mortar

Table 1. Sociocultural characteristics of respondents on the *soumbala* production-sale and consumption.

Variable		Producer-sellers		Consumers		Total	
		N(80)	F (%)	N(80)	F (%)	N(160)	F (%)
Sex	Female	80	100	43	53.8	123	76.87
	male	-	-	37	46.30	37	23.12
Ages (years)	≤25	3	3.75	20	25.00	23	14.37
	26-30	2	2.50	14	17.50	16	10.00
	31-35	7	8.75	10	12.50	17	10.62
	>35	68	85.00	36	45.00	104	65.00
Instruction level	Illiterate	55	68.8	20	25.0	75	46.87
	Local	2	2.50	7	8.80	9	5.62
	Franco-arab	-	-	1	1.30	1	0.62
	Primary	18	22.50	26	32.50	44	27.50
	Secondary	5	6.30	13	16.30	18	11.25
	University	-	-	13	16.30	13	8.12
Ethnic groups	*Bambara*	1	1.30	-	-	1	0.62
	Bissa	-	-	2	2.50	2	1.25
	Birifor	7	8.80	1	1.30	8	5.00
	Bobo/Dioula	7	8.80	10	12.50	17	10.62
	Bwaba	1	1.30	-	-	1	0.62
	Dagara	3	3.80	10	12.50	13	8.12
	Dafin	-	-	1	1.30	1	0.62
	Gouin	2	2.50	5	6.30	7	4.37
	Gouroussi	1	1.30	1	1.30	2	1.25
	Karaboro	-	-	2	2.50	2	1.25
	Lobi	14	17.50	21	26.30	35	21.87
	Mossi	26	32.50	19	23.80	45	28.12
	Samo	7	8.80	4	5.00	11	6.87
	Senoufo	7	8.80	2	2.50	9	5.62
	Toussian	1	1.30	-	-	1	0.62
	Turka	3	3.80	2	2.50	5	3.12
Religion	Animist	15	18.80	9	11.30	24	15.00
	Muslim	41	51.20	29	36.30	70	43.75
	Christian	24	30.00	42	52.50	66	41.25

N=Number, F= Frequency.

(100%) with addition of ash (58.8%) or sand (55%) to allow cotyledons dehulling. Then, the dehulled cotyledons are washed using faucet/tap water (60%), pipe borne water (37.5%), well water (21.3%) or stream/river course water (8.8%). After washing, the cotyledons are drained, sorted and parboiled twice for 1 to 3 h. The parboiled cotyledons are drained-cooled for 30 min in a pannier. For fermentation, the resulting cotyledons are spread onto plastic bag/tank (70.1%), in panniers (46.3%), canary (25%) or calabash (2.5%). Some producers spray millet floor (12.5%), salt powder (10.00%) onto cotyledons, and cover it with fresh leaves (8.8%). The product is then submitted to spontaneous fermentation for 2 to 3 days. The fermented condiment resultant is slightly sun-dried almost 8 h and directly rolled into balls (85%) or often ground and mounded in balls (30%). S*oumbala* balls are more sun-dried, unpacked and keep in pannier (63.7%), bowl (22.5%), and plastic bag (12.5%) or in canary (1.3%) for sale.

From production to sale, the *soumbala* followed different routes as shown in Figure 3: the direct route (1) from the producer-sellers to consumers and the indirect

Table 2. *Soumbala* production and sale.

Variable	Modalities and frequency (N)
Type of production	Artisanal (100%), Semi-industrial (0.00%)
Perfect mastering of processing	Yes (100%), No (0.00%)
Years of experience	≤2 (2.5%), 2-6 (13.8%), 6-10 (6.30%), ≥10 (77.60%)
Number of employees	1-3 (92.50%), 4-6 (7.5%)
Reasons of production	Economic (97.50%), Socio-cultural (42.50%)
Seeds supplier	Collectors (100%), Self-suppliers (5.00%)
Quantity of seeds transformed per month	5-10kg (3.80%), 10-20kg (25.0%), ≥20kg (72.50%),
Energy source	Wood (100%), Gas (0.00%)
Materials of processing	Aluminum pot (100%), Canary (17.50%), Mortar et pestle (100%), Bowl, Pannier and sieve (100%)
Fermentation process	Spontaneous (100%), Controlled (0.00%)
Materials of fermentation	Plastic bag (72.50%), Pannier (43.60%), Calabash (2.50%), Canary (25.00%), Fresh leaves (8.80%)
Quantity of *soumbala* produced per month	≤ 5kg (2.50%), 5-10kg (23.80%), 10-15kg (73.80%)
Type of sale	Wholesale (73.8%), Retail (98.80%)
Quantity sold per week	Totality (80.00%), Half of production (40.00%)
Sale price	25 FCFA/unit (100%), 50 FCF/3balls (8.75%)
Does the activity profitable?	Yes (91.30%), No (8.80%)
Income rate (%)	≤ 12 (7.50%), 14-16 (8.80%), 20-22 (21.30%); ≥ 22 (62.50%)
Usage of income generated	Management of activity (100%), Household cost (70.00%), Personal needs (30.00%)
Your expectation to improve the quality of *soumbala*	Training on GMP and Plan Hygiene (PH), and technical advises (87.5%), Modernization of the production (30.00%), Promotion and valorization of product (87.5%), Creation of partnership (20.00%)

route (2) from producer-wholesalers to purchaser-resellers or supermarkets who supply the consumers. A third circuit (3) existed between parents or related close persons, who sometime supply *soumbala* as a gift to consumers. The importance of the different routes depended on the quantity of *soumbala* produced and the actors involved.

Consumer’s assessment on the condition of *soumbala* production and sale

Table 3 shows the consumer’s assessment of the condition of *soumbala* production and sale. Respondents consumed *soumbala* daily (88.80%) or every two days (11.30%) in various dishes with high significant difference (Chi^2 = 111.47, p<0.0001) in consumption frequencies. The dominant ethnic group consumers were *Lobi* (26.30%) and *Mossi* (23.80%) with high significant difference (Chi^2 = 208.75, p<0.0001). Women were the main group of consumers with high significant difference (Ch^2 = 49.56, p<0.003). The whole cotyledons balls were the most consumed form of *soumbala* (92.50%) with highly significant difference (Chi^2 = 103.23, p<0.0001). The reasons given were multiple and varied from one to another consumer (Table 3). The major part of consumers (65.00%) know the origin of *soumbala*, and the main supply sources were producers’ sites (60.00%) and/or the markets/streets (67.50%) with high significant difference (Chi^2 =93.50, p<0.0001). Consumers (100%) had good appreciation of *soumbala and* its taste varied from one consumer to another as shown in Table 3 with high significant difference (Chi^2 = 95.06, p<0.0001). The criterion of choice both of seller and *soumbala* varied from one consumer to another (Table 3) and the main reasons given were the search of good food enhancer and their health enhancement (95.00%). The price of sale of condiment was judged acceptable by half consumers (50.00%) with high significant difference (Chi^2 = 62.189, p<0.0001). However, some consumers (32.00%) doubted the safety and quality of *soumbala* sold, even though it met the expectations of majority (98.00%).

All consumers found that the production of *soumbala* is artisanal, and their expectation for improvement of quality of *soumbala* varied from one to another (Table 3). Only 8.80% of consumers know the existence of semi-modern technology, whereas 72.50% of all consumers think that this technology could help to improve production of

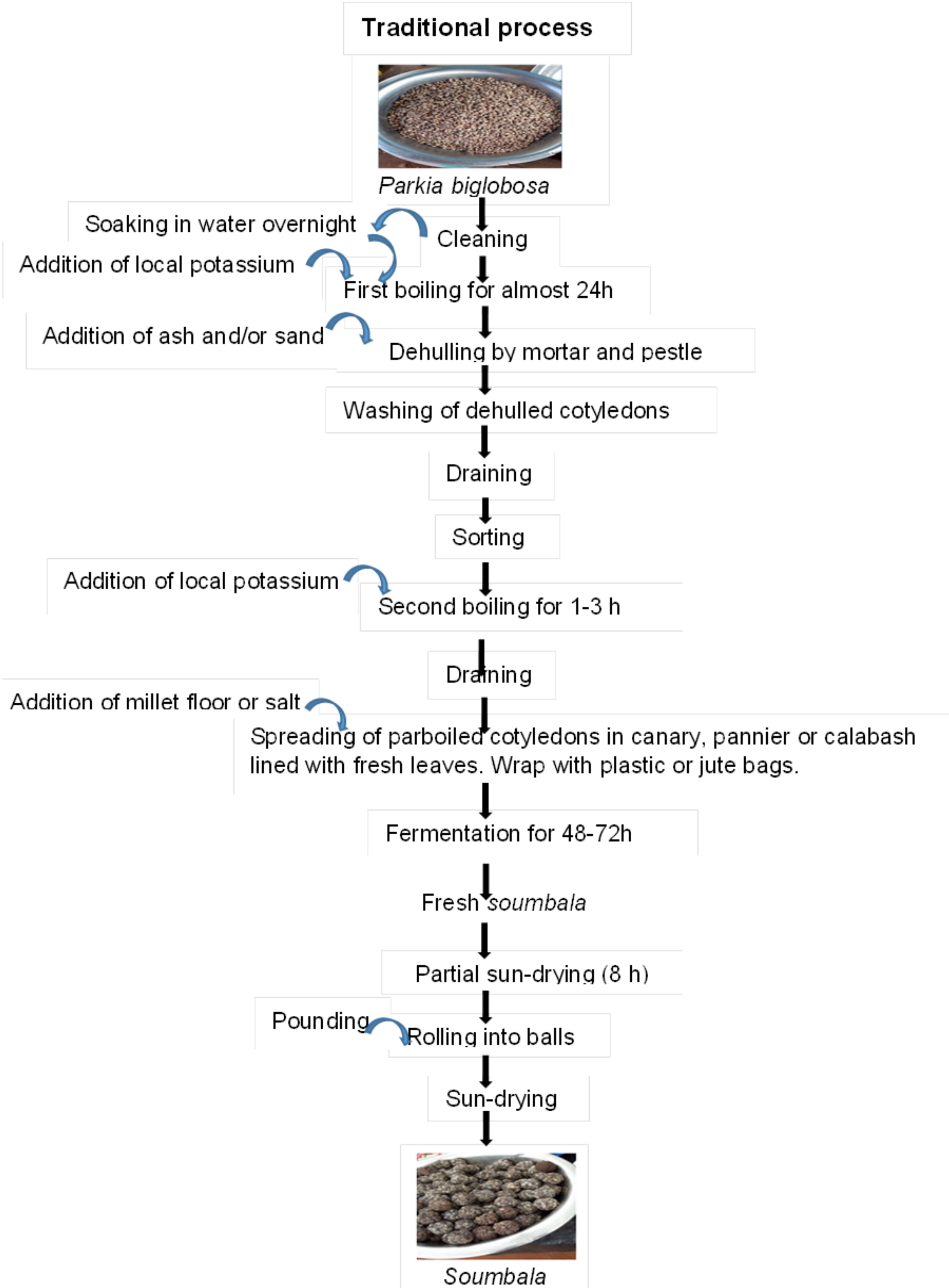

Figure 2. Flow diagram of traditional *soumbala* production in Burkina Faso.
↓ = Main steps ↷ = Secondary actions in the process. Adapted from Ouoba (2017)

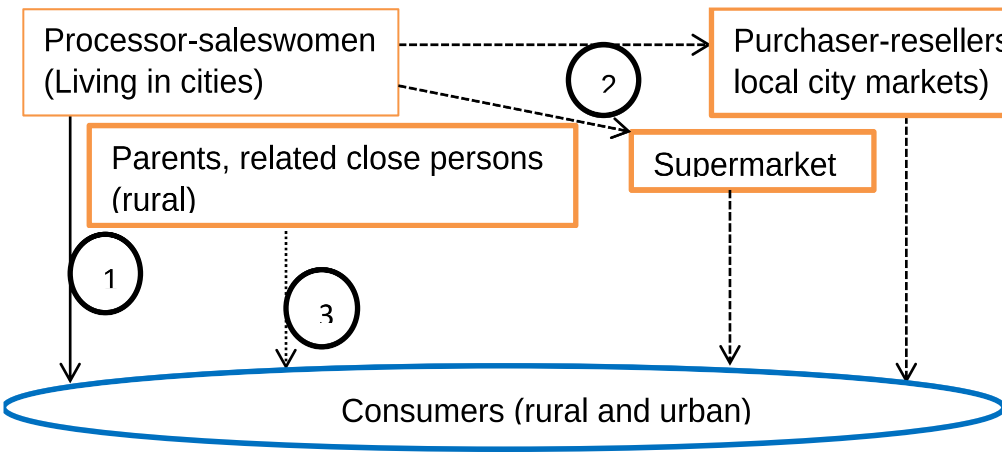

Figure 3. Marketing distribution of the *soumbala* in Burkina Faso.

Table 3. Consumption and assessment of traditional *soumbala* sale.

Variable	Modalities and frequencies
Consumption of *Soumbala*	Yes (100%), No (0.00%)
	Daily (88.80%), Every two days (11.30%)
Types of meals of *soumbala* usage	Gravy (97.5%), Soup (93.8%), Fry rice (96.3%), Chicken (76.30%).
Reasons of consumption	Availability (23.80%), Natural food enhancer and nutritional value (88.80%), Therapeutic virtues (77.50%), Cultural identity (30.00%).
Types of therapeutic virtues of *soumbala*	Arterial tension regulator (70.10%), Prevention and treatment of diabetes (20.60%), Fight against malnutrition at children (7.20%), Virility stimulator (2.10%).
Source of supply	Producer-sellers (60.00%), Market/streets (67.50%), Shop (6.3%), Self-production (12.5%), Gift (8.80%)
Your criterion choice of seller	Hygiene quality (93.80%), Taste of soumbala (78.80%), Cost of product (35.00%), No-one (2.50%)
Your criterion choice of good *soumbala*	Natural with good organoleptic and hygienic qualities (92.50%), Odor attracting flies (2.5%), No-one (5.00%)
Reasons of criterion choice	Food enhancer and health preservation (95.00%), Presence of flies attest good product (1.70%), No-one (3.30%)
Type of *soumbala* bought	Powdered balls (7.50%), Whole seeds balls (92.50%)
Sale price	25FCFA/ball (91.25%), 50FCFa/3balls (8.75%)
Appreciation of sale price	Cost (48.80%), Accessible (56.30%)
State at slight of eye	Clean (45.00%), Acceptable (51.50%), Dirty (3.80%)
Taste of *soumbala* bought	Sweet (96.30%), Bitter (13.80%), Salted (10.00%)
Does *soumbala* contain suspect elements?	Yes (70.00%), No (30.00%)
Types suspect elements	Dust (15.00%), Sand (70.00%), Vegetal and or plastic Debris (25.00%), Insect (8.80%)
Does *soumbala* meet you expectations?	Yes (98.00%), No (2.00%)
What is your perception of the technology of *soumbala* production?	Artisanal (100%), Modern (0.00%)
What are your expectations for the improvement of *soumbala* quality?	Respect of GMP and PH (52.30%), Usage of homologated packing (28.50%), Support and guide the Small and Mean Enterprises for normalized production (19.20%)
Do you know any semi-modern technology of production of *soumbala*?	Yes (8.80%), No (91.20%)
Your opinion on modernization of *soumbala* production	Normalization of product (72.50%), No idea (27.50%)

Figure 4. Safety quality of fermentation process, sun-drying and sale of *soumbala.* a=fermentation of *soumbala* in canary in Kitchen, b= Open sun drying of *soumbala*, c and d = Sale of *soumbala* with other condiments in market places.

soumbala.

Sanitary risk along the food chain

Sanitary risk of soumbala processing-sale

The artisanal processing of *soumbala* and its sale practices in the local markets (Figure 4) are associated with some sanitary risks that often make the product questionable for health and safety for the consumers. The place of processing and the sale environment was considered as some of the main risks of *soumbala* contamination in addition to the practices of processor-sellers (Table 4). *Soumbala* processors produced their condiments at home and interference with domestic activities and animals were observed.

The processing of African locust bean seeds involved a restricted workforce of 1 to 3 persons (91.3%) without any training on good manufacturing practices and hygiene rules. The seeds processing (boiling, dehulling and washing) are mainly done in an open area and fermentation took place in the kitchen of the houses. Certain processors used alkaline ash (potassium) (17.50%) for seeds softening during the first boiling, ash (58.80%) and/or sand (55.00%) to allow cotyledons dehulling during the seeds peeling in mortar, with high significant difference (Chi^2 = 65.46, p=0.0001). The water used for processing is from various sources: faucet/tap (60%), pipe borne (37.50%), well (21.30%) and stream/river course (8.80%), and stored in canary (local pot), metal drums or plastics bowls with high significant difference (Chi^2 = 36.90, p≤0.0001). It was clean (67.30%), however, some processors (21.30%) have reported to vary the type of water used. Aluminum pots (100%) or canaries (17.50%) were the main cooking equipment, while fermentation was conducted in plastic bag/jute (72.50%), in panniers (46.30%), in canary (25.00%) or in calabashes (2.50%) with high significant difference (Chi^2 = 79.18, p<0.0001). These fermentation equipment were found dirty (43.8%) with high significant difference (Chi^2 = 38.50, p≤0.0001).

For the spontaneous fermentation process (Figure 4a), some producers spray millet floor (12.5%), table salt (10.10%) onto cotyledons, and cover it with fresh leaves (12.50%) with high significant difference (Chi^2 = 96.27, p<0.0001). The obtained *soumbala* is either hand-rolled directly into balls (97.50%) or ground and hand-moulded in balls (13.80%) and then sun-dried on an open floor place (92.50%) or on a table (8.50%). The *soumbala* balls were sun dried more (Figure 4b) during 2 days (70.00%) or 3 days (30.00%) with high significant

Table 4. Sanitary risks along processing to sale of *soumbala.*

State	Variable		Modality and frequency (N)
Processing and sales environment	Place of processing		Free area (30.50%), House (69.50%)
			Clean (6.30%), Acceptable (72.50%), Dirty (21.3%)
	Presence of :		Dust: Yes (21.30%), No (78.8%)
			Puddles: Yes (20.00%), No (80.0%)
			Stray animals, Insects and poultry: Yes (22.50%), No (77.50%)
	State the point of sale		Clean (3.80%), Acceptable (65.00%) Dirty (31.30%)
Seeds processing	Components used		Potassium (17.50%), Ash (58.80%), Sand (55.00%), Nothing (21.30%)
Fermentation Process	Appreciation of materials		Clean (1.30%), Acceptable (55.00%), Dirty (43.3%)
	Components added	Millet floors	Yes (12.50%), No (87.50%)
		Salt	Yes (10.00%), No (90.00%)
Operation after fermentation	First open sun-drying		Yes (100%), No (0.00%)
	Addition of salt		Yes (10.10%), No (89.89%)
	Hand-moulding		Whole seeds balls (97.50%), Pounded balls (16.3%)
	Second open sun-drying		Yes (100%), No (0.00%)
	Place of drying		Floor areas (92.5%), Table (8.50%)
	Packing		Yes (0.00%), No (100%)
	Material of conservation		Canary (1.30%), Pannier (63.70%), Bowl (22.50%), Plastic bag (12, 50%)
Hygiene	Training on GMP and PH		Yes (0.00%), No (100%)
	Quality control document		Yes (0.00%), No (100%)
	Quality controller		Yes (0.00%), No (100%)
	Special work dress		Yes (5.00%), No (95.00%)
	State of dress		Clean (100%), Dirty (0.00%)
	Cleaning of the material		Yes (100%), No (0.00%)
	Origin of the water		Faucet (60.00%), Pipe borne (37.50%), well (21.30%), River course (8.80%).
	State at of eye		Clean (63.70%), Acceptable (27.50%), Dirty (8.80%)
	Variation of type of water		Yes (21.30%), No (78.80%)
Often production of bad quality *soumbala*?			Yes (20.0%), No (80.00%)
Do you Know food contamination pathway?			Yes (23.80%), No (76.30%)
Knowledge of GMP and hygienic rules			Yes (32.50%), No (67.50%)
Sale places			Local Market (100%), Home (60%)
Packing used for sale			Ordinary paper (5.00%), Plastic sachet (73.80%), No packaging (26.30%)

difference (Chi^2 = 12.80, p=0.0001). Then, it was unpackaged (100%) and conserved either in pannier (63.70%), bowl (22.50%), plastic bag (12.50%) or canary (1.30%) with high significant difference (Chi^2 = 65.46, p≤0.0001). Some processors (20.00%) attested to often produced bad quality *soumbala* with high significant difference (Chi^2 = 28.80, p≤0.0001).

The producers sold their unpacked *soumbala* at home (60%) or in the open area market places (100%) (Figure 4c and d) with significant difference (Chi^2 = 8.00, p=0.01). They used plastic sachets (73.8%), ordinary papers (5.00%) or nothing (26.30%) to sale *soumbala* with high significant difference (Chi^2 = 56.64, p≤0.0001). The presence of dust (21.30%), puddles (20.00%), stray animals, insects and poultry (22.50%) was observed from some producers' sites and places of sale.

For the sanitation level, 21.30 and 31.30% of processors had dirty places of processing and sale, respectively. Places of sale were found dirtier than the places of processing based on hygienic conditions. In terms of hygiene, no producer-sellers had a quality monitoring manual and quality control process in place. Only, 23.80% attested to know food contamination pathway and 32.50% have knowledge of GMP and PH.
5.00% of the producer-sellers used special clean work dress that was found clean (100%). All processors (100%) attested to regularly washing their production equipment.

Sanitary risk analysis from consumers

The sanitary risks linked to consumers' practices are

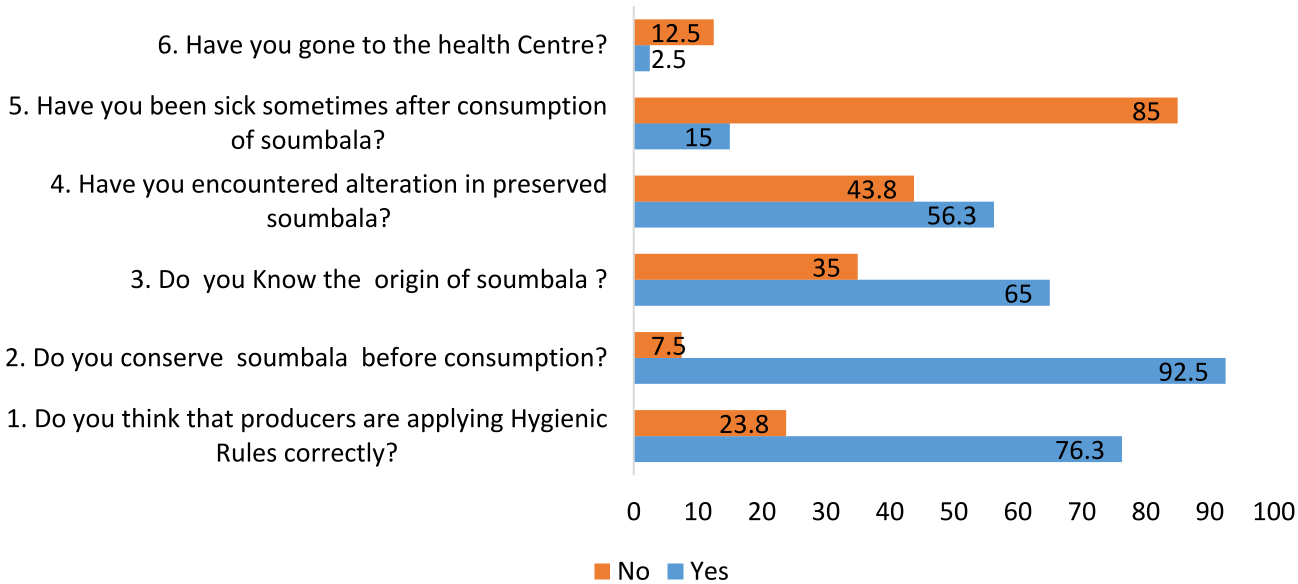

Figure 5. Practices of consumer's.

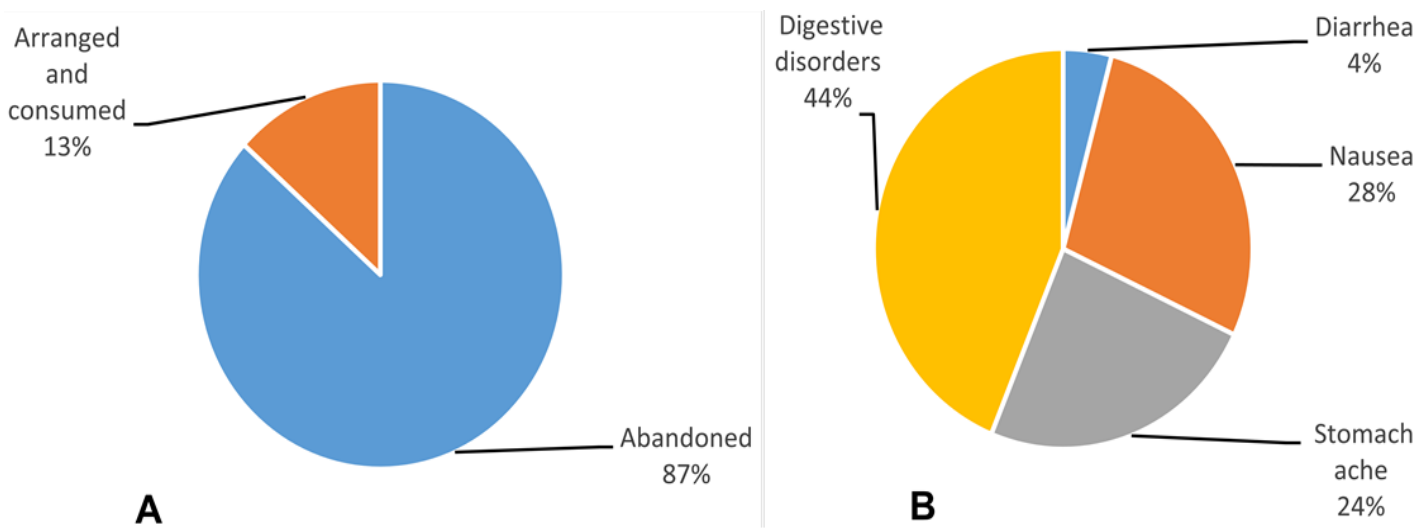

Figure 6. Management of spoiled soumbala (A) and clinical signs manifested by consumer (B).

summarized in Figures 5 to 7. As shown in Figure 5, 76.30% of consumers attested that producers applied GMP and PH, 35.00% did not know the origin of *soumbala*, and 7.50% conserved the bought condiment for almost 1 month before use. More than half (56.30%) reported to encounter some impurities in the product bought with a significant difference (Chi^2 = 12.80, $p<0.0003$). Some cases of sickness were reported by 15.00% of consumers after consumption of *soumbala* dishes with a significant difference (Chi^2=10.25, $p<0.03$). However, only 2.5% of them went to health centre.

In a case of visible alteration (Figure 6A), *soumbala* was not consumed (87%) or arranged for consumption (13%). Clinical signs are shown in Figure 6B. Only 2.5% of concerned people went to health centre.

The perception of state of sales environment and opinion on *soumbala* quality differed from one locality to another and from one consumer to another (Figure 7) with a significant difference (Chi^2 = 30.92, $p<0.0001$). To buy *soumbala*, consumers used indirect qualification

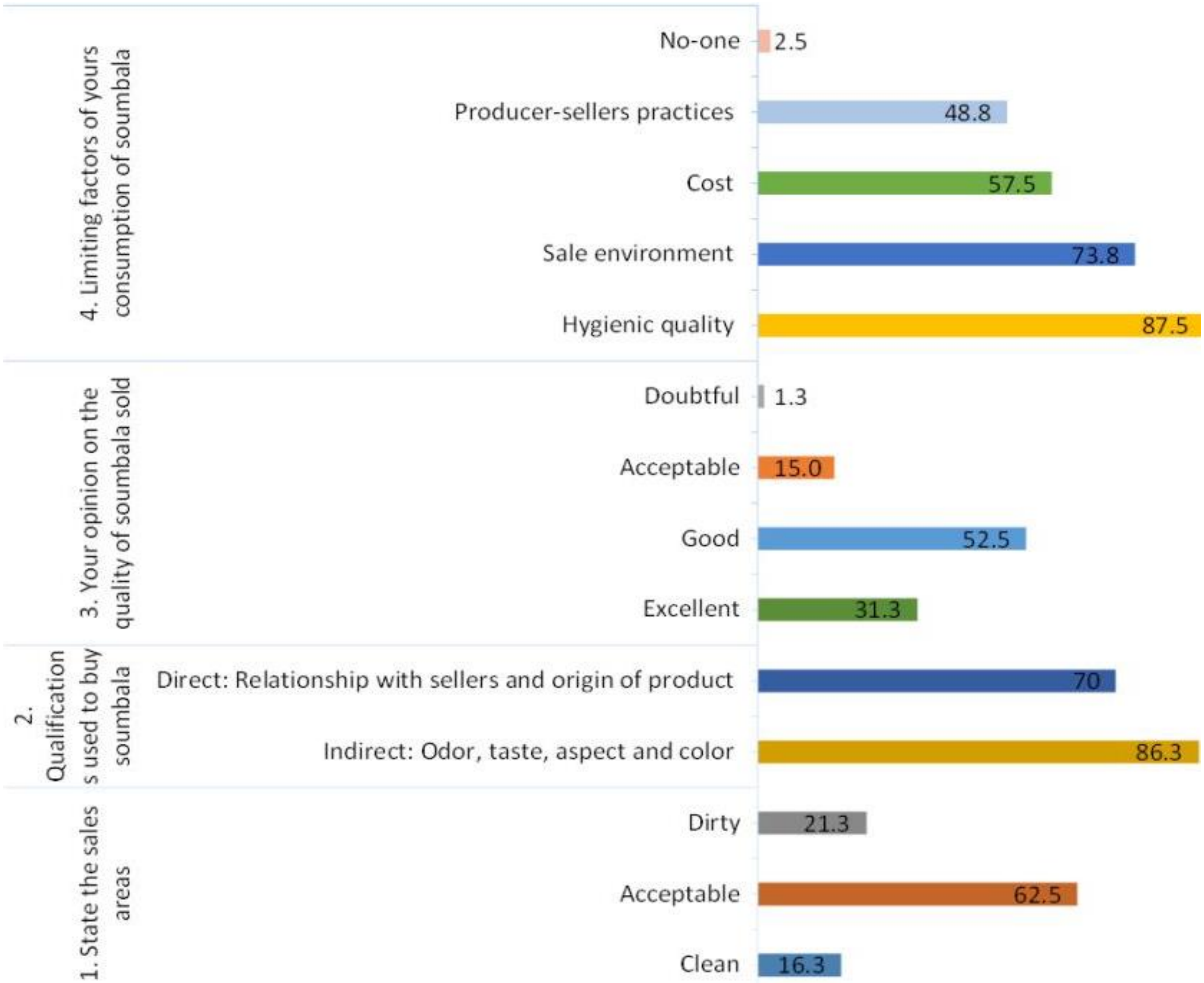

Figure 7. Sales environment (**1**), Criteria used to buy *soumbala* (**2**), Opinion of consumers (**3**), and limiting factors to consumption of *soumbala* (**4**).

(86.3%) based on its taste, odor, color, appearance, and/or direct qualification (70.0%) based on confident relationship with producer-seller. The hygienic quality is one of the major factors that could limit *soumbala* consumption as suggested by the majority of consumers (87.5%) in Figure 7 with a significant difference (Chi^2 = 62.29, p< 0.03).

DISCUSSION

Soumbala is an alkaline condiment of West Africa, very prized by the local populations. It is used in cooking of various dishes, preferentially in the preparation of sauces of rice, soups, *couscous*, *Poulet au soumbala*, *riz gras au soumbala*, and other dishes basis of cereals in Burkina Faso (Somda et al., 2014). It is a rich source of essential nutrient and vitamins that contributed to enhance food taste and flavor and to fight against malnutrition (Ouoba, 2017). *Soumbala* contributed to food diversification and security and nutritional balance and to improve health of consumers. Its production served as economic source for rural household women (Millogo, 2008; APFNL, 2013).

The study of sociocultural characteristics of the respondents showed that they are constituted of men and women of different age's groups. The majority have limited level of education. The main actors in the *soumbala* sector are women, with *Mossi* (28.12%) and *Lobi* (21.87%) as the dominant ethnic groups (Table 1). *Mossi* is the dominant ethnic group in Burkina Faso and was found before (Cheyns and Bricas, 2003) to be one of the main ethnical groups responsible for *soumbala* production and current consumption (Somda et al., 2014).

The traditional process used by local producers for *soumbala* production was originally based on know-how of elderly women who transfer their empirical knowledge from generation to generation within the family. Thereby, the young girls learned with their mothers or close related persons since the processing of *soumbala* is perceived as an important culinary art and identity typical to each ethnic group and transfers to the more confident person of the family. However, today, with the growing demand of *soumbala* often linked to poverty and the need of for income, non-experienced young women in the urban areas with less training and indigenous culinary art knowledge produce *soumbala* that is often rejected by some consumers because of their low quality and unsafe (Cheyns and Bricas, 2003).

The results of investigations showed that the hygienic status quality and safety of *soumbala* are very doubtful based on various practices of producers-sellers. The majority of processors are illiterate (68.80%) and exert their activity in poor hygienic conditions. These producers have limited knowledge of GMP and Plan Hygiene (PH) and produced *soumbala* of doubtful quality and safety. They collect *P. biglobosa* seeds on tree or market and process the seeds in their homes in non-adequate hygienic conditions. The physical conditions and infrastructure in the sites of *soumbala* production are generally poor. Their artisanal processing of *soumbala,* using rudimentary equipment and spontaneous fermentation, led to a final product with varying quality from one ethnic group to another and one region to another (Millogo, 2008). Practices such as use of ash and/or sand for seed dehulling, spreading of millet floor onto cotyledons and covering with fresh leaves (12.5%) for spontaneous fermentation in simple equipment such as plastic bags or panniers are some of the main points of lack of GMP and hygiene affecting the quality of condiment. Additionally, hand-moulding, use of an open area for sun drying and the lack of wrapper even though some sellers affirm to use plastic sachets for sale as well as unsuitable sale conditions, increase the non-compliant hygienic status of *soumbala*. Of course, the equipment and preparations of fermented condiments still lack safety and quality controls while packaging and presentations are traditional. The various practices in many of the steps are critical points with high risk and source for microbial contamination during production and sale of *soumbala.* Indeed, the condiment is stored and sale in inappropriate conditions and exposed to the effects of moisture, dust, and temperature as well as to microbial and insect attack. There is no subsequent step to eliminate possible pathogenic microorganisms that could be led to health risks for the consumers. Overall, the final product proposed to the consumers is sometimes of poor hygienic quality (Somda et al., 2014).

Following the above information, due to its increasing demand with the context of urbanization, DTA/IRSAT/CNRST has designed a semi-modern technology called ALTECH to standardize the production of *soumbala* (Cheyns and Bricas, 2003; Millogo, 2008). This technology is using mixed-starter cultures of *Bacillus subtilis* strains to obtain the original organoleptic characteristics of artisanal *soumbala* consumed by the consumers of different ethnic background as cultural identity specific to each dialect and locality. Unfortunately, this technology no longer produced *soumbala* due to the seasonal availability of raw material and equipment cost and unavailability to the rural low incomes producers (Millogo, 2008). Hence, the traditional process remained the main technology. Today, the stakeholders who are mostly illiterates need training session in GMP and PH to improve the technology and quality of their products to satisfy the needs of consumers especially the urban consumers.

The marketing distribution circuit of *soumbala* is entirely driven by women composed of producers-sellers. This activity is well known as women's job since processed vegetable foods are commonly sold in markets and streets by producers-saleswomen. Similar findings have been reported in previous studies on the traditionally processed *soumbala* sold in Burkina Faso (Cheyns and Bricas, 2003; Millogo, 2008; Ouoba, 2017). Indeed, *soumbala* marketing played an important socio-economic role since the incomes generated maintain their activities and to manage household spending. Thus, women used a part of their income to buy food, pay family bills, pay schools fees etc. (Millogo, 2008) and so the generated incomes represented an important part in the economy of rural women and poverty alleviation in Burkina Faso (MECV, 2010; Somda et al., 2014).

In term of consumption, 88.8% of the respondents consumed *soumbala* on a daily basis for and every second day for the others (11.3%) mainly during family meals. Women are the major group of consumers and they are also the main actors in processing and sale of *soumbala*. This food seasoning is used to enhance the flavor and taste of various dishes as others similar local fermented food condiments such as *bikalga* (Parkouda et al., 2008) and *Maari* (Kaboré et al., 2012). There are many reasons given by consumers for *soumbala* consumption such as food taste enhancer, increase nutritional value, therapeutic virtue, cultural identity and improvement of man virility. Similar reports have been given (Cheyns and Bricas, 2003; Millogo, 2008). Indeed, *soumbala* is found to be rich in essential nutrients and some vitamins (Ouoba, 2017) and served as a low-cost meat for poor people. Its consumption is believed to help to fight against malnutrition of children, to regulate arterial tension preventing cardiovascular illness, to prevent and/or to fight against diabetes.

However, the practices in use make the consumption of *soumbala* a major sanitary risk. The criteria used by consumers to buy *soumbala* based on indirect qualifications and/or direct qualifications are non-standard. Indeed, despite the use of these criteria to purchase good quality of *soumbala,* incertitude appeared in the quality of this traditional condiment, since a non-negligible number of consumers reported to often find impurities such as sand, plastic or vegetable debris, dust, insect in *soumbala*. Unfortunately, some of them (15.00%) still used altered *soumbala*. Consequently, cases of illness such as digestive trouble, nausea, stomach aches, and diarrhea have been reported by consumers after consumption of *soumbala* dishes (Figure 6). However, only a few numbers visited a health centre in case of illness.

Therefore, the nutritional and socio-economic valorization and the promotion of *soumbala* based on norms of hygiene and quality required structural reorganization of economic actors in groups/associations, cooperatives, unions and finally federation (APFNL, 2013). These economic interest group (EIG) can benefit from training on the GMP and hygienic rules for the production of safe and higher quality *soumbala.* Thus, they can be obtained for their product a quality norm from Directorate for Standardization and Quality Promotion (FASONORM), a certificate on the sanitary quality from Food Technology Direction (DTA) of IRSAT or National Laboratory of Public Health (NLPH). Moreover, the national federation could benefit from appropriation of license and protected label trade from the African Organization of Intellectual Property (AOIP) for the promotion of *soumbala* at international level.

Conclusion

This study was designed to evaluate safety and quality linked to the different practices applied during the production and sale of local *soumbala* in Burkina Faso. Results obtained in this study revealed that the sanitary risk associated to these practices for the consumers challenge, all actors in the production/distribution/ consumption of *soumbala* to enable a healthy diet, as well as educate and raise awareness of good hygiene practices and sanitation to protect the health of consumers. There is an essential need to set up training programs on sanitary condition for traditional producers-sellers to allow them to incorporate good manufacturing practices and plant hygiene to ensure production of more safe and higher quality *soumbala* with desired organoleptic characteristics and nutritional quality meeting the ever-growing demand and needs of urban and other consumers. The nutritional quality and therapeutic values of *soumbala* and the source of income generated for the producers, indicated the necessity to adopt and spread the mastered technology ALTECH of DTA/IRSAT. This novel technology should be available at low-cost to rural producers for the best valorization and promotion of marketable *soumbala* production and poverty alleviation. Reorganization of actors is required in provincial and regional cooperatives. The authorities should create mechanisms for quality and hygienic control to adhere these norms, and it should be obligatory. Finally, if the government intensifies actions in favor of *soumbala* actors; some of the goals can be accomplished in the near future: The adoption of the modern ALTECH technology for all association producers, adoption of quality norms for *soumbala* producers by the provincial and regional unions and improve trustworthiness of the consumers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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