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Assessment of the microbiological quality of soybean skewers sold in the city of Ouagadougou and the antibiotic resistance of *Escherichia coli* and *Staphylococcus aureus* isolates

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Abstract

Introduction: Soy skewers have been part of the Burkinabe diet for several years. The objective of this study is to contribute to the food safety of soy skewers sold in the city of Ouagadougou.

Methods: A total of 72 samples, including 36 of tofu and 36 of ready-to-eat soy skewers, were collected from producers/sellers in the 12 districts of the city of Ouagadougou for microbiological analysis using standardized methods. The analyses focused on counting the total mesophilic aerobic flora, yeasts and molds, total and thermotolerant coliforms, *Escherichia coli* and *Staphylococcus aureus*. *Escherichia coli* and *Staphylococcus aureus* were isolated for antibiotic resistance testing.

Results: According to current microbiological criteria, 19.45 % of soy skewer samples were of satisfactory quality, 8.33 % were of acceptable quality, and 72.22 % were of unsatisfactory quality. For the tofu samples, 5.56 % were of satisfactory quality, 8.33 % were of acceptable quality, and 86.11 % were of unsatisfactory quality. Pathogens such as *E. coli* and *S. aureus* isolated from tofu and soy skewers showed resistance to certain antibiotics.

Conclusion: In view of the results, which show a significant number of samples that do not comply with standards, training for stakeholders on good hygiene practices and the processing of tofu and soy skewers is necessary to minimize the risk of food poisoning.

Keywords: Soy Skewers; Tofu; Microbiological Quality; Antibiogram; Ouagadougou

1. Introduction

Soy (*Glycine max*) products are highly nutritious foods containing protein, carbohydrates, lipids, bioactive compounds, vitamins B, phosphorus, potassium, calcium, magnesium, zinc, and iron [1, 2, 3]. Among soy-based products are soy skewers, which are prepared from tofu. Tofu is a gelatinous food of Chinese origin obtained by coagulating soy milk. Thanks to its health benefits, particularly its high protein and nutrient content, it has become very popular around the world [4]. The tofu is cut into appropriate shapes, fried in hot oil for 5 to 10 minutes, seasoned with spices, and then simmered or grilled [5] to make soy skewers. These skewers are sold in the streets and markets and are popular at

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ceremonies. Food sold on the streets of our cities is a major public health problem due to the multiplicity and diversity of the microbial flora it carries [6]**.** Indeed, the risk of foodborne illness is high when consuming certain street foods due to the questionable quality of raw materials, poor environment, inadequate infrastructure, preparation conditions, and insufficient personal hygiene of those handling the food [7, 8, 9]**.** In Ouagadougou, soy-based products especially tofu and soy skewers are mainly produced on a small scale, mostly by women who have not received training in agri-food production and who are often unaware of Good Hygiene Practices and Good Manufacturing Practices (GHP/GMP) during processing and preservation**.**

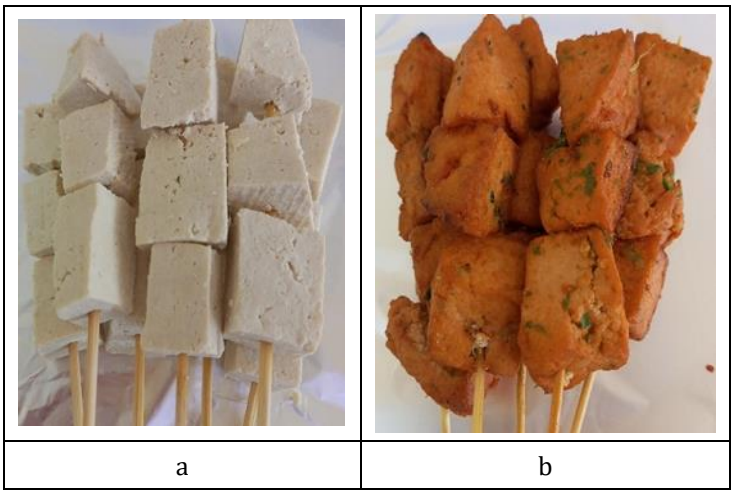
To our knowledge, there are few studies on soy skewers. However, some studies, such as that by Solefack *et al.* [5] in Cameroon have focused on identifying critical points in the manufacture of soy skewers from soybeans, and that by Ezenwa *et al.* [10] in Nigeria on evaluating the nutritional and sensory characteristics of tofu prepared using different cooking methods. However, numerous studies have been conducted on tofu around the world. Some of these studies have focused on the nutritional characteristics of tofu, its microbiological quality and commercialization [5, 1, 11, 12, 13]**,** improving the shelf life of tofu [14, 15, 16, 17], the identification of microorganisms in tofu [4, 18]**,** and the use of waste from tofu production for animal feed [19]. These studies revealed that, from a microbiological standpoint, a large majority of tofu and soy skewer samples did not comply with current standards. A high level of microbial diversity was also found in the samples, which could promote the exchange of genetic material and lead to the acquisition of antibiotic resistance genes by certain pathogens [20, 21]. In addition, studies conducted in Burkina Faso on coated meat skewers and grilled mutton have also found high microbial loads with the presence of certain pathogens that may be responsible for food poisoning [22, 23]. In view of these results and the usual conditions under which soy skewers are processed and sold, it is necessary to investigate the hygienic quality of soy skewers sold in the city of Ouagadougou. The purpose of this study is therefore to contribute to the safety of soy skewers in the city of Ouagadougou by improving knowledge about their microbiological quality.

2. Material and Methods

2.1. Material

The biological material consisted of:

- Tofu or soy cheese (Figure 1. a), which is obtained from soy milk curdled by adding an acid solution or magnesium sulfate;
- Soy skewers (Figure 1. b), which are obtained from seasoned fried and grilled tofu;
- Reference strains of *Escherichia coli* ATCC 51813 and *Staphylococcus aureus* ATCC25923 used as positive controls.



a b

Figure 1 Samples of tofu and soy skewers: a. Tofu, b. Soy skewers

2.2. Methods

2.2.1. Site and sampling

The study was conducted in the 12 districts of the city of Ouagadougou from February to July 2022. One neighborhood per district was selected as a study site (Table 1). At each study site, three visits were made to sample tofu and soy skewers produced by independent producers. A total of 72 samples were taken under normal sales conditions, packaged in sterile freezer bags, and labeled. The samples were transported to the laboratory in a cooler containing ice. Once at the laboratory, the analyses were carried out within 24 hours. Table I shows the sampling sites and sample codes.

Table 1 Sampling site and sample code

Districts	Sectors	Neighborhoods	Sample codes of tofu	Sample code of skewers
1	4	Kamsonghin	A1-T	A1-SS
2	8	Larlé	A2-T	A2-SS
3	16	Tampouy	A3-T	A3-SS
4	18	Somgandé	A4-T	A4-SS
5	24	Kalghondé	A5-T	A5-SS
6	26	Cissi	A6-T	A6-SS
7	30	Nagrin	A7-T	A7-SS
8	36	Bissigin	A8-T	A8-SS
9	37	Marcouci	A9-T	A9-SS
10	45	Tabtenga	A10-T	A10-SS
11	50	Karpala	A11-T	A11-SS
12	52	Goose foot	A12-T	A12-SS

A1-T to A12-T: Tofu from district 1 to tofu from district 12; A1-SS to A12-SS: Soy skewer from district 1 to soy skewer from district 12.

2.2.2. Enumeration of total mesophilic aerobic flora

The total mesophilic aerobic flora (TMAF) count was performed on Plate Count Agar (Liofilchem, Italy) after incubation at 30 °C for 72 hours in accordance with International Standard Organisation standard [24].

2.2.3. Enumeration of yeasts and molds

The international standard [25] was used for the enumeration of yeasts and molds. Seeding was performed in chloramphenicol Sabouraud agar (Liofilchem, Italy) and the plates were incubated at 25 °C in a Memmert oven for 5 to 7 days before colony counting.

2.2.4. Enumeration of total and thermotolerant coliforms

The international standards [26] and [27] standards were used for counting total and thermotolerant coliforms, respectively. Seeding was performed on Violet Red Bile Lactose medium (Liofilchem, Italy). The plates were incubated at 37 °C for total coliforms and at 44 °C for thermotolerant coliforms in incubators [Binder, Germany] for 24 hours.

2.2.5. Enumeration of Staphylococcus aureus

Mannitol Salt Agar medium (Oxoid, United Kingdom) was used to count staphylococci. The seeds were sown in bulk and the boxes were incubated in a Binder (German) incubator at 37 °C for 48 hours. After incubation, suspicious golden yellow colonies were counted. A coagulase test was performed to identify coagulase-positive staphylococci.

2.2.6. Enumeration of Escherichia coli

E. coli counting was performed in accordance with standard [28] **.** The inoculation was carried out in agar medium TBX (Liofilchem, Italy), followed by incubation at 44°C for 24 hours. After incubation, the bleu green colonies were counted and then isolated.

2.3. Antibiogram test

The isolates confirmed as *S. aureus* and *E. coli* following biochemical testing were inoculated for the antibiogram. The antibiogram was performed using the diffusion method on agar medium according to [29]**.**

The antibiogram test was performed on *S. aureus* and *E. coli* isolates following the emergence of antibiotic resistance. The choice of antibiotics to be tested was based on the bacteria identified and their possible use in the host.
For each isolate, a bacterial suspension was prepared from a 24-hour culture, homogenized, and standardized to 0.5 MacFarland. This suspension was seeded on the surface of Mueller-Hinton medium (Liofilchem, Italy) within 15 minutes of inoculum preparation. The plates were left to dry for 5 minutes on the bench before the discs were placed on them. The antibiotic discs were placed on the MH medium using sterile bacteriological forceps, pressing lightly on each disc and maintaining a distance of 1.5 cm between each disc and the wall of the Petri dish and 3 cm between two discs. The dishes were then incubated at 37 °C for 24 hours in aerobic conditions. After incubation, the results were read by measuring the inhibition diameters. The sensitivity profile of each bacterium to the antibiotics tested was determined by referring to a reading table showing the correlation between the inhibition diameter and the minimum inhibitory concentration (MIC), which allowed the bacteria to be classified as sensitive, intermediate, or resistant [30]**.**

2.4. Statistical analysis of data

The microbiological results were compared to standards and the different proportions were calculated using Excel 2016 software.

3. Results

3.1. Microbiological quality of skewered meat and soy tofu samples

Tables 2 and 3 show the microbial loads of the tofu samples and seasoned skewers, respectively. The microbiological load is expressed in CFU/g. The microbial loads of the tofu ranged from 2.3 x 10^5 to 1.2 x 10^{14} CFU/g for TMAF, from less than 10 to 1.9 x 10^6 CFU/g for yeasts and molds, from less than 10 to 2.3 x 10^6 CFU/g for total coliforms, from less than 10 to 1.6 x 10^6 CFU/g for thermotolerant coliforms, from less than 10 to 1.5 x 10^5 CFU/g for *E. coli* and less than 10 to 1.8 x 10^3 CFU/g for *S. aureus* (Table 2). According to the microbiological criteria, 5.56 % of the tofu samples were of satisfactory quality, 8.33 % were of acceptable quality, and 86.11 % were of unsatisfactory quality. The microbial loads of soy skewers ranged from 6.4 x10^3 to 5.0 x10^9 CFU/g for TMAF, from less than 10 to 1.4 x10^5 CFU/g for yeasts and molds, and from less than 10 to 3.9 x 10^5 CFU/g for total coliforms, from less than 10 to 1.5 x 10^5 CFU/g for thermotolerant coliforms, from less than 10 to 5.2 x 10^4 CFU/g for *E. coli* and less than 10 to 1.9 x 10^1 CFU/g for *S. aureus* (Table 3). According to the applicable microbiological quality criteria, 19.45 % of the soy skewer samples were of satisfactory quality, 8.33 % were of acceptable quality, and 72.22 % were of unsatisfactory quality.

Table 2 Microbiological load of plain tofu samples expressed in CFU/g

Sampling week	Samples	TMAF (CFU/g)	YM (CFU/g)	TC (UFC/g)	TTC (CFU/g)	*E. coli* (CFU/g)	*S. aureus* (CFU/g)	OA
1	A1-T	3.7 x 10^8	5.0 x 10^3	1.5 x 10^5	1.4 x 10^5	< 10	< 10	NS
2	A1-T	2.9 x 10^8	3.6 x 10^3	9.6 x 10^5	7.2 x 10^5	< 10	< 10	NS
3	A1-T	1.2 x 10^{14}	3.7 x 10^3	7.4 x 10^4	8.6 x 10^4	< 10	< 10	NS
1	A2-T	1.3 x 10^9	5.4 x 10^2	1.3 x 10^3	1.2 x 10^3	< 10	< 10	NS
2	A2-T	8.1 x 10^8	< 10	2.6 x 10^4	9.6 x 10^3	< 10	6.8 x 10^1	NS
3	A2-T	1.4 x 10^8	6.27 x 10^3	4.36 x 10^5	3.82 x 10^5	< 10	< 10	NS
1	A3-T	8.1 x 10^8	7.0 x 10^2	1.40 x 10^5	2.6 x 10^5	< 10	8.2 x 10^1	NS

2	A3-T	1.2×10^9	2.7×10^2	5.2×10^5	3.7×10^5	< 10	< 10	NS
3	A3-T	7.2×10^8	2.4×10^3	1.6×10^5	1.6×10^6	< 10	< 10	NS
1	A4-T	2.7×10^6	3.1×10^2	3.6×10^3	1.8×10^3	5.1×10^2	< 10	NS
2	A4-T	3.6×10^9	2.7×10^2	3.2×10^3	2.7×10^3	1.4×10^3	5.3×10^2	NS
3	A4-T	6.1×10^7	5.9×10^3	1.8×10^6	1.2×10^6	1.5×10^5	< 10	NS
1	A5-T	1.9×10^8	1.3×10^5	3.8×10^5	2.7×10^5	< 10	< 10	NS
2	A5-T	3.6×10^8	4.0×10^3	9.8×10^3	1.5×10^4	< 10	< 10	NS
3	A5-T	9.1×10^8	1.5×10^4	5.4×10^1	5.4×10^4	< 10	< 10	NS
1	A6-T	3.6×10^8	1.8×10^4	1.3×10^5	7.6×10^4	< 10	< 10	NS
2	A6-T	7.1×10^8	1.9×10^6	1.3×10^5	1.5×10^6	< 10	< 10	NS
3	A6-T	6.0×10^8	5.5×10^2	1.5×10^6	9.6×10^4	< 10	< 10	NS
1	A7-T	3.2×10^8	1.2×10^4	1.3×10^5	1.3×10^4	< 10	< 10	NS
2	A7-T	6.5×10^8	1.3×10^6	2.6×10^4	1.2×10^6	< 10	< 10	NS
3	A7-T	3.5×10^6	2.8×10^3	1.1×10^5	2.8×10^4	< 10	< 10	A
1	A8-T	4.4×10^9	7.8×10^2	6.7×10^3	4.3×10^2	7.9×10^2	< 10	NS
2	A8-T	4.6×10^9	1.0×10^3	9.1×10^2	5.5×10^2	1.2×10^2	< 10	NS
3	A8-T	2.3×10^8	8.0×10^3	3.2×10^5	5.1×10^5	1.1×10^5	< 10	NS
1	A9-T	9.1×10^3	< 10	< 10	< 10	< 10	< 10	S
2	A9-T	1.9×10^9	1.1×10^3	1.5×10^4	1.8×10^4	< 10	< 10	NS
3	A9-T	6.6×10^8	< 10	3.8×10^4	1.5×10^4	< 10	< 10	NS
1	A10-T	2.0×10^6	4.3×10^2	2.1×10^3	2.6×10^3	< 10	< 10	A
2	A10-T	9.1×10^8	3.6×10^2	5.3×10^3	5.2×10^3	< 10	1.8×10^3	NS
3	A10-T	1.0×10^9	9.9×10^3	2.8×10^4	3.3×10^4	< 10	< 10	NS
1	A11-T	4.5×10^7	1.5×10^5	3.4×10^5	4.1×10^5	< 10	< 10	NS
2	A11-T	9.5×10^7	9.9×10^3	6.6×10^5	2.7×10^5	< 10	< 10	NS
3	A11-T	6.1×10^6	3.7×10^4	2.0×10^6	1.4×10^6	< 10	< 10	A
1	A12-T	2.3×10^5	< 10	1.8×10^1	1.8×10^2	< 10	< 10	S
2	A12-T	1.2×10^9	1.4×10^6	6.6×10^5	1.2×10^6	< 10	< 10	NS
3	A12-T	3.2×10^9	4.6×10^3	2.0×10^6	5.4×10^5	< 10	< 10	NS
Criteria*	< m	10^6	-	-	-	10	10^3	S
	> M	10^7	-	-	-	10^2	10^4	NS
Quality (%)	S	5.56				83.33	97.22	5.56
	A	11.11	-	-	-	0	2.78	8.33
	NS	83.33				16.67	0	86.11

A1-T to A12-T: Tofu from district 1 to tofu from district 12; S: Satisfactory, NS**:** Non-satisfactory, A: Acceptable; OA: Overall assessment; TMAF: Total mesophilic aerobic flora; YM: Yeasts and molds; TC: Total coliforms; TTC: Thermotolerant coliforms; *: [31].

Table 3 Microbiological load of seasoned kebab samples

Sampling week	Samples	TMAF (CFU/g)	YM (UFC/g)	TC (UFC/g)	TTC (CFU/g)	*E. coli* (CFU/g)	*S. aureus* (CFU/g)	OA
1	A1-SS	1.4×10^7	1.1×10^3	8.6×10^2	5.5×10^2	< 10	< 10	NS
2	A1-SS	1.1×10^7	4.5×10^1	3.4×10^2	2.6×10^2	< 10	< 10	NS
3	A1-SS	3.0×10^7	5.5×10^3	6.8×10^4	6.5×10^4	< 10	< 10	NS
1	A2-SS	8.5×10^7	< 10	4.5×10^3	1.1×10^2	5.2×10^4	< 10	NS
2	A2-SS	3.6×10^7	3.5×10^2	4.6×10^2	5.1×10^2	1.5×10^3	< 10	NS
3	A2-SS	1.4×10^8	2.3×10^2	3.3×10^4	7.5×10^4	4.8×10^4	< 10	NS
1	A3-SS	5.6×10^7	2.7×10^1	6.7×10^2	4.8×10^2	< 10	< 10	NS
2	A3-SS	1.1×10^8	2.7×10^3	1.3×10^3	< 10	< 10	< 10	NS
3	A3-SS	3.0×10^8	2.7×10^3	2.1×10^4	1.7×10^4	< 10	< 10	NS
1	A4-SS	6.4×10^3	1.6×10^2	< 10	< 10	< 10	< 10	S
2	A4-SS	1.9×10^4	1.8×10^1	< 10	< 10	< 10	< 10	S
3	A4-SS	9.2×10^5	3.5×10^2	1.4×10^2	2.7×10^1	< 10	< 10	A
1	A5-SS	6.2×10^4	3.3×10^3	< 10	< 10	< 10	< 10	S
2	A5-SS	4.5×10^6	5.5×10^1	1.1×10^2	8.2×10^1	< 10	< 10	NS
3	A5-SS	5.6×10^8	1.1×10^4	4.5×10^1	5.5×10^1	< 10	< 10	NS
1	A6-SS	3.5×10^7	3.6×10^1	7.3×10^1	1.8×10^1	< 10	< 10	NS
2	A6-SS	1.7×10^6	9.6×10^3	3.5×10^3	4.7×10^2	< 10	< 10	NS
3	A6-SS	6.0×10^7	1.5×10^2	4.9×10^3	1.8×10^3	< 10	< 10	NS
1	A7-SS	3.3×10^7	< 10	< 10	< 10	< 10	< 10	NS
2	A7-SS	2.1×10^7	4.5×10^3	4.2×10^3	1.9×10^4	< 10	< 10	NS
3	A7-SS	3.6×10^7	1.2×10^2	1.0×10^4	1.2×10^4	< 10	< 10	NS
1	A8-SS	1.3×10^8	9.1×10^0	< 10	2.7×10^1	< 10	< 10	NS
2	A8-SS	1.3×10^6	4.5×10^1	< 10	3.6×10^1	< 10	< 10	NS
3	A8-SS	5.0×10^9	7.5×10^3	1.5×10^5	1.5×10^5	5.2×10^4	9.1×10^1	NS
1	A9-SS	2.7×10^8	4.5×10^2	3.9×10^5	8.3×10^3	< 10	< 10	NS
2	A9-SS	3.6×10^8	1.0×10^2	9.1×10^1	1.8×10^1	< 10	< 10	NS
3	A9-SS	7.3×10^6	9.1×10^0	2.1×10^2	9.1×10^0	< 10	< 10	NS
1	A10-SS	1.8×10^7	1.4×10^5	1.0×10^3	6.9×10^2	< 10	< 10	NS
2	A10-SS	5.9×10^7	1.2×10^2	< 10	4.5×10^2	< 10	< 10	NS
3	A10-SS	4.2×10^4	< 10	< 10	< 10	< 10	< 10	S
1	A11-SS	8.5×10^4	< 10	3.6×10^1	9.1×10^0	< 10	< 10	S
2	A11-SS	9.1×10^3	< 10	< 10	< 10	< 10	< 10	S
3	A11-SS	8.3×10^5	< 10	< 10	< 10	< 10	< 10	A
1	A12-SS	3.5×10^6	3.1×10^3	1.0×10^4	1.2×10^4	< 10	< 10	NS

2	A12-SS	1.5×10^4	< 10	< 10	< 10	< 10	< 10	S
3	A12-SS	1.1×10^5	9.1×10^1	2.1×10^2	5.5×10^1	< 10	< 10	A
Criteria°	< m	10^5	10^4	10^3	10^3	10	10^3	S
	> M	10^6	3×10^4	3×10^3	3×10^3	1×10^2	10^4	NS
Quality (%)	S	19.45	94.44	66.67	75.00	88.89	100	19.45
	A	8.33	2.78	2.78	2.78	0	0	8.33
	NS	72.22	2.78	30.55	22.22	11.11	0	72.22

A1-SS to A12-SS: Soy skewer from district 1 to soy skewer from district 12; **S:** Satisfactory, **NS:** Non-satisfactory, A: Acceptable; OA: Overall assessment; TMAF: Total mesophilic aerobic flora; YM: Yeasts and molds; TC: Total coliforms; TTC: Thermotolerant coliforms, °: [31,33].

3.2. Antibiogram results for isolated strains

A total of 8 isolates of *S. aureus* and 6 isolates of *E. coli* tested positive in biochemical confirmation tests. The antibiotic resistance of these isolates was tested and the results are presented in Figures 2 and 3. Figure 2 shows resistance in *S. aureus* isolates, with varying proportions depending on the antibiotic families considered. In fact, resistance (Figure 4) of all isolates (100 %) was observed to Aztreonam, Ceftazidime, and Co-trimoxazole. Seventy-five percent of isolates showed resistance to Amoxiclav and Amoxicillin, and 25 % showed resistance to Lycomycin. Only 12.50 % of isolates showed resistance to Chloramphenicol, Erythromycin, Norfloxacin, and Vancomycin. However, all isolates were sensitive to Clindamycin and Tobramycin. Figure 3 shows that all *E. coli* isolates (100 %) showed resistance to Aztreonam, Ceftazidime, Lycomycin, Erythromycin, Co-trimoxazole, Amoxicillin, and Clindamycin. Sixty-six point sixty-six percent (66.66 %) and 33,34 % of isolates showed resistance to chloramphenicol and tobramycin, respectively. Furthermore, no resistance was observed to norfloxacin.

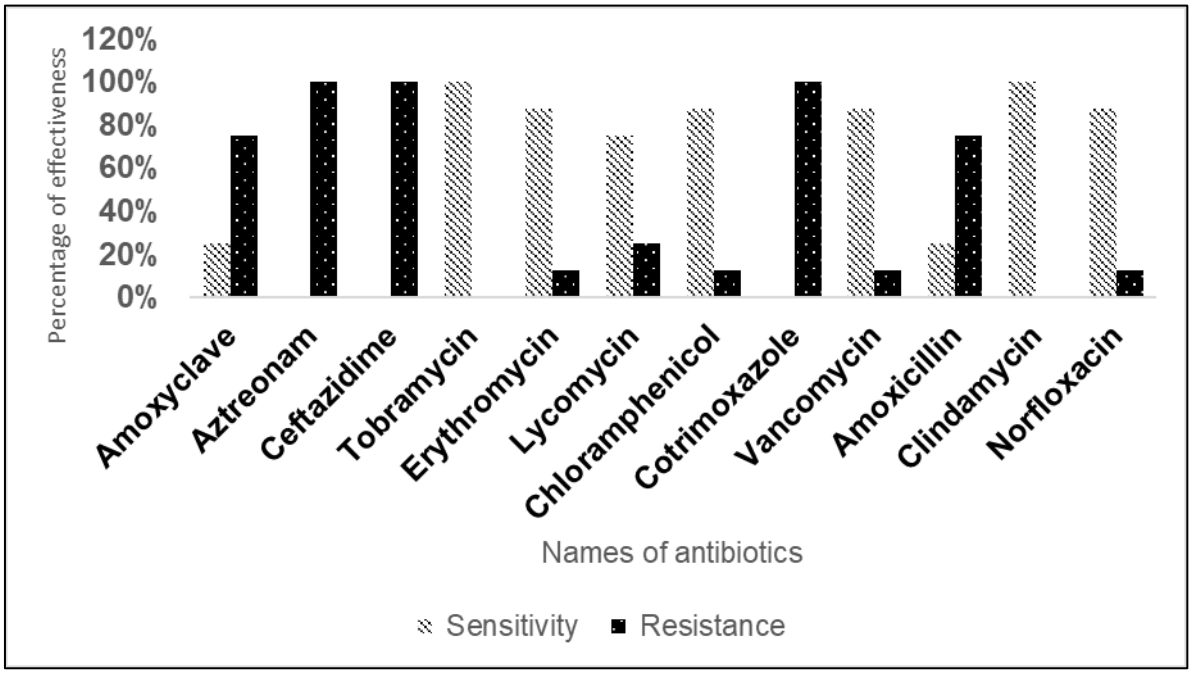
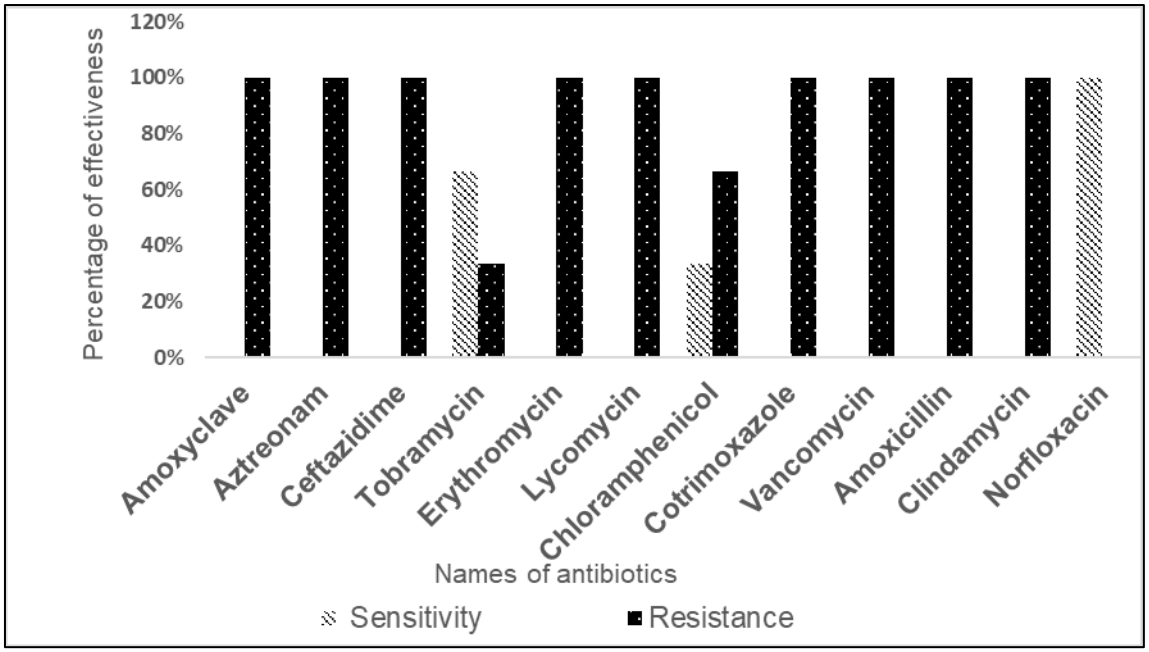


Figure 2 Efficacy of antibiotics tested on *S. aureus* strains isolated from tofu and seasoned soy skewers



. Figure 3 Efficacy of antibiotics on *E. coli* strains isolated from plain and seasoned soy skewers**.**

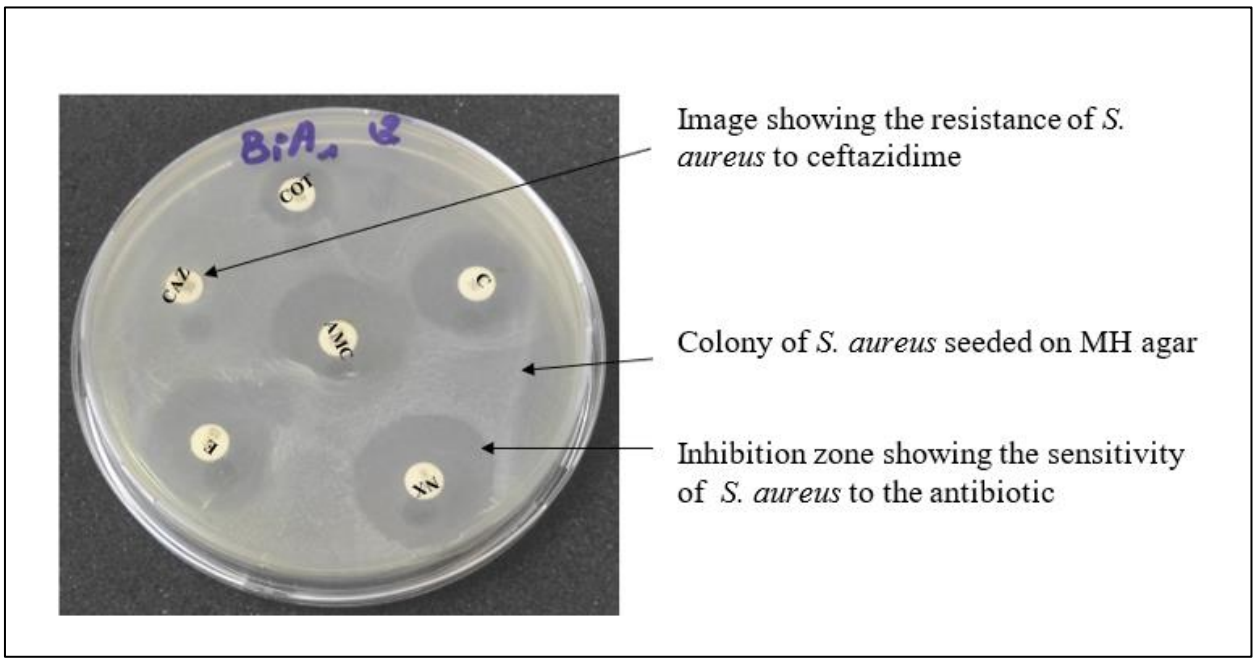


Figure 4 Antibiogram of *S. aureus* against six antibiotics tested

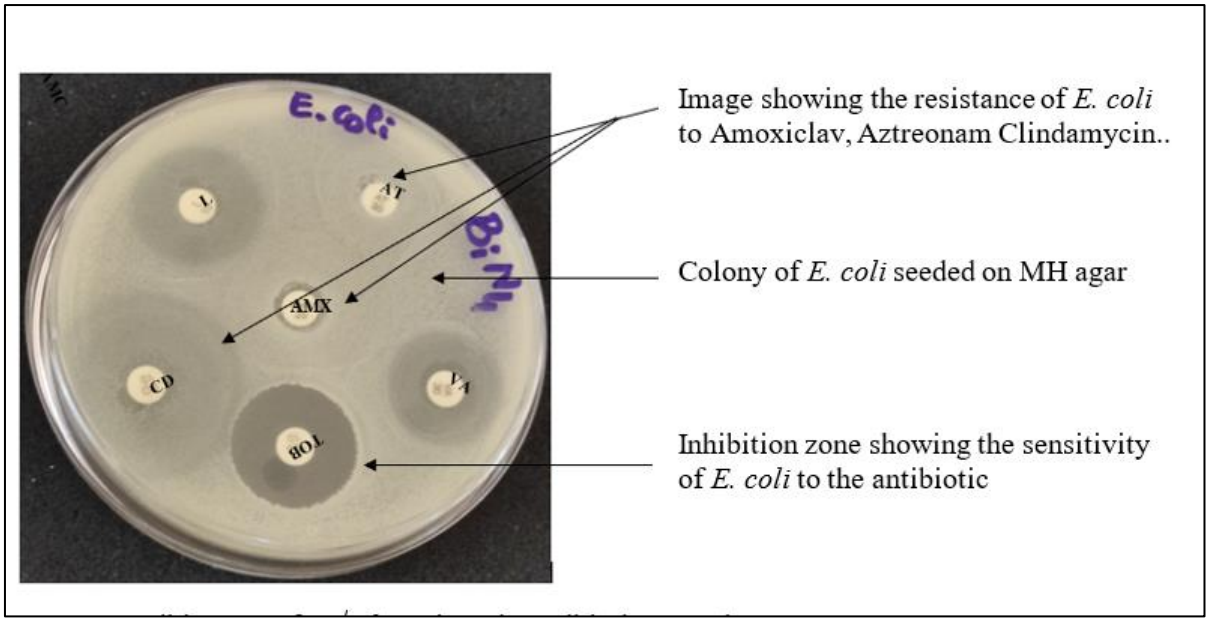


Figure 5 Antibiogram of *E. coli* against six antibiotics tested

4. Discussion

The analyses reveal that, overall, up to 86.11 % of the tofu used to make soy skewers was of unsatisfactory quality according to the microbiological quality criteria applicable to tofu in Quebec [31]**.** These results are similar to the 86% of non-compliant samples obtained by Solefack *et al.* [5] in Cameroon when analyzing samples taken at different stages of tofu and soy skewer production. This high rate of non-compliant tofu samples could be due to insufficient application of good hygiene and manufacturing practices for tofu. These results could also be related to the storage time of the tofu. Indeed, Riyad *et al.* [17] observed a significant increase in the number of germs in tofu from 6.0 x 10^1 to 1.1 x 10^{10} CFU/g when stored at 4°C for 6 days. Soy skewers obtained by seasoning and cooking tofu also had a high rate (72.22 %) of samples of unsatisfactory quality. This result could be due to the presence of spores from spore-forming bacteria that could not be destroyed by cooking. Studies have reported the presence of spore-forming bacteria such as *Bacillus subtilis and Bacillus cereus* in tofu [15, 13]**.** The consistently high microbial loads in soy skewers, and especially the presence of total and thermotolerant coliforms, could be due to recontamination of the soy skewers after cooking. This recontamination is often due to manual handling by vendors, packaging, and exposure to the open air, which promotes contact with dust and flies [5]**.** An analysis of the results by microbiological parameter shows that the majority of tofu and soy skewer samples were of unsatisfactory quality for FAMT. With microbial loads ranging from 2.3 x 10^5 to 1.2 x 10^{14} CFU/g, the majority of tofu samples analyzed had a higher FMAT load than those found by Solefack *et al.* [5] in Cameroon, Wang *et al.* [15] in China, and Ribeiro *et al.* [12] in Brazil in tofu samples with the highest loads of 7.79 log CFU/g, 2.40 log CFU/g, and 8.2 x 10^6 CFU/g, respectively. As for soy skewers, their TMAF load was still high in most samples (6.4.10^3 to 5.0 x 10^9 CFU/g). High levels of TMAF in soy skewers sold could indicate poor hygiene conditions during production, storage, transport, and even distribution [7].

Yeasts and molds, total coliforms, and thermotolerant coliforms were found in most samples of tofu and soy skewers. Many authors have also reported the presence of these germs in soy-based products [32, 5, 18]. According to the microbiological quality criteria applicable to cooked ready-to-eat foods in Quebec [31], 94.44 %, 66.67 %, and 75.00 % of the soy skewer samples were of satisfactory microbiological quality for these three parameters, respectively. For total coliforms and thermotolerant coliforms, the highest values were 3.9 × 10^5 CFU/g and 7.5.10^4 CFU/g respectively. Pathogenic germs such as *E. coli* and *S. aureus* were found in 16.67 % and 11.11 % of tofu samples, and in 11.11 % and 2.78 % of soy skewers, respectively. These rates are lower than the 50 % and 100 % found by Ribero *et al.* [12], 28 % *E. coli* and 26 %, 59 % *S. aureus* by Ananchaipattana *et al*. [13] and Solefack *et al.* [5]**.** With regard to *S. aureus*, only the load in one tofu sample was unsatisfactory. In the soy skewer samples, the *S. aureus* load varied between less than 10 and 9.1.10^1 CFU/g. According to Quebec's microbiological quality criteria [31], and [33]**,** all soy skewer samples were of satisfactory quality for *S. aureus*. The presence of *S. aureus* in some samples could be due to poor handling throughout the production chain up to the point of sale, related to staff hygiene. Studies have reported that food handlers are often healthy carriers of *S. aureus*, particularly on their hands and in their nasal cavities [34, 35, 36]. The low levels of *S. aureus* and *E. coli* in the samples should not obscure the health risk. Strains of *E. coli* with significant pathogenic potential have

been isolated from commercial soybean powder in Nigeria [32]**.** Certain serotypes of *E. coli* can cause a variety of health problems, ranging from mild gastrointestinal symptoms to serious, potentially fatal conditions [37, 38, 39]**.** In cases of *E. coli* or *S. aureus* infections, antibiotics are generally prescribed for treatment. However, the *E. coli* isolates showed resistance to the antibiotics tested except for Norfloxacin. The antibiogram also showed that the *S. aureus* isolates were resistant to a number of antibiotics. *E. coli* strains are well known for their natural resistance to many antibiotics. Many factors contribute to this increase in strain resistance, including the mobility of genetic elements among different species of the strain and the misuse of antibiotics [20, 21]**.** The use of certain antibiotics is becoming less effective than before, and emphasis should be placed on hygiene measures to limit the number of infections.

5. Conclusion

This study revealed that the soy and tofu skewers sold in various neighborhoods of the city of Ouagadougou were generally of unsatisfactory quality according to quality criteria. Only the results from two out of twelve sites were satisfactory. Given the high levels of certain bacteria, seasoned soy skewers could cause food poisoning. The antibiogram revealed that *S. aureus* was resistant to Aztreonam, Ceftazidime, Co-trimoxazole, Amoxiclav, and Amoxicillin. The *E. coli* strains were resistant to Aztreonam, Ceftazidime, Lycomycin, Erythromycin, Co-trimoxazole, Amoxicillin, and Clindamycin. The results of these antibiograms showed that both strains were sensitive to both Tobramycin and Norfloxacin. In light of the results showing a significant number of samples that do not comply with standards and contain antibiotic-resistant pathogenic bacteria, it is necessary to strengthen the capacities of the actors concerned in terms of good hygiene practices and the processing of tofu and soy skewers in order to minimize the risk of food poisoning linked to the consumption of these products.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors'.

Authors' Contributions

This work was carried out in collaboration among all authors. All authors contributed equally to the conception and design of this study. All authors read and approved the final manuscript.

References

[1] Anjum S, Agnihotri V, Rana S, Pandey A, Pande V. The Impact of Processing Methods and Conditions on Nutritional Properties of Soybean-Based Tofu: A Review. J Food Eng Technol. 2023 Jun 30;12(1):1–13.

[2] Chevalier D, Debeuf C, Joubrel G, Kocken M. Les aliments au soja : consommation en France , qualités. 2016;23(4).

[3] Hama-Ba F, Siedogo M, Ouedraogo M, Dao A, Dicko HM, Diawara B. Modalites de consommation et valeur nutritionnelle des legumineuses alimentaires Au Burkina Faso. African J Food, Agric Nutr Dev. 2017;17(4):12871–88.

[4] Matsui M, Tanino T, Ito M, Nomura C, Guionet A, Takahashi K, et al. Growth Properties and Sensitivities to Various Bactericidal Methods of Cold-Tolerant Microorganisms Isolated from Packed Tofu. Agronomy. 2022 Feb 1;12(2).

[5] Solefack EN, Tiencheu B, Zokou R, Tiwo CT, Kohole AHF, Teboukeu GB, et al. Microbiological Quality of commercial Soy Cheese (Tofu) Skewers and Determination of Critical Control Points during Production in the West Region of Cameroon. J Food Qual Hazards Control. 2024;11(1):26–38.

[6] Baba-Moussa L, Bokossa YI, Baba-Moussa F, Ahissou H, Adeoti Z, Yehouenou B, et al. Etude des possibilités de contamination des aliments de rues au Bénin: cas de la ville de Cotonou. Journal de la Recherche Scientifique de l'Univer. 2006;8(2014):149–56.

[7] Zhang X, Li Y, Sun J, Kan H, Wang Z, Xiang P. A preliminary study on the quality of street vended foods around a university in Kunming, China. Food Sci Nutr. 2020; 8(12):6670–9.

[8] Islam S, Nasrin N, Rizwan F, Nahar L, Bhowmik A, Ahmed M. Microbial Contamination of Street Vended. Southeast Asian J Trop Med Public Heal. 2015;46(3):480–5.

[9] Mepba HD, Achinewhu SC, Aso SN, Wachukwu CK. Microbiological quality of selected street foods in Port Harcourt, Nigeria. J Food Saf. 2007;27(2):208–18.

[10] Ezenwa HC, Anyika-elekeh JU, Iheme GO. Ezenwa Et Al, 2022 (Produksi Tahu). Niger J Nutr Sci. 43(1):5–12.

[11] Han IB, Cha SH, Park WH, Park SB, Bak SL, Jeong EW, et al. Quality and functional characteristics of tofu prepared rapidly from soybeans dried after soaking in water. J Food Process Preserv. 2022;46(2):1–13.

[12] Ribeiro TTBC, Costa G, da Costa M. Contaminação microbiana em tofu industrial. Cienc Rural. 2017;47(3).

[13] Ananchaipattana C, Hosotani Y, Kawasaki S, Pongswat S, Latiful BM, Isobe S, et al. Bacterial contamination of soybean curd (Tofu) sold in Thailand. Food Sci Technol Res. 2012;18(6):843–8.

[14] Du J, Zhang M, Qiu L, Mujumdar AS, Ma Y. Novel technologies for improving quality of tofu products and their packaging: A critical overview. Vol. 1, Food Safety and Health. John Wiley and Sons Inc; 2023. p. 41–59.

[15] Wang C, Zhou S, Du Q, Qin W, Wu D, Raheem D, et al. Shelf life prediction and food safety risk assessment of an innovative whole soybean curd based on predictive models. J Food Sci Technol. 2019 Sep 1;56(9):4233–41.

[16] Hamad A, Nurlaeli E, Pradani DY, Djalil AD, Hartanti D. Application of lemongrass as natural preservatives for tofu. J Teknol dan Ind Pangan. 2019 Dec;30(2):100–9.

[17] Riyad YM, Naeem MMM, Helmy MM, Sorour MA. Preparation Of Edible Coating Incorporated With Lemon Balm (Melissa Officinalis L.) For Extending Shelf Life Of Tofu. Int J Sci Technol Res. 2020;9(08):1–8.

[18] Rossi F, Felis GE, Martinelli A, Calcavecchia B, Torriani S. Microbiological characteristics of fresh tofu produced in small industrial scale and identification of specific spoiling microorganisms (SSO). LWT-Food Sci Technol. 2016 Jul 1;70:280–5.

[19] I Gusti Nyoman Gde Bidura, Eny Puspani, I Made Suasta. Quality improvement of Tofu waste as the raw material of duck feed with fermentation of yeast culture. GSC Biol Pharm Sci. 2024;29(2):086–91.

[20] Felgate H, Crossman LC, Gray E, Clifford R, Correia A, Dean R, et al. Known mechanisms cannot account for a third of reduced susceptibility in non-aureus staphylococci. npj Antimicrob Resist. 2023;1(1):1–7.

[21] Rachel Contarin, Antoine Drapeau, Pauline François, Jean-Yves Madec, Marisa Haenni EDF. The interplay between mobilome and resistome in Staphylococcus aureus. Microb Genet. 2024;15(10):1–18.

[22] Douamba Z, Tankoano A, Kaboré D, Compaore-Sereme D, Ouédraogo M, Samadoulougou-Kafando PMJ, et al. Microbiological Quality of Fresh and Grilled Mutton Sold in Ouagadougou, Burkina Faso. Food Nutr Sci. 2022;13(12):986–1000.

[23] Kabore D, Tankoano A, Palenfo Lolt, Samandoulgou S, Pare A, Sawadogo/Lingani H. Qualité microbienne de viandes de bœuf fraîche et grillée vendues dans quelques points de vente de la ville de Ouagadougou, Burkina Faso: Microbiological quality of beef meat sold in Ouagadougou. Sci Nat Appliquées. 2015;34:147–56.

[24] ISO 4833-1: 2013. NORME INTERNATIONALE ISO 4833-1,microbiologie de la chaine alimentaire_Méthode horizontale pour le dénombrement des micro-organismes_Partie 1: Comptage des colonies à 30 °C par la trchnique d' ensemensement en profondeur. 2013;9p.

[25] 21527-1. Microbiologie des aliments — Méthode horizontale pour le dénombrement des levures et moisissures — Partie 1: Technique par comptage des colonies dans les produits à activité d'eau supérieure à 0,95. Int Stand Organisazation. 2008;2008:9p.

[26] ISO-4832. International standard microbiology of food and animal feeding enumeration of coliforms colony-count. Int Stand Organisazation. 2006; 6p.

[27] NF-V08-060. Microbiologie des aliments - Dénombrement des coliformes thermotolérants par comptage des colonies obtenues à 44 °C. 2009, 10p.

[28] Iso-16649-2. Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of-glucuronidase-positive Escherichia coli — Part 2: Colony-count technique at 44 °C using 5-bromo-4-chloro-3-indolyl-D-glucuronide. Int Stand Organisazation. 2008; 8p.

[29] Bauer AW, Kirby WM, Sherris JC, Turck M. Antibiotic susceptibility testing by a standardized single disk method. Am J Clin Pathol. 1966 ;45(4):493-6. PMID: 5325707.

[30] Dubreuil L, Goldstein F, Jarlier V, Morel C, Philippon A, Rouveix B, et al. Comité de l 'antibiogramme de la Société Française de Microbiologie. Société Française Microbiol. 2022;1.1:181.

[31] Dumont MM. Guidelines For the interpretation of analytical results In food microbiology. 2019. 58 p.

[32] Harmony Iheukwumere I, Marigold Iheukwumere C, Chukwuebuka Unaeze B, Enoch Nwakoby N, Obinna Ekesiobi A, Olivia Obianom A, et al. Public Health Implications of Escherichia coli Contamination in Powdered Soybean. Journal of Chemical Health Risks.

[33] Guiraud JP. Microbiologie alimentaire. 1er Edition.Dunod; Paris, France, 1998.652p.

[34] Phan A, Mijar S, Harvey C, Biswas D. Staphylococcus aureus in Foodborne Diseases and Alternative Intervention Strategies to Overcome Antibiotic Resistance by Using Natural Antimicrobials.Microorganisms. 2025. 13: 1-37.

[35] Zheng X, Liang S, Wen L, Wang H, Bai Y, Wang Y, Cao L, Li D, Guo J, Chen Y, Wang C, Liu X, Zhang C: Foodborne outbreak of enterotoxigenic *Staphylococcus aureus* at a school in Hebei, China. Food Res. Int. 2025; 214, 116645.

[36] Fernandes A, Ramos C, Monteiro V, Santos J. Virulence Potential and Antibiotic Susceptibility of S . aureus Strains Isolated from Food Handlers. 2022;1–12.

[37] Mudau KL, Ntobeng LR, Kalu CM, Tekere M. Pathogenicity and virulence factors of Escherichia coli discovered using next generation sequencing technologies and proteomics. Front Bacteriol. 2025; 4: 1-9.

[38] FİLİK N, Filik F. Escherichia coli: Germ Theory, A Bacterial Killer Mechanism, Virulence, Pathogenicity Islands (PAIs), Pathogenesis, Secretion Systems. Acta Nat Sci [Internet]. 2023;4(1):77–86.

[39] Gambushe SM, Zishiri OT, El Zowalaty ME. Review of Escherichia coli O157:H7 Prevalence, Pathogenicity, Heavy Metal and Antimicrobial Resistance, African Perspective. Infect Drug Resist. 2022;15:4645–73.