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# *Theme*

# RESEARCH OF PATHOGENIC BACTERIA IN FOOD OF ANIMAL ORIGIN

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# DEDICATE

I dedicate this work

In memory of my dear **Selma**, who has always been an incredible psychological motivation for me to insist on achieving my goals.

To my **father**, **mother** and **brother** for their constant support in my studies and in my Life, encouragement and confidence in me.

Thanks to all.

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**LIST OF ABREVIATION**

**AESA :** European food safety authority.

**AMC :** Amixicillin-clavulanic acid.

**AMR:** Antimicrobial Resistance.

**ATM :** Azetreonam.

**CDC:** Centers for Disease Control.

**CTX :** Cefoxamine.

**ERT :** Ertapenem.

**EUCAST:** European Committee on Antimicrobial Susceptibility Testing.

**FOX :** Cefoxitin.

**GMT:** Gelose modified Touati.

**HIV**: Human immunodeficiency virus.

**INTS**: Invasive No Typhoidal *Salmonella*.

**MDR:** Multi-Drug Resistance.

**MENA :** Middle east and north africa.

**MH :** Mueller hinton.

**MIC:** Minimal inhibitory concentration.

**MICs :** Minimum inhibitory concentration in solid media.

**MZ :** Mergeuz.

**NTS**: No Typhoidal *Salmonella*.

**ONPG:** Ortho-nitrophenyl-b-galactoside.

**PDR:** Pan drug resistance.

**TDA:** Tryptophan deasaminase

**TSI**: Triple Sugar Iron.

**UFC :** Unite formant colonie.

**VH :** Viande hache.

**WHO:** World health organization.

**XDR:** Extensive resistance.

**XLD:** Xylose-Lysine-Deoxycholate.

## INTRODUCTION

Minced meat is widely consumed in Europe. In Serbia as well as in other Balkan and some Mediterranean countries, minced meat is an inseparable part of traditional dishes (e.g. moussaka, sarma), and meat products (e.g. sausages, hamburger) (Djordjević et al., 2018). The role of food in human exposure to antimicrobial-resistant bacteria is a growing food safety issue (Mesbah Zekar et al., 2017). Contamination of minced meat with *Salmonella* is still considered a major problem in food hygiene (Stock & Stolle, 2001). Minced meat is one of the food items rather frequently associated with outbreaks of salmonellosis. On the one hand, this product is predisposed to contamination because many processing steps are involved in its manufacture, which all potentially contribute to an increase in *Salmonella* counts in the final product. It was. On the other hand, in Germany, the common practice of consuming raw minced meat increases the risk of *Salmonella* infection. To improve consumer protection, the Council Directive 94/65/EC, entitled‘ ‘ laying down the requirements for the production and placing on the market of minced meat and meat preparations,’’ defines temperature and time limits for the production of minced meat (Stock & Stolle, 2001).

The mincing process disrupts the meat's cellular structure, releasing tissue fluids and making the minced meat a highly nutritious medium supporting bacterial growth; mincing also allows the migration of surface bacteria throughout the product. Therefore, it presents a highly perishable product that needs to be wrapped or packaged and chilled immediately to an internal temperature of not more than 2 ◦C or frozen to -18 ◦C during storage and transport (Regulation (EC) 853/2004) (Djordjević et al., 2018). The majority of *Salmonella* outbreaks are associated with the consumption of foods (Gallegos-Robles et al., 2008).

*Salmonella spp* is responsible for the highest number of hospitalization and cases of death due to foodborne illness (Bohaychuk et al., 2006). Foodborne diseases can cause significant morbidity and mortality in both humans and livestock, and considerable economic losses (Nikiema et al., 2021). It is a major worldwide public health involvement, accounting for 93.8 million food-borne illnesses and 155,000 deaths per year (Rahman et al., 2018).

*Salmonella* strains other than *Salmonella* Typhi and *Salmonella* Paratyphi are referred to as non-typhoidal *Salmonella* and are predominantly found in animal reservoirs. NTS infections are characterized by gastroenteritis or ‘stomach flu. Infants, young children, elderly people, and immunocompromised patients are highly susceptible to NTS infections and develop more severe symptoms than normal individuals (Scallan et al. 2011).

Invasive disease is seen most commonly in sub-Saharan Africa, where certain NTS serovars and sequence types are endemic, including *Salmonella* enterica serovars Typhimurium sequence type (ST) 313, Enteritidis ST, Dublin, and Isangi. A recently emerged highly invasive *Salmonella Typhimurium* strain, ST 313, has caused large epidemics of NTS bacteremia showing resistance to multiple antimicrobial agents, including those recommended as first-line treatment. Similarly, a new variant of multidrug-resistant *Salmonella* Typhimurium, ST 34, has been associated with invasive disease in immunocompromised patients in Vietnam. Antimicrobial-resistant infections are associated with poorer clinical outcomes and higher case fatality (« The global burden of non-typhoidal *Salmonella* invasive disease », 2019).

NTS serotypes are among the most common causes of bacterial bloodstream infections in sub-Saharan Africa with an estimated 680.000 deaths per year, mainly among children below the age of five. The high prevalence of invasive Non-Typhoidal *Salmonella* (iNTS) disease in sub-Saharan Africa is in sharp contrast to industrialized countries, where NTS serotypes mainly cause self-limiting gastroenteritis occasionally progressing to invasive infection. The two serotypes which are most commonly implicated in iNTS in Sub-Saharan Africa are *Salmonella enterica* subspecies enterica Typhimurium (in particular Sequence Type (ST) 313 lineage II) and *Salmonella enterica* subspecies enterica Enteritidis (hereafter referred to as *Salmonella* Typhimurium and *Salmonella* Enteritidis). Important risk factors are young age, *Plasmodium* falciparum malaria, malnutrition, and HIV infection. While NTS gastroenteritis is generally considered a zoonotic disease with abroad host range transmitted through consumption of contaminated meat and dairy products, the reservoir, source of transmission, and mode of transmission of iNTS in sub-Saharan Africa remain unknown (Post et al., 2019).

*Salmonella* was given its name after Daniel E. Salmon who was the veterinary surgeon that first isolated (what was called at the time) “Bacillus choleraesuis” from porcine intestines in 1884. This name was changed in1900 to“*Salmonella* choleraesuis” by Lignieres (Ryan et al., 2017). Based on biochemical characteristics, *Salmonella* is grouped into three species: *Salmonella choleraesuis*: Have only one serovar, and affects swine; *Salmonella typhi*: Have only one serovar, and affects mainly human; *Salmonella enteritidis* which contain about 2000 serovars (Rahman et al., 2018).

Following the comparative analysis of the genes coding for ribosomal RNAs and using DNA-DNA hybridization techniques, it was proposed that the genus *Salmonella* be divided into two distinct species: *Salmonella enterica* and *Salmonella bongori*. The first species is

itself subdivided into 6 subspecies: *enterica, salamae, arizonae, diarizonae, houtenae,* and *indica* (Grimont et al., 2000). In addition to this subdivision into species and subspecies, at present, 2,541 serotypes are officially recognized. These result from the multiple combinations of somatic O antigens, which are polysaccharides in nature, flagellar H antigens, which are proteinaceous, and capsular (Vi) antigens. The genetic determinants of these factors are sufficiently stable to perform reliable epidemiological investigations. The type of classification according to O and H antigens is called the Kauffmann-White scheme (Grimont et al., 2000).

This bacteria is a flagellated, Gram-negative bacterium belonging to the *Enterobacteriaceae* family (Biochemical and Molecular Mechanisms of Antibiotic Resistance in *Salmonella* spp. - ScienceDirect, s. d.). They are straight, non-spore-forming rods, medium-sized, measuring about (0.7 - 1.5 × 2.0 - 5.0Mm), non-capsulated, facultatively anaerobic, and can grow well under both aerobic and anaerobic conditions. They are chemoorganophilic, having both a respiratory and fermentative type of metabolism. The optimum temperature to support their growth is 37o C. They can grow within a pH range of approximately 4.0 - 9.0, with an optimum pH of around 7.0 (Rahman et al., 2018). Generally, they ferment glucose, mannitol, sorbitol, and xylose but not lactose and sucrose. Genus *Salmonella* is negative for oxidase, urease, Beta-galactosidase, phenylalanine deaminase, DNAase, ONPG test, and Indole. But they reduce nitrates to nitrites and are positive for catalase and produce hydrogen sulfide (H2S). In contrast to other enteric bacteria, the growth of *Salmonella* is not inhibited by certain chemicals, such as brilliant green, sodium tetrathionate, and sodium deoxycholate. Therefore these compounds are used in selective media to isolate *Salmonella* (Rahman et al., 2018).

The habitat of the genus *Salmonella* seems to be limited to the digestive tract of humans and animals. Thus, the presence of *Salmonella* in other habitats (water, food, natural environment) is explained by fecal contamination. Some serovars (serotypes) have a habitat limited to a host species, such as humans (serovars Typhi, Paratyphi A), sheep (serovar Abortusovis), or fowl (Gallinarum). Different infectious syndromes can be caused by *Salmonella* serovars, e.g. serovar Typhi causes typhoid in humans, serovar Typhimurium causes diarrhea in humans and other animal species and a typhoid-like syndrome in mice, serovar Abortusovis is responsible for abortion in ewes and serovar Dublin has been associated with different extra-intestinal infections in AIDS patients (Wray & Wray, 2000).

*Salmonella* can grow in plants and can survive in protozoa, soil, and water. Hence, broad-host-range *Salmonella* can be transmitted via feces from wild animals, farm animals, and pets or by consumption of a wide variety of common foods: poultry, beef, pork, eggs, milk, fruit, vegetables, spices, and nuts (Silva et al., 2014). Human and their feces have sometimes been identified as a risk factor for commercial poultry contamination because of the dissemination and amplification of *Salmonella* in poultry flocks (Rahman et al., 2018). Moreover, other important means of transmission include Vertical transmission: which Means transmission of *Salmonella* from infected breeder flocks to their progeny, and Horizontal transmission: *Salmonella* can also spread horizontally within and between flocks. It is mediated by mechanisms including direct bird-to-bird contact, ingestion of contaminated feces, litter, foodstuff, water, or personnel, equipment, and the environment (Rahman et al., 2018).

Concerning the isolation and identification of the *Salmonella* germ, typically buffered peptone water was used for the first enrichment, and then selenite cysteine broth and Rappaport-Vassiliadis broth were used for selective enrichment. Finally, xylose lysine deoxycholate (XLD) and Hecktoen agar were used to help isolate *Salmonella* strains ((Deriet et al., 2019). The samples collected from minced meat and merguez were subjected to an extended cultural procedure. All *Salmonella* isolates were subjected to antimicrobial susceptibility tests.

The development of antimicrobial resistance (AMR) among foodborne pathogens such as *Salmonella* has been associated with an increased number of human and animal deaths, a longer duration of hospitalization, and high costs of treatment due to therapy failure. Several clones of multidrug-resistant (MDR) *Salmonella* emerged during the late 1990s and early 2000s and since then, their prevalence both in humans, domestic animals, and other wildlife species have expanded globally. Whereas, the risk of infection is high because of unhygienic living conditions, close contact and sharing of houses between animals and humans, and the traditions of consumption of raw or undercooked animal-origin food items(Abebe et al., 2020).

The emergence of antimicrobial resistance in *Salmonella* strains is a serious health problem worldwide (Chiu et al. 2002). According to WHO, pathogens, for new antibiotics are urgently needed. One of the highest attention needed pathogens is *Salmonella*, which is resistant to fluoroquinolone. Recently, a report has shown that tetra and Penta-resistance are found in *Salmonella* (Xiang et al., 2020).

The development of resistance from multidrug (MDR), and extensive resistance (XDR) leading to pan drug resistance (PDR) may cause a post-antibiotic era in which bacterial infections cannot be controlled by antibiotics. Generally, pathogenic bacteria have mechanisms to face many risks surrounding them (Alenazy, 2022). In the early 1960s, the first incidence of *Salmonella* resistance to a single antibiotic, namely chloramphenicol, was reported (Montville & Matthews 2008). Since then, the frequency of isolation of *Salmonella* strains with resistance to one or more antimicrobial agents has increased in many countries, including the USA, the UK, and Saudi Arabia (Yoke-Kqueen et al. 2008). Antimicrobial agents such as ampicillin, chloramphenicol, and trimethoprim-sulfamethoxazole are used as the traditional first-line treatments for *Salmonella* infections. *Salmonella spp* resistant towards these agents are referred to as multi-drug resistant (MDR) (Rowe et al. 1997).

Africa and Asia are two continents with a high isolation frequency of S. Typhi displaying MDR phenotype (Ochiai et al. 2008). With the emergence of resistance to traditional antibiotics, fluoroquinolones and extended-spectrum cephalosporins have been introduced as the antimicrobial agents of choice in treating MDR S. Typhi (Sood et al. 1999). However, reports show an increase in the number of cases of typhoid *Salmonella* developing resistance towards fluoroquinolones. In countries with a higher incidence of MDR isolates, S. Paratyphi displays a higher level of resistance towards fluoroquinolones compared to S. Typhi (Hasan et al. 2008). Nalidixic acid resistance, which is used as an indicator of reduced susceptibility of ciprofloxacin and other fluoroquinolones, is displayed by isolates from Pakistan, India, and Vietnam, with high incidence rates of 59%, 57%, and 44%, respectively (Ochiai et al. 2008). As for NTS, the number of strains developing the MDR phenotype has increased in many countries since the first emergence of MDR S. Typhimurium DT104 strains in 1990 (Helms et al. 2005).

The emergence of MDR *Salmonella* strains poses a great challenge in terms of effective treatment of the infections caused by these strains (Eng et al., 2015). The objective of this work is to study the *Salmonella* germ as a food contaminant that results in human diseases. This study is based on the research of this germ in food of animal origin (merguez and minced meat) on the Algerian territory. After its isolation on selective media, this strain will be subsequently identified biochemically.

## RESULTS

### 1. Isolation and identification

Seven strains of *Salmonella* were isolated on the selective media and they were identified (Table 1).

**Table 1 :** Table of Results of biochemicals tests used for the identification of *Salmonella* strains :

| CODE/TEST | H2S | SUCROSE | MANNITOL | UREASE | TDA | Lactose |
|---|---|---|---|---|---|---|
| *Salmonella* reference | + | - | + | - | - | - |
| *E.coli* | - | - | + | - | - | + |
| *Proteus* | + | - | - | + | + | - |
| MZ7N | + | - | + | - | - | - |
| MZ1N | + | - | + | - | - | - |
| MZ3N | + | - | + | - | - | - |
| MZ11N | + | - | + | - | - | - |
| MZ7R | + | - | + | - | - | - |
| VH87N | + | - | + | - | - | - |
| VH87R | + | - | + | - | - | - |

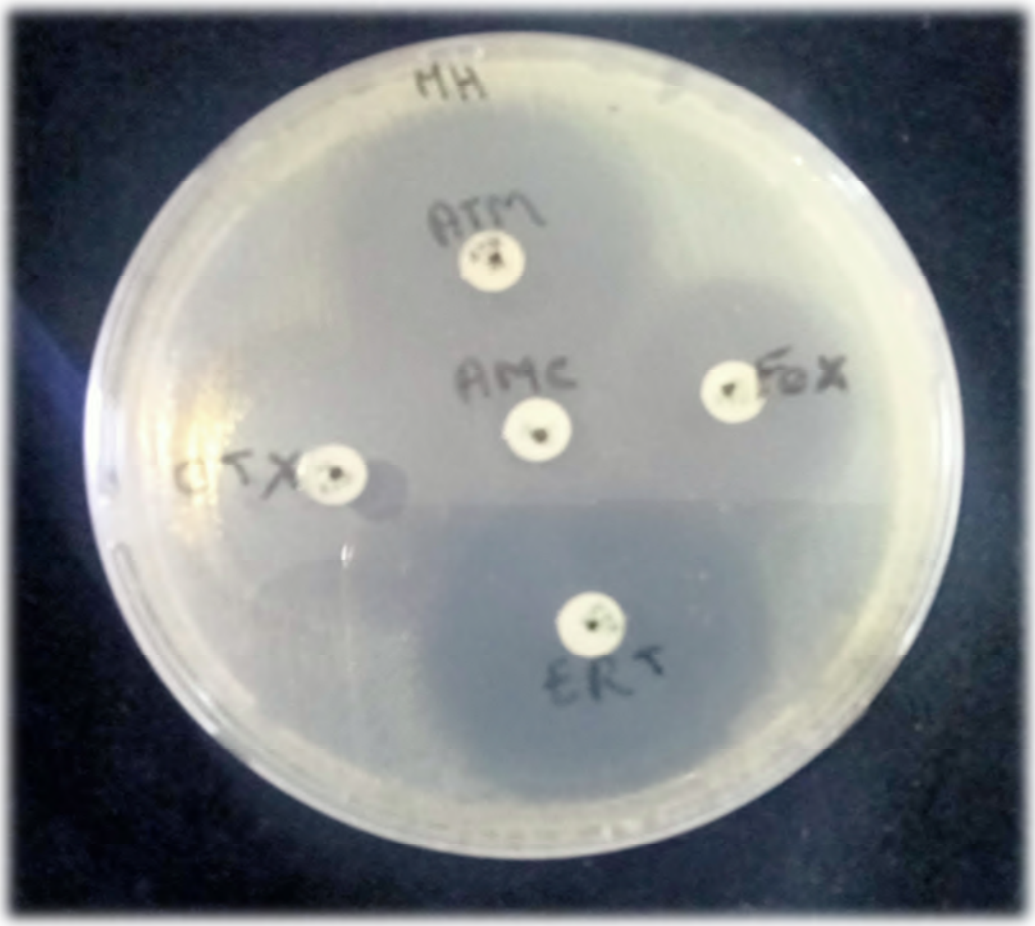
Firstly, among the 205 samples collected, we noticed the presence of *Salmonella* in 2.10°/₀ (n=2) of minced meat and 4.54°/₀ (n=5) of merguez (Table 2).

**Table 2 :** Table of Prevalence of isolated strains.

| Strains | Number of samples | Number of strains | Prevalence |
|---|---|---|---|
| VH | 95 | 2 | 2,10°/₀ |
| MZ | 110 | 5 | 4,54°/₀ |

Secondly, according to the antibiogram, all the isolated strains were susceptible to aztreonam, cefotaxime, ertapenem, cefoxitin, and amoxicillin-clavulanic acid (Figure 1).

**Figure 1:** Antibiogram results.



Finally, according to EUCAST, the strains MZ1N and MZ11N were resistant to ciprofloxacin (<0.125), the strains MZ7N and MZ7R were multi-drug resistant (Resistant to: cefazolin (MIC>8), ampicillin (MIC>16), gentamicin (MIC>8) and ciprofloxacin (MIC=8). (Table 3).

**Table 3 :** Table of MICs of *Salmonella* results.

| Code/ATB | Cefazoline | Ampicillin | Gentamicin | Ciprofloxacin |
|---|---|---|---|---|
| *Salmonella* | 4 | 1 | <0.5 | <0.5 |
| *E.coli* | 4 | 8 | <0.5 | <0.5 |
| MZ7N | >8 | >16 | >8 | 8 |
| MZ1N | 2 | 1 | <0.5 | <0.125 |
| MZ3N | 2 | 1 | <0.5 | <0.06 |
| MZ11N | 2 | 4 | <0.5 | <0.125 |
| MZ7R | >8 | >16 | >8 | 8 |
| VH87N | 2 | 1 | <0.5 | <0.06 |
| VH87R | 4 | 1 | <0.5 | <0.06 |

## DISCUSSION

The present study was conducted to investigate the prevalence of *Salmonella* in merguez and minced meat. Seven strains were isolated, with a prevalence of 3.41°/₀, although all samples collected in the study were first cultured in Rappaport-Vassiliadis. This may be because Rappaport-Vassiliadis enriches the growth of *Salmonella*. Although the number of samples tested was small, these data suggest that the four-strain protocol may be useful also for stressed organisms. All steps of the suggested procedure should be followed and a combination of different cultural media should be used to isolate these strains. The disadvantage presented by small samples was easily overcome by the pre-enrichment and enrichment steps.

Five strains were isolated from the samples of merguez and two from minced meat. A prevalence of 17.64°/° of red meat sampled in butcheries in El-kseur and 1.81°/° in Bejaia city were contaminated by *Salmonella*, however, no *Salmonella* was isolated in Oued-ghir, Amizour, Aoukas, Kheratta, Sidi-aich, Akbou, and Tazmalt. Among the isolated strains, 2 multiresistant antibiotics were identified (28.57°/°) and 4 strains were resistant to ciprofloxacin (57.14°/°).

The presence of *Salmonella* in the analyzed samples indicates that they were contaminated before and/or during the sale. It reflects neglect of the hygiene rules of the sellers in the preparation and sale of products. As *Salmonella* is often present in foods of animal origin, contamination of red meat can occur during slaughter, grinding, handling, and preparation of the final product. The rate of contamination is also related to the factors of contamination.

To the best of our knowledge, there are limited systematic reviews that addressed the burden of NTS in food (Rami H. Al-Rifai, 2019). A study conducted in 2021, shows the existence of a high rate of contamination by *Salmonella* in merguez and minced meat sold in butcheries of Bejaia (10.6%), and high rates of resistance were detected to tetracycline (52.9%).

Few studies describing NTS of clinical or environmental origin have been reported in Algeria (Deriet et al., 2019), despite herself, she represents one of the primary causes of salmonellosis in both humans and food animal production (Djeghout et al., 2017).

Nineteen countries of the Arab League have published data for antimicrobial susceptibility for the WHO priority organisms. As for *Salmonella spp*, the prevalence of fluoroquinolone

resistance has exceeded 30% in several areas (Moghnieh et al., 2018). In Sub-Saharan Africa, NTS, mostly caused by *Salmonella* Typhimurium and *Salmonella* Enteritidis, is a major public health problem. In Tunisia, *Salmonella* food-borne infections are an emerging public health problem (Oueslati et al., 2021). Results reveal the prevalence of (8.8%) of NTS in food in the Middle East and North Africa region. The estimated pooled NTS prevalence varied widely across the 13 countries in MENA, as well as, across the tested food commodities. The highest pooled estimates in four countries (Tunisia, Pakistan, Saudi Arabia, and Iraq) are merely attributed to the weight of the study-level NTS prevalence observed in land animals or aquatic food. For instance, the pooled NTS prevalence in land animal food was 23.9%, 17.7%, and 14.4% in Tunisia, Pakistan, and Iraq, respectively. In Saudi Arabia, a prevalence of 25.0% was reported in frozen meat (15.0%) and fresh meat (45.0%) in Jeddah (Iyer et al., 2013). In Morocco, *Salmonella* is responsible for 42.8% of food-borne diseases (Ed-Dra et al., 2019). This high prevalence of fresh meat was attributed to small butcher shops that often do not practice proper sanitation methods during the slaughtering and packing of meat products (Iyer et al., 2013).

There was an observed increase in the pooled NTS prevalence from 4.0% in studies conducted before the year 2010 to 12.7% in studies conducted in or after 2010. This increase should not be considered as an over-time rise in the burden of NTS in food in the MENA region, but it is the pooled estimates of available study-level prevalence measures in MENA countries before or after 2010 (Rami H. Al-Rifai, 2019). Larger slaughter facilities in Africa have been shown to have a greater incidence of *Salmonella*, at all stages of the slaughter process, than smaller facilities (Hassanien et al., 2006). *Salmonella enterica* serovar Typhimurium was the most commonly identified *Salmonella* serovar in African food animals and animal products. The presence of *Salmonella enterica* serovar Typhi and *Salmonella enterica* serovar Paratyphi in samples of food animal origin is particularly troubling and strongly indicates the need for increased hygiene measures to ensure food animals are not exposed to human feces and human feces do not contaminate the community meat supply (Thomas et al., 2020).

In developing countries such as Iran, however, there are no statistics on the incidence of food poisoning and infections. It can be expected that due to improper production, storage, distribution, and consumption of food, the prevalence of food poisoning and foodborne diseases is much higher than in developed countries. Iran is one of the developing countries (Aghalari et al., 2021). The overall prevalence of S. enterica at the carcass of beef level was

22.7% in eastern, central, and southern Ethiopia and About 20% of S. enterica exhibited phenotypic multidrug resistance. The most frequently detected resistance was to Tetracycline (28.9%), followed by Streptomycin (22.2%) and Sulfisoxazole (20.0%) (Zelalem et al., 2022).

The beef was the second largest source of human illness in the United States, accounting for 29% of cases (Guo et al., 2011). Although they are less associated with human infection than pork, beef products have recently been involved in major outbreaks caused by multidrug-resistant *Salmonella* in both Europe and North America, According to AESA, *Salmonella* Typhimurium was the most prevalent serovar in beef, with 12 isolates (19.7%) reported out of 61 detected serovars, whereas for cattle herds it was 2nd, accounting for 308 out of 1,177 *Salmonella* isolates (26.2%) (Ferrari et al., 2019).

The spread of *Salmonella spp* throughout the meat production chain can be attributed to several factors, such as the management system applied to breeding and slaughtering practices and post-slaughter manipulation as well as hygienic care during different chain production stages (Ferrari et al., 2019)

Cases of *Salmonella enterica* infection occur worldwide; however, some diseases are more common in different regions. Non-typic salmonellosis occurs more frequently in industrialized countries, while enteric fever occurs primarily in developing countries (especially in Asia). Each year, there are approximately 1.3 billion cases of non-typic salmonellosis worldwide. The World Health Organization estimates that 17 million cases and more than 500,000 deaths are attributable to typhoid fever each year. The disease peaks in the summer and fall and primarily affects children. In developing countries, salmonellosis is partly responsible for the morbidity and mortality associated with childhood diarrhea, as the bacteria are involved in about 20% of cases (Canada, 2001). The contamination of food products with *Salmonella* generates serious consequences for public health and the economy (Elgroud et al., 2015).

In the United States; NTS is the leading cause of bacterial foodborne illnesses with 1.35 million cases, 26,500 hospitalizations, and 420 deaths (CDC, 2019). Studies have shown that beef products are also susceptible to *Salmonella* contamination (Rose et al., 2002; Zaidi et al., 2008; Sallam et al., 2014 ). *Salmonella* prevalence differs seasonally; frequency peaks during the summer through early fall and troughs during the winter (Barkocy-Gallagher et al, 2003; Dargatz et al., 2003; McEvoy et al., 2003). Feedyard location also affects *Salmonella* prevalence; southern regions have a higher prevalence of *Salmonella* than northern regions

(Dargatz et al., 2003; Rivera-Betancourt et al., 2004; Haneklaus et al., 2012). Additionally, cattle type affects *Salmonella* prevalence; feedlot cattle are more frequent carriers than cull cows and bulls (Gragg et al., 2013a; Webb et al., 2017).

The U.S. Department of Health and Human Services reported an increase in *Salmonella* infections from 13.6 to 16.4 cases per 100,000 population, which represented a 17.1% increase from 1997 to 2011. In the European Union, *Salmonella*-infected gastroenteritis was the second most frequently reported foodborne illness with 91,408 clinical cases reported by thirty EU/EEA countries, and a confirmed case rate of 25.4 cases per 100,000 population in 2014 compared to 21.4 cases per 100,000 population in 2013, which represented a 19% increase in the notification rate (Pornsukarom et al., 2018). In Europe, since 2014, *Salmonella spp* has been the second-highest bacterial agent, after Campylobacter, causing gastroenteritis in humans (Oueslati et al., 2021).

NTS gastroenteritis is expressed by digestive signs (diarrhea, vomiting, and abdominal pain) associated with fever and depression. The first symptom appears approximately 12 to 24 h after ingestion of the contaminated food. The acute phase lasts approximately 24 to 48 h. Symptoms resolve spontaneously, and symptomatic treatment is generally sufficient. In children, the elderly, and immune-compromised persons, digestive infections can progress to sepsis and meningitis, leading to death. Antimicrobial therapy is therefore prescribed to particularly sensitive persons. Uncontrolled use of antimicrobials in poultry farming leads to the selection of multidrug-resistant *Salmonella* strains. The alarming increase in antimicrobial resistance is another aspect of the public health concern of *Salmonella* infection. It was shown that a proportion of multidrug-resistant *Salmonella* found in humans are of animal origin and have acquired their resistance genes in breeding before being transmitted to humans through food (Oueslati et al., 2021).

At present, preventive measures for enteric fever concentrate on access to safe water and food, proper sanitation, and the use of typhoid vaccines. Ensuring the safety of water for consumption is the main goal for the elimination of possible transmission routes of typhoid *Salmonella* as well as NTS. This important measure has been successfully achieved in industrialized countries, such as in Europe and the USA, but not in developing and underdeveloped countries (Clasen et al. 2007). As for NTS, one effective measure is to restrict the inappropriate use of antibiotics in food animals and their feed (Talbot et al. 2006).

Proper handling and cooking of food are measures proposed to eradicate the bacterial contamination of food. In many countries, food irradiation has been greatly promoted owing to its effectiveness in reducing the risk of food contamination. Approved by several public health agencies, including the WHO and CDC, the technology of food irradiation is only partially utilized in some areas in Europe and the USA because of the risk of radioactivity (Osterholm & Norgan 2004).

Evaluation of meat at the retail level is recognized as a useful way to assess the risk of consumer exposure to enteric pathogens and antimicrobial resistance. During meat handling processes, meat may become contaminated with bacteria from the animal's digestive tract, even under conditions of strict hygiene (Worku et al., 2022). Furthermore, large-scale high-quality research in countries with limited data is needed to enhance our understanding of NTS epidemiology (Rami H. Al-Rifai, 2019). It has been shown that the implementation of greater hygiene measures in slaughter systems has been successful in reducing the number of cases of salmonellosis in Europe (European Food Safety Authority (EFSA): European Centre for Disease Prevention Control, 2012). Where prevalence data show that end product samples are highly contaminated with *Salmonella*, as was the case for poultry meat and organs, local and national policymakers and enforcers may be able to more effectively develop control measures to reduce potential pathogens in the food chain (Thomas et al., 2020).

The prevalence of antibiotic resistance genes in foodborne strains is needed, especially from a One Health perspective (Pławińska-Czarnak et al., 2022).

## CONCLUSION

Many food types have been implicated as *Salmonella* outbreak vehicles, despite sanitary measures implemented over recent decades, this pathogen is far from being reduced or eradicated.

This study confirms that the circulation of *Salmonella* persists in our region, but that the prevalence remains low even after inoculation in a wide range of culture media.

The data presented here compile an overview of *Salmonella* distribution in animal-based foods, which is essential since veterinary source literature is still dispersed, if not absent. Animal-based food data are essential, since, when added to clinical data, they may facilitate the identification of potential reservoirs. However, as observed here, many of these data are either sparse or absent. In addition, disparities regarding the number of studies in some regions are also noted, i.e., much is studied concerning one matrix, e.g., poultry, while another is not, as in the case of red meat.

Finally, this study aimed to subsidize prevention actions and specific control programs for each continent and animal-based products.

**Prospects:**

However, few studies have been carried out on the contamination of food of animal origin and it is, therefore, necessary to :

- Know the health status of the animals before slaughtering them.
- Observed vendor hygiene rules in the preparation and sale of meats.
- Initiated screening tests.
- Monitor the prevalence and antibiotic resistance of *Salmonella* in food of animal origin.
- Safe food preparation practices including cooking, reheating of food, and adequate refrigeration is as should be carried out.
- The need for structured national plans in the region to target infection control and antimicrobial stewardship.
- Good control, surveillance, and health education are needed.
- The need to implement interventions for improvement of sanitary practices in abattoirs.

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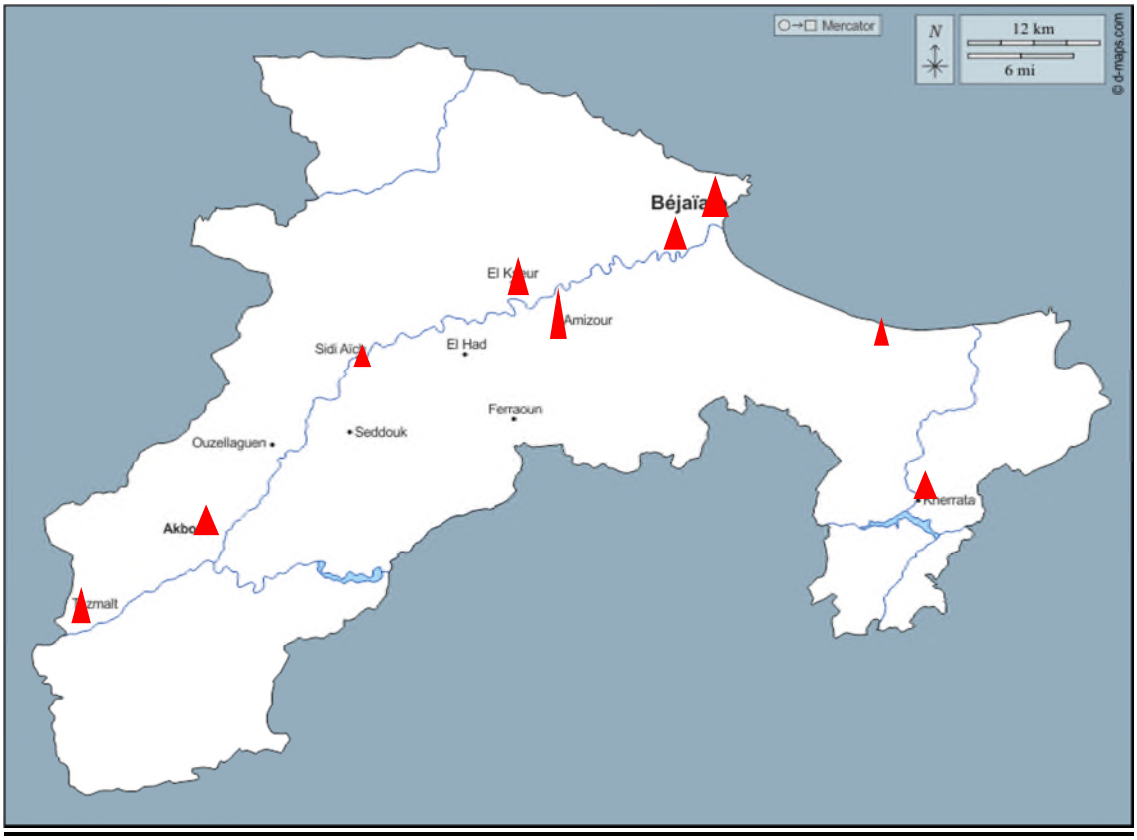
## Appendixes

**Appendix 1** : Geographical map of the wilaya of Bejaia which represents the regions where the samples were collected.



**Appendix 2 :** Table of Antibiotics tested.

| Antibiotics | S > | R < |
|---|---|---|
| ATM | 26 | 21 |
| CTX | 20 | 17 |
| ERT | 22 | 16 |
| FOX | 19 | 19 |
| AMC | 19 | 19 |

**Appendix 3 :** Table of Preparation of antibiotic stock solutions for MICs determination.

| Concentration in stock solution (mg/l) | Volume stock solution (ml) | Volume distilled water (ml) | Concentration obtained (mg/l) | Final concentration (mg/l) |
|---|---|---|---|---|
| 2560 | 1 | 7 | 320 | 16 |
| 320 | 1 | 1 | 160 | 8 |
| 320 | 1 | 3 | 80 | 4 |
| 320 | 1 | 7 | 40 | 2 |
| 40 | 1 | 1 | 20 | 1 |
| 40 | 1 | 3 | 10 | 0.5 |
| 40 | 1 | 7 | 5 | 0.25 |
| 5 | 1 | 1 | 2.5 | 0.125 |
| 5 | 1 | 3 | 1.25 | 0.06 |

**SUMMARY**

**Context:** The contamination of food of animal origin with *Salmonella* generates serious consequences for public health and the economy.

**The objective of the study:** This study was conducted to determine the prevalence and antibiotic susceptibility of *Salmonella* in food of animal origin in the region of Bejaia.

**Methods:** This research was carried out from April 16$^{th,}$ 2022 to June 23$^{th}$ 2022, and a total of 205 samples were collected in different butcher's stores in the wilaya of Bejaia. Suspect isolates were identified by biochemical tests and were submitted to antimicrobial susceptibility tests for 9 antibiotics.

**Results:** A total of 7 positive samples were identified giving an overall prevalence of 3.41%. Two multidrug resistant strains were detected and 4 strains were resistant to ciprofloxacin.

**Conclusion:** Of the 7 strains isolated in this study, two strains were identified as multiresistant to antibiotics. It is therefore important to monitor the prevalence and antibiotic resistance of Salmonella found in food of animal origin.

**RESUME**

**Context :** La contamination des aliments d'origine animale par des salmonelles entraîne de graves conséquences pour la santé publique et l'économie.

**Objectif de l'etude :** Cette étude a été menée pour déterminer la prévalence et la sensibilité aux antibiotiques des *Salmonella* dans les aliments d'origine animals dans la region de Béjaia.

**Methodes :** Cette recherche a été réalisée du 16 avril 2022 au 23 juin 2022 et Un total de 205 échantillons a été prélevé dans différentes boucheries de la wilaya de Bejaia . Les isolats suspects ont été identifiés par des tests biochimique, et ont été soumis à des tests de sensibilité antimicrobienne pour 9 antibiotiques.

**Resultats :** Un total de 7 échantillons positifs ont étais identifié donnant une prévalence globale de 3,41%. Deux souches multirésistantes ont été détecter et 4 souches ont été résistantes a la ciprofloxacine.

**Conclusion :** Sur les 7 souches isolées au cours de cette étude, deux multirésistante aux antibiotiques ont été identifiée. Il est donc important de surveiller la prévalence et la résistance des *Salmonella* qui se trouvent dans les aliments d'origine animal aux antibiotiques.