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**Microbiological quality of raw vegetables in Ouagadougou: enumeration of *Escherichia coli* and detection of *Salmonella* spp. and antibiotic resistance profiles**

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**Contributions**: Adama Pamba Séré: conceptualization, methodology, investigation, writing - original draft. Abdoudramane Sanou: methodology, validation. Hiliassa Coulibaly: formal analysis. Edwige Noelle Roamba, Roger Dakuyo: investigation. Kabakdé Kaboré: resources. Kiessoun Konaté: supervision. Donatien Kaboré: writing - review and editing. Mamoudou Hama Dicko: supervision, project administration. All authors read and approved the final manuscript.

**Conflict of interest**: the authors declare no competing interests.

**Ethics approval and consent to participate**: informed consent was obtained from all subjects involved in the survey. The study did not involve clinical trials or collection of human biological samples; thus, formal ethics committee approval was waived according to local regulations.

**Availability of data and materials**: the datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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**Abstract**
This study explores the microbiological quality of raw vegetables and salads in Ouagadougou, Burkina Faso, by assessing contamination levels and antimicrobial resistance of isolated bacteria across the supply chain. A total of 300 samples were collected from production fields, urban markets, and mass catering sites, and analyzed for *Escherichia coli* and *Salmonella* spp. using ISO standard methods. Susceptibility testing was performed on isolates. The results show that contamination levels vary significantly ($p<0.05$), with *E. coli* concentrations reaching up to 4.08 ± 0.04 log CFU/g. The prevalence of *Salmonella* spp. remains low (0 to 3%), with contamination detected only in ready-to-eat salads. In terms of antimicrobial resistance, *E. coli* isolates showed high resistance to amoxicillin (62.12%), and the Multi-Antibiotic Resistance (MAR) index exceeded 0.2 for 45.5% of isolates. Among *Salmonella* spp. isolates, 42.11% were resistant to amoxicillin, but notable sensitivity to fluoroquinolones and carbapenems (84.21%) was observed. These findings highlight that agricultural practices and final preparation hygiene are critical control points and confirm the vegetable supply chain as a reservoir for antimicrobial resistance, providing essential data to guide public health policies in Ouagadougou.

**Introduction**
Raw fruits and vegetables play an important role in the diet, providing essential nutrients and helping to reduce chronic diseases (FAO *et al.*, 2023). Their consumption has increased worldwide, and this trend is strong in African cities such as Ouagadougou, the capital of Burkina Faso (Havelaar *et al.*, 2015). However, because of their high-water content, these products are conducive to the proliferation of pathogens such as *Escherichia coli* and *Salmonella*, leading to risks of food-borne illnesses (Alegbeleye *et al.*, 2018). In the specific context of Ouagadougou, the vegetable supply chain presents unique challenges. A significant portion of the fresh produce is grown in peri-urban agricultural fields, where the use of untreated or poorly treated wastewater for irrigation is a common practice due to water scarcity. This directly exposes crops to a wide range of enteric pathogens (Amoah *et* al., 2006; Dao *et al.*, 2018). From these fields, vegetables are transported to a complex network of markets, ranging from large wholesale hubs to numerous smaller retail and informal street vendors. Handling practices at these bustling markets are often suboptimal, with prolonged exposure to environmental contaminants and a general lack of cold chain infrastructure, which further exacerbates microbial risks (Rouamba *et al.*, 2021). Finally, a large part of the population consumes these vegetables as ready-to-eat salads prepared by street food vendors and collective catering services, locally known as “maquis”. At this final stage, hygiene practices during washing, cutting, and handling are critical but often inadequate, creating significant opportunities for cross-contamination (Nikiema *et al.*, 2021). This situation makes the microbiological safety of raw vegetables a major public health concern in the region. In Burkina Faso, pathogens such as *E. coli* and *Salmonella* are frequently found in raw vegetables, leading to food-borne infections that can cause severe gastrointestinal disorders. According to recent WHO figures, foodborne diseases cause a significant burden globally, with around 600 million people falling ill each year (Havelaar *et al.*, 2015). In addition to pathogenic germs, the risk is compounded by the emergence of antibiotic resistance, a growing threat fueled by the uncontrolled use of antibiotics in agriculture and public health. This is a particularly pressing issue in Burkina Faso, where health facilities report an increase in resistant infections (Walsh *et al.*, 2023). The selection of antibiotic-resistant pathogenic

bacteria represents a serious threat to human health and a major challenge for public health, both locally and internationally (Salam *et al.*, 2023).

In order to improve the hygienic quality of raw vegetables sold in Ouagadougou, it is essential to identify the pathogens responsible for contamination and to understand the dynamics of their transmission along the supply chain. This study was therefore designed to assess the microbiological risks at critical points of the vegetable supply chain in Ouagadougou, from production fields to final consumption, by evaluating the prevalence and concentration of *E. coli* and *Salmonella* spp. and characterizing their antibiotic resistance profiles.

## Materials and Methods

### *Study area, period, and design*

This prospective study was conducted from November 1, 2023, to September 30, 2024, to assess the microbiological risks along the entire vegetable supply chain in Ouagadougou, the capital of Burkina Faso. The sampling sites were selected to represent the three main stages of the city's food supply system: production, distribution, and final consumption (Figure 1).

- Production sites: the gardening fields of Tanghin, Zaghtouli, and Kossodo were chosen as they are the main peri-urban areas supplying Ouagadougou with fresh vegetables.
- Market sites: the markets of Dapoya, Larlé, Pissy, Somgandé, and Zogona were selected to represent both major wholesale distribution hubs and high-traffic retail markets.
- Catering sites: collective catering establishments in densely populated districts (Gounghin, Boulmiougou, Wemtenga, Zone 1, Patte d'Oie) were included to represent points of final consumption.

### *Survey*

A cross-sectional survey was conducted to gather data on the practices of stakeholders. A structured questionnaire was administered to 20 producers, 100 vendors, and 100 caterers. The questionnaire focused on key factors influencing contamination, including irrigation water sources, use of fertilizers, post-harvest handling, and hygiene practices. The questionnaire is available in the *Supplementary file*. The questionnaire was pre-tested on a pilot group of five participants from each category to assess clarity and internal consistency; minor wording adjustments were made accordingly. All responses were anonymous: no personal identifiers were recorded, and participants were informed that participation was voluntary and that data would be used solely for research purposes.

### *Sampling strategy and sample collection*

A total of 300 samples were collected across the different stages of the supply chain. The distribution of these samples is detailed in Table 1. Samples from production fields and markets consisted of raw vegetables, specifically tomato (*Solanum lycopersicum*), cucumber (*Cucumis sativus*), onion (*Allium cepa*), and lettuce (*Lactuca sativa*). Samples from catering sites were ready-to-eat salads, which generally consisted of a mixture of freshly cut lettuce, tomato, cucumber, and onion.

All samples were collected aseptically using sterile gloves and placed into individual sterile stomacher bags. They were immediately stored in a cooler with ice packs to maintain a temperature of approximately 4°C and transported to the laboratory for analysis within 4 hours of collection.

***Microbiological analyses***

For each sample, a 25 g portion was homogenized in 225 ml of Buffered Peptone Water (BPW, Bio-rad, France) using a Stomacher (Seward Limited, England) to create the $10^{-1}$ suspension, following the general guidelines of ISO 7218:2007. *E. coli* were enumerated on HiCrome UTI Selective Agar (HIMEDIA, India) according to ISO 16649-2. The detection of *Salmonella* spp. was performed according to the NF EN ISO 6579-1:2017 standard, using a 25 g test portion for pre-enrichment in BPW, followed by selective enrichment in MKTTn and RVS broths, and isolation on Hektoen Enteric (HE) agar. Suspect colonies were confirmed using biochemical tests and the API 20E gallery (bioMérieux, France).

***Antibiotic resistance profiles***

Antibiotic susceptibility was analysed using the Kirby-Bauer disk diffusion method on Mueller-Hinton agar. Interpretation was performed according to the 2023 guidelines of the European Committee on Antimicrobial Susceptibility Testing (EUCAST; breakpoint tables v13.0, 2023). Quality control was performed using Escherichia coli ATCC 25922 as the reference strain, with inhibition zone diameters verified to fall within the acceptable ranges specified in the EUCAST guidelines. The 17 antibiotics tested are listed in Table 2.

***Data analysis***

All experiments were performed in triplicate (n=3). Bacterial counts were converted to logarithmic units (log CFU/g). Data are expressed as mean ± standard deviation. A one-way analysis of variance (ANOVA) followed by Tukey's HSD post-hoc test was used to compare mean contamination levels across the different sites. A p-value $<0.05$ was considered statistically significant. Microbial isolates were identified using the API Web platform, version 4.1.

**Results**

***Characterization of the vegetable supply chain and survey findings***

The supply chain for vegetables used to prepare salads in mass catering follows a complex and informal route. Analysis of this chain and the results from our survey identified several critical areas of risk. From the survey administered to producers, 65% (13 out of 20) reported using surface water (river or dam water) for irrigation without any prior treatment, and 40% (8 out of 20) acknowledged using animal manure that was not fully composted. Among vendors, 80% (80 out of 100) reported storing their vegetables at ambient temperature without refrigeration, and 95% (95 out of 100) indicated that vegetables were handled by multiple people before the final sale. In the catering services, only 30% (30 out of 100) reported using a specific disinfectant for washing vegetables, with the majority relying on tap water alone.

The vegetable supply chain for salad preparation in mass catering establishments comprises three stages: horticultural production in peri-urban and interior zones surrounding Ouagadougou, commercialization through wholesale and retail markets, and final preparation in mass catering facilities. Vegetables from both local and distant production areas are consolidated at wholesale markets, then distributed to retail outlets and food service providers. This multi-stage supply chain presents cumulative microbiological and post-harvest risks, with potential pathogenic contamination from production through preparation. Comprehensive food safety management at each critical control point is necessary to ensure microbiological safety and nutritional integrity of the final product represented by Figure 2.

- Vegetable production in fields: the microbiological quality and safety of vegetables are determined by environmental and agricultural factors, with contamination risks originating from soil, irrigation water, and animal manure containing pathogenic bacteria such as *E. coli*, *Salmonella*, and *Listeria monocytogenes*.
- Vegetable sales in wholesale and retail markets: fresh produce experiences substantial post-harvest losses (up to 50%) and increased contamination risks due to inadequate infrastructure, mechanical damage during transport, and repeated handling by multiple vendors and consumers in uncontrolled environmental conditions.
- Preparation of vegetable valads in mass catering: raw vegetable consumption following washing, cutting, and mixing operations presents elevated risks of cross-contamination and pathogenic bacterial proliferation, requiring strict implementation of Hazard Analysis and Critical Control Point (HACCP) principles to ensure microbiological safety and prevent foodborne illness outbreaks.

***Microbial contamination by site and vegetable type***

The microbiological analysis revealed significant contamination of vegetables and ready-to-eat salads. The concentrations of *E. coli* and the prevalence of *Salmonella* spp. are presented in Table 3. *E. coli* loads were highest in samples from collective catering sites, with a mean concentration of 4.01±0.11 log CFU/g in Gounghin, and from one of the production fields (Zaghtouli), which showed a similarly high load of 4.08±0.04 log CFU/g. Market samples showed intermediate contamination levels. A one-way ANOVA confirmed that these differences between sites were statistically significant ($p<0.05$).

The prevalence of *Salmonella* spp. was highest in samples from collective catering sites, with detection rates ranging from 1.5% to 3.0%. In contrast, no *Salmonella* spp. was detected in any of the samples collected directly from the production fields or urban markets, strongly suggesting that contamination with this pathogen occurs at the final preparation stage.

When analyzed by vegetable type (Table 4), lettuce consistently showed the highest mean *E. coli* contamination levels at both production fields (3.85 log CFU/g) and markets (3.95 log CFU/g), significantly higher than other vegetables ($p<0.05$). This highlights lettuce as a particularly high-risk product for microbial contamination.

***Antibiotic resistance profiles***

The antibiotic resistance profiles of *Escherichia coli* and *Salmonella* spp. isolates are presented in Table 5. *E. coli* isolates showed high resistance to amoxicillin (62.12%) and amoxicillin/clavulanic acid (55.30%). For *Salmonella* spp. isolates, a notable proportion (42.11%) were resistant to amoxicillin.

***Multi-Antibiotic Resistance index***

To assess the overall risk associated with antibiotic exposure, the Multi-Antibiotic Resistance (MAR) index was calculated for each *E. coli* and *Salmonella* spp. isolate (Table 6). A significant portion of isolates from both species exhibited resistance to multiple antibiotics. For *E. coli*, 71.2% (94 out of 132) of isolates were multi-drug resistant (MDR), defined as resistance to at least one agent in three or more antimicrobial categories. A high-risk threshold is often defined by a MAR index > 0.2. In this study, 45.5% of *E. coli* isolates surpassed this threshold, indicating that they originated from high-risk environments of antimicrobial use. For *Salmonella* spp., 36.8% (7 out of 19) of isolates were classified as MDR, and 26.3% of isolates had a MAR index greater than 0.2.

**Discussion**

The high levels of fecal indicator bacteria (*E. coli*) and the presence of a primary pathogen like *Salmonella* translate directly into a significant risk of foodborne disease for the population of Ouagadougou. These pathogens are responsible for a range of illnesses from self-limiting gastroenteritis to severe, life-threatening systemic infections. Recent studies on the burden of foodborne disease in Burkina Faso have identified bacterial hazards as a major contributor to the nation's overall disease burden, with vegetables being a key transmission vehicle (Dinede *et al.*, 2023; Sosah and Donkor, 2025). The consumption of raw salads, a common practice, bypasses any thermal kill step, making the consumer directly vulnerable to the infectious dose of pathogens present. This risk is not uniformly distributed; vulnerable populations such as children, the elderly, pregnant women, and immunocompromised individuals are at a much higher risk of developing severe complications from these infections (Grace, 2015; Abakari *et al.*, 2018). The recurring nature of these outbreaks, as suggested by the data, likely contributes to a high background level of diarrheal disease, a leading cause of morbidity and mortality in the region (Havelaar *et al.*, 2015). The agricultural and handling practices identified as sources of contamination are not simply matters of negligence but are deeply rooted in the socio-economic context of urban and peri-urban agriculture in West Africa. The reliance on untreated surface water for irrigation, a primary contamination pathway, is often a consequence of limited access to and the high cost of safe municipal water sources (Akinde *et al.*, 2016; Bognini *et al.*, 2024). Similarly, the use of raw or improperly composted manure is driven by the need for affordable soil fertilizers to maximize yields on small, often insecure land plots. For many urban farmers, agriculture is a precarious livelihood, and investments in safety measures are perceived as secondary to immediate economic survival (Asomani-Boateng, 2002; Drechsel and Keraita, 2014; Sarré *et al.*, 2023). Downstream in the supply chain, the conditions in markets and catering establishments reflect similar constraints. Overcrowded markets often lack basic sanitation infrastructure, such as clean water for washing produce and proper waste disposal systems (DeWaal *et al.*, 2022; Kushitor *et al.*, 2022). For street food vendors and small-scale caterers, the lack of formal training, coupled with economic pressure to minimize costs (*e.g.*, by not using disinfectants), leads to the perpetuation of unsafe food handling practices (Kussaga *et al.*, 2014; Oguntoyinbo, 2014). Therefore, the microbiological contamination observed is a symptom of a wider systemic issue linked to poverty, rapid urbanization, and inadequate public infrastructure (Tanga, 2019; Obasi *et al.*, 2026). The situation in Ouagadougou is not unique. Studies from across West Africa, including Ghana, Nigeria, and Togo, report similar findings of high microbial loads and pathogenic contamination in fresh produce sold in urban markets (Paudyal *et al.*, 2017; Abakari *et* al., 2018; Cudjoe *et al.*, 2022). This regional pattern highlights common challenges: rapid urbanization straining resources, similar agricultural systems reliant on contaminated water sources, and informal food sectors that are difficult to regulate (Amoah *et al.*, 2007; Otoo and Drechsel, 2018). The prevalence of specific pathogens and their antibiotic resistance patterns may vary, but the fundamental drivers poverty, lack of infrastructure, and insufficient training are consistent (Okojie and Isah, 2019; Mensah *et al.*, 2002). This comparative perspective underscores that isolated interventions in one city or country will have limited success. A coordinated, regional approach to food safety standards, cross-border trade, and agricultural policy is necessary to address this transboundary public health issue (WHO, 2015; FAO, 2019). Regarding seasonality, sampling was conducted over a full year (November 2023 to September 2024), spanning both the dry and rainy seasons. Although a systematic seasonal sub-analysis was beyond the scope of this study, higher contamination levels were generally observed during the rainy season, which is consistent with findings from the same region (Dao *et al.*, 2018), where surface runoff events can transport fecal contaminants directly onto growing crops and into irrigation water sources. This seasonal dimension deserves targeted investigation in future studies.

The detection of MDR *E. coli* with high MAR indices is arguably the most alarming finding, as it situates the vegetable supply chain as a critical vector for the dissemination of antibiotic resistance. The high resistance to amoxicillin and other common antibiotics reflects intense selective pressure, likely stemming from their overuse in both human medicine and livestock farming in the region (Grace, 2015; Van *et al.*, 2012). These resistance genes, once present in bacteria in the environment, can be transferred to human pathogens through the food chain. This creates a vicious cycle where the bacteria causing foodborne illnesses are also more difficult to treat, leading to longer hospital stays, higher treatment costs, and increased mortality (WHO, 2018). The presence of MDR bacteria in fresh produce transforms a common food item into a mobile reservoir of resistance genes, contributing to the silent pandemic of antimicrobial resistance (AMR) (Manyi-Loh *et al.*, 2018). While the observed sensitivity of *Salmonella* to first-line antibiotics offers a temporary reprieve, it is a fragile situation. The development of a national action plan to combat AMR, which integrates surveillance in the agricultural and environmental sectors, is a public health imperative for Burkina Faso and its neighbors. It should be explicitly acknowledged that the statistical interpretation of antimicrobial resistance frequencies for *Salmonella* spp. is limited by the small number of isolates obtained (n=19). These results should therefore be considered as preliminary and indicative rather than definitive, and must be interpreted with caution. Larger studies targeting Salmonella specifically would be needed to draw robust conclusions about resistance patterns of this pathogen in the Ouagadougou food chain.

Addressing this multifaceted problem requires a multi-pronged, integrated approach that addresses the root causes at each stage of the supply chain.

•At the production level: low-cost, sustainable interventions are paramount. This includes promoting the use of simple, on-farm water treatment methods like sand filtration, and providing practical training on proper composting techniques to ensure the inactivation of pathogens in manure. Agricultural extension services must be empowered to disseminate Good Agricultural Practices (GAPs) effectively. Financial incentives, such as micro-credits or subsidies for accessing safer irrigation water or certified inputs, could also be explored to overcome the economic barriers faced by farmers.

•At the market and distribution level: improving basic sanitation infrastructure in markets is a fundamental step. This involves providing access to clean water for washing produce, dedicated hand-washing stations for vendors, and improved waste management systems. Training programs for vendors should focus on simple, high-impact practices like separating raw produce from other goods, using clean containers, and minimizing direct hand contact.

•At the final preparation (catering) level: given that this stage was identified as the critical point for *Salmonella* contamination, interventions here must be prioritized. Mandatory, certified hygiene training for all food handlers, based on the core principles of Hazard

Analysis and Critical Control Points (HACCP), is essential. This training must be practical, culturally appropriate, and emphasize the risks of cross-contamination. The promotion and subsidized provision of effective, food-grade disinfectants (*e.g*., chlorine-based solutions) could significantly reduce pathogen loads. Public awareness campaigns targeting consumers about the risks of raw salads and how to identify safer food vendors can also drive demand for higher safety standards.

•At the governance and policy level: a robust national food safety policy is the bedrock upon which all other interventions are built. This requires strengthening the capacity of regulatory agencies to enforce standards and conduct routine surveillance. Crucially, this surveillance must be integrated, monitoring for both key pathogens and AMR trends in the food, agriculture, and environmental sectors (a "One Health" approach). Fostering inter-ministerial collaboration between the Ministries of Health, Agriculture, and Environment is critical to avoid siloed efforts and ensure a coherent national strategy.

## Conclusions

The contamination of the vegetable supply chain in Ouagadougou is not merely a technical problem but a complex socio-ecological issue. It serves as a clear pathway for the transmission of enteric pathogens and, more insidiously, a conduit for the proliferation of antibiotic resistance within the community. The evidence strongly indicates that while fecal contamination is pervasive from the farm level, the final preparation stage in mass catering represents the most critical juncture for the introduction of *Salmonella* and the ultimate risk to consumers. Addressing this public health threat requires moving beyond simplistic solutions to embrace an integrated, multi-stakeholder "farm-to-fork" strategy. Such a strategy must combine farmer and vendor education with tangible investments in water and sanitation infrastructure, underpinned by strengthened governance and a robust, integrated surveillance system for both pathogens and AMR. Investing in food safety is not a luxury but an essential investment in public health, social equity, and sustainable economic development for Burkina Faso.

## References


Abakari G, Cobbina SJ, Yeleliere E, 2018. Microbial quality of ready-to-eat vegetable salads vended in the central business district of Tamale, Ghana. Int J Food Contam 5:3

Akinde SB, Sunday AA, Adeyemi FM, Fakayode IB, 2016. Microbes in irrigation water and fresh vegetables: potential pathogenic bacteria assessment and implications for food safety. Appl Biosaf 21:89-96.

Alegbeleye OO, Singleton I, Sant'Ana AS, 2018. Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: a review. Food Microbiol 73:177-208.

Amoah P, Drechsel P, Abaidoo RC, Ntow WJ, 2007. Pesticide and pathogen contamination of vegetables in Ghana's urban markets. Arch Environ Contam Toxicol 50:324-31.

Asomani-Boateng R, 2002. Urban cultivation in Accra: an examination of the nature, practices, problems, potentials and urban planning implications. Singapore J Trop Geogr 26:591-607.

Bognini H, Kagambèga A, Tiendrebéogo B, Sawadogo A, Barro N, 2024. Microbiological evaluation and possible origins of the microbial contamination of vegetables in Ouagadougou (Burkina Faso). Afr J Microbiol Res 18:39-45.

Cudjoe DC, Balali GI, Titus OO, Osafo R, Taufiq M, 2022. Food safety in Sub-Sahara Africa, an insight into Ghana and Nigeria. Environ Health Insights 16:11786302221142484.

Dao J, Stenchly K, Traoré O, Amoah P, Buerkert A, 2018. Effects of Water Quality and Post-Harvest Handling on Microbiological Contamination of Lettuce at Urban and Peri-Urban Locations of Ouagadougou, Burkina Faso. Foods 7:206.

DeWaal CS, Okoruwa A, Yalch T, 2022. Regional Codex guidelines and their potential to impact food safety in traditional food markets. J Food Prot 85:947-54.

Dinede G, Amenu K, Alonso S, Mutua F, Roesel K, Lindahl JF, Sousa FM, Ulrich P, Guadu T, Dione M, Ilboudo G, Knight-Jones TJD, Grace D, 2023. Foodborne hazards in food in Burkina Faso, 1990-2019: a systematic review and meta-analysis. Front Sustain Food Syst 7:1232992.

Drechsel P, Keraita B, 2014. Irrigated urban vegetable production in Ghana: characteristics, benefits and risk mitigation. 2nd ed. IWMI. doi: 10.5337/2014.219.

FAO, 2019. The future of food and agriculture: alternative pathways to 2050. Available from: https://openknowledge.fao.org/server/api/core/bitstreams/e51e0cf0-4ece-428c-8227-ff6c51b06b16/content.

FAO, IFAD, UNICEF, WFP, WHO, 2023. The state of food security and nutrition in the world 2023: urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Available from: https://openknowledge.fao.org/items/445c9d27-b396-4126-96c9-50b335364d01.

Grace D, 2015. Food safety in low and middle income countries. Int J Environ Res Public Health 12:10490-507.

Havelaar AH, Kirk MD, Torgerson PR, Gibb HJ, Hald T, Lake RJ; Praet N, Bellinger DC, de Silva NR, Gargouri N, Speybroeck N, Cawthorne A, Mathers C, Stein C, Angulo FJ, Devleesschauwer B, World Health Organization Foodborne Disease Burden Epidemiology Reference Group, 2015. World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. PLoS Med 12:e1001923.

Kushitor SB, Badu M, Kushitor MK, 2022. "Working with little:" access to market infrastructure and its effect on food handling and food safety among vegetable traders in an African city. Front Sustain Food Syst 6:724190.

Kussaga JB, Jacxsens L, Tiisekwa BPM, Luning PA, 2014. Food safety management systems performance in African food processing companies: a review of deficiencies and possible improvement strategies. J Sci Food Agric 94:1697-708.

Manyi-Loh C, Mamphweli S, Meyer E, Okoh A, 2018. Antibiotic use in agriculture and its consequential resistance in environmental sources: a review. Molecules 23:795.

Mensah P, Yeboah-Manu D, Owusu-Darko K, Ablordey A, 2002. Street foods in Accra, Ghana: how safe are they? Bull World Health Organ 80:546-54.

Nikiema MEM, Pardos de la Gandara M, Compaore KAM, Ky Ba A, Soro KD, Nikiema PA, Barro N, Sangare L, Weill FX, 2021. Contamination of street food with multidrug-resistant Salmonella, in Ouagadougou, Burkina Faso. PLoS One 16:e0253312.

Obasi CN, Mogborukor NA, Dooka BD, Madaki PD, Frazzoli C, Haddad M, Orisakwe OE, 2026. Food contamination and safety in Nigeria: a systematic synthesis of heavy metals, microbial pathogens, and health risk metrics. Food Saf Health 4:1-19.

Oguntoyinbo FA, 2014. Safety challenges associated with traditional foods of West Africa. Food Rev Int 30:338-58.

Okojie PW, Isah EC, 2019. Food hygiene knowledge and practices of street food vendors in Benin City, Nigeria. Int J Consum Stud 43:528-35.

Otoo M, Drechsel P, 2018. Resource recovery from waste: business models for energy, nutrient and water reuse in low-and middle-income countries. Routledge, Milton Park, UK.

Paudyal N., Anihouvi V, Hounhouigan J, Matsheka MI, Sekwati-Monang B, Amoa-Awua W, Atter A, Ackah NB, Mbugua S, Asagbra A, Abdelgadir W, Nakavuma J, Jakobsen M, Fang W, 2017. Prevalence of foodborne pathogens in food from selected African countries–a meta-analysis. Int J Food Microbiol 249:35-43.

Rouamba SS, Tapsoba F, Bazié BSR, Youl O, Savadogo S, Kabré E, Sangare L, Savadogo A, 2021. Assessment of the contamination of Lactuca sativa L. (lettuce) and Lycopersicon esculentum (tomato) by pesticides: case of market gardeners in Ouagadougou. Int J One Health 7:251-6.

Salam MA, Al-Amin MY, Salam MT, Pawar JS, Akhter N, Raaban AA, Alqumber MAA, 2023. Antimicrobial resistance: a growing serious threat for global public health. Healthcare 12:1946.

Sarré FB, Dièye Y, Seck A, Faye C, Dieng M, 2023. High Level of Salmonella Contamination of Leafy Vegetables Sold around the Niayes Zone of Senegal. Horticulturae 9:97.

Sosah FK, Donkor ES, 2025. Microbial foodborne outbreaks in Africa: a systematic review. Int Health 17:893-902.

Tanga PT, 2019. The contribution of urban agriculture to household food security in the city of Bamenda, Cameroon. GeoJournal 84:103-21.

Van TTH, Nguyen HN, Smooker PM, Coloe PJ, 2012. The antibiotic resistance characteristics of non-typhoidal Salmonella enterica isolated from food-producing animals, retail meat and humans in South East Asia. Int J Food Microbiol 154:98-106.

Walsh TR, Gales AC, Laxminarayan R, Dodd PC, 2023. Antimicrobial resistance: addressing a global threat to humanity. PLoS Med 20:e1004264.

WHO, 2015. WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015. Available from: https://www.who.int/publications/i/item/9789241565165.

WHO, 2018. Antimicrobial resistance: global report on surveillance. Availabel from: https://www.who.int/publications/b/31459.

Online supplementary material

Annex 1. Survey form on agricultural practices of vegetable and fruit producers.

Annex 2. Survey form on vegetable and fruit sales practices in markets.

Annex 3. Survey form on fruit and vegetable salad sales practices in collective catering.

Annex 4. Survey form for consumers of fruits and vegetable salads in collective catering.

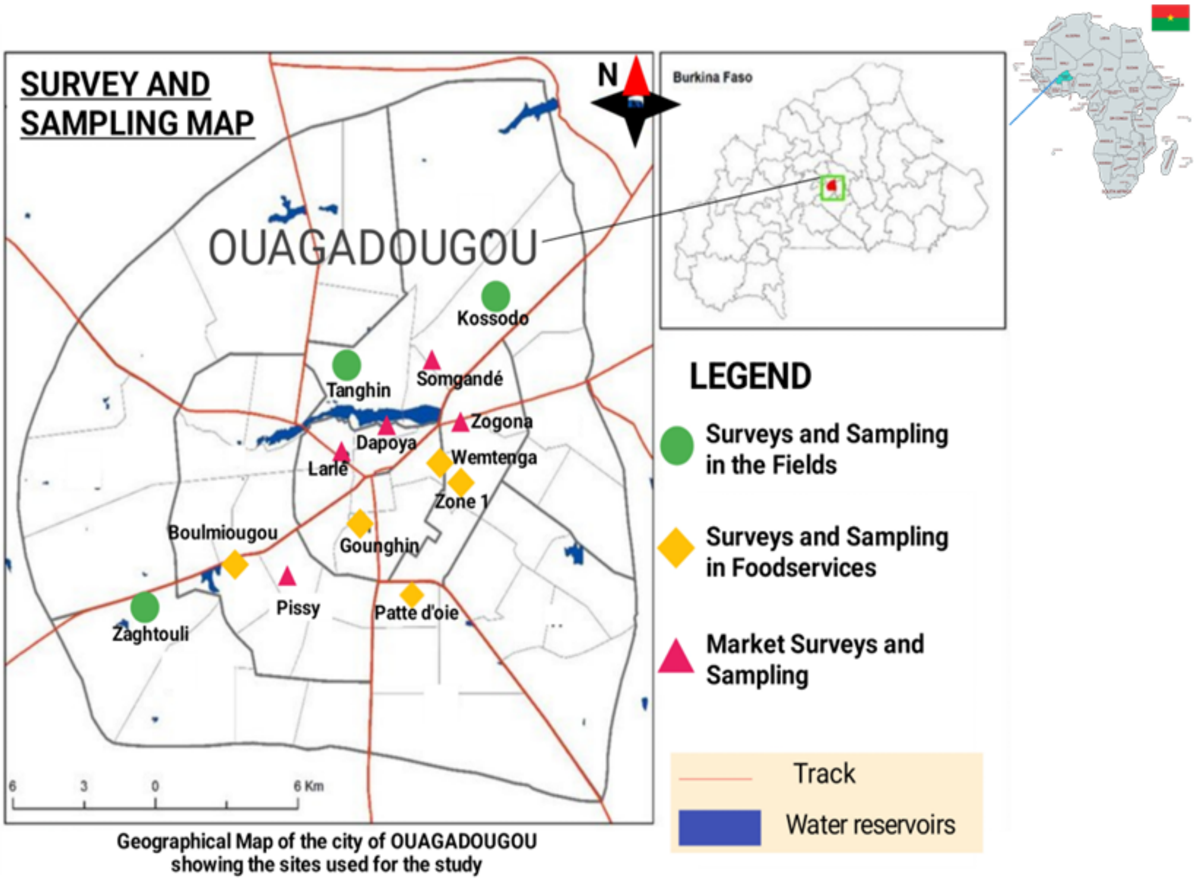


**Figure 1. Map of Ouagadougou showing the approximate location of production sites, markets, and catering districts included in the study.**

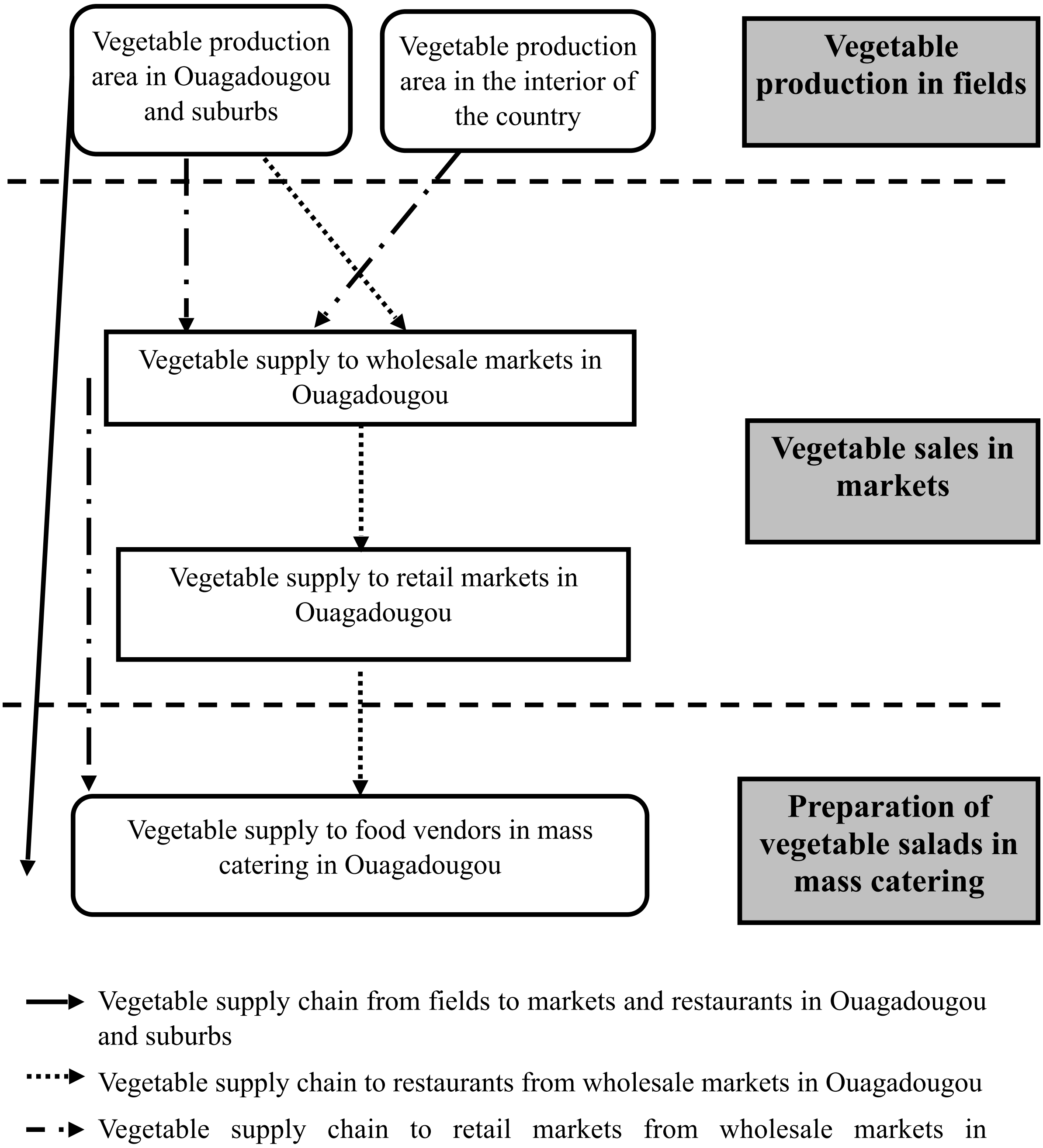


**Figure 2. Vegetable supply chain for the preparation of vegetable salads in mass catering.**

**Table 1. Detailed distribution of vegetable and salad samples collected.**

| Site type | Site name | Sample type | Vegetable type | Number of samples |
|---|---|---|---|---|
| **Production fields** | Tanghin | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 15 (distributed among types) |
| | Zaghtouli | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 15 (distributed among types) |
| | Kossodo | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 15 (distributed among types) |
| **Sub-total** | | | | **45** |
| **Markets** | Dapoya | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 21 (distributed among types) |
| | Larlé | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 21 (distributed among types) |
| | Pissy | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 21 (distributed among types) |
| | Somgandé | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 21 (distributed among types) |
| | Zogona | Raw vegetables | Tomato, Cucumber, Onion, Lettuce | 21 (distributed among types) |
| **Sub-total** | | | | **105** |
| **Catering sites** | Gounghin | Ready-to-eat salad | Mixed | 30 |
| | Boulmiougou | Ready-to-eat salad | Mixed | 30 |
| | Wemtenga | Ready-to-eat salad | Mixed | 30 |
| | Zone 1 | Ready-to-eat salad | Mixed | 30 |
| | Patte d'oie | Ready-to-eat salad | Mixed | 30 |
| **Sub-total** | | | | **150** |
| **Total** | | | | **300** |

The exact number of samples for each specific vegetable type at each field and market was not equal but was balanced to ensure representation.

**Table 2. Antibiotics used in the study.**

| Antibiotics | Disk load (µg) | Inhibition zones (mm) | |
|---|---|---|---|
| | | Zone diameter breakpoints S≥ (mm) | Zone diameter breakpoints R< (mm) / Acceptable range for E. coli ATCC 25922 |
| Amoxicillin (AMX) | 10 | 18-19 | 15-24 |
| Amoxiclav (AMC) | 30 | 21 | 18-24 |
| Cefotaxime(CTX) | 30 | 28 | 25-31 |
| Ceftazidime (CAZ) | 30 | 25-28 | 22-30 |
| Cefepime (FEP) | 30 | 27-32 | 24-34 |
| Imipenem (IPM) | 10 | 29 | 26-32 |
| Ertapenem (ETP) | 10 | 28-30 | 25-33 |
| Nalidixic acid (NA) | 30 | 25 | 22-28 |
| Ciprofloxacin (CIP) | 5 | 33 | 29-37 |
| Ofloxacin (OFX) | 5 | 30-33 | 27-36 |
| Gentamicin (CN) | 10 | 23 | 19-26 |
| Tobramycin (TOB) | 10 | 24-28 | 21-30 |
| Kanamycin (K) | 30 | 30-32 | 27-35 |
| Amikacin (AK) | 30 | 32-35 | 29-38 |
| Triméthoprim-sulfamethoxazole (SXT) | 25 | 26 | 23-29 |
| Tetracycline (TE) | 30 | 28-31 | 25-34 |
| Chloramphenicol (C) | 30 | 30-33 | 27-36 |

**Table 3. Mean concentration of *E. coli* and prevalence of *Salmonella* spp. in vegetable and salad samples by site.**

| Sample type | No. of samples (n) | *E. coli* concentration (mean log CFU/g ± SD) | Prevalence of *Salmonella* spp. (% of positive samples) |
|---|---|---|---|
| **Fields (raw vegetables)** | | | |
| Tanghin | 15 | $3.40 \pm 0.05^{b}$ | 0 |
| Zaghtouli | 15 | $4.08 \pm 0.04^{a}$ | 0 |
| Kossodo | 15 | $2.90 \pm 0.06^{d}$ | 0 |
| **Markets (raw vegetables)** | | | |
| Dapoya | 21 | $3.54 \pm 0.06^{b}$ | 0 |
| Larlé | 21 | $3.45 \pm 0.07^{b}$ | 0 |
| Pissy | 21 | $3.38 \pm 0.04^{bc}$ | 0 |
| Somgandé | 21 | $2.93 \pm 0.08^{d}$ | 0 |
| Zogona | 21 | $3.65 \pm 0.09^{b}$ | 0 |
| **Collective catering (ready-to-eat salads)** | | | |
| Gounghin | 30 | $4.01 \pm 0.11^{a}$ | 3.3 |
| Boulmiougou | 30 | $3.95 \pm 0.05^{ab}$ | 3.3 |
| Wemtenga | 30 | $2.88 \pm 0.05^{d}$ | 3.3 |
| Zone 1 | 30 | $2.88 \pm 0.04^{d}$ | 3.3 |
| Patte d'oie | 30 | $3.78 \pm 0.07^{b}$ | 3.3 |

Means within the same column followed by different superscript letters (a, b, c, d) are significantly different ($p < 0.05$) based on Tukey's HSD test.

**Table 4. Mean *E. coli* concentration by vegetable type at production fields and markets.**

| Vegetable type | *E. coli* concentration at production fields (mean log CFU/g ± SD) | *E. coli* concentration at markets (mean log CFU/g ± SD) |
|---|---|---|
| Lettuce | $3.85 \pm 0.25^{a}$ | $3.95 \pm 0.30^{a}$ |
| Cucumber | $3.10 \pm 0.15^{b}$ | $3.25 \pm 0.20^{b}$ |
| Tomato | $2.95 \pm 0.10^{b}$ | $3.15 \pm 0.18^{b}$ |
| Onion | $2.80 \pm 0.20^{b}$ | $2.90 \pm 0.22^{b}$ |

SD, standard deviation. Means within the same column followed by different superscript letters (a, b) are significantly different ($p<0.05$). This table presents aggregated data; contamination levels varied between individual sites as shown in Table 3.

**Table 5. Antibiotic resistance of *E. coli* and *Salmonella* spp. strains isolated from collected raw vegetables.**

| **Antibiotics (concentration in µg)** | **Resistance to the antibiotic** | | | |
|---|---|---|---|---|
| | ***E. coli*, n (%)** | | ***Salmonella* spp., n (%)** | |
| | Sensitive (%) | Resistant (%) | Sensitive (%) | Resistant (%) |
| Amoxicillin (10) | 50 (37.88) | 82 (62.12) | 11 (57.89) | 8 (42.11) |
| Amoxiclav (30) | 59 (44.70) | 73 (55.30) | 15 (78.95) | 4 (21.05) |
| Cefotaxime (30) | 123 (93.18) | 9 (6.82) | 16 (84.21) | 3 (15.79) |
| Ceftazidime (30) | 124 (93.94) | 8 (6.06) | 16 (84.21) | 3 (15.79) |
| Cefepime (30) | 122 (92.42) | 10 (7.58) | 16 (84.21) | 3 (15.79) |
| Imipenem (10) | 124 (93.94) | 8 (6.06) | 16 (84.21) | 3 (15.79) |
| Ertapenem (10) | 124 (93.94) | 8 (6.06) | 16 (84.21) | 3 (15.79) |
| Nalidixic acid (30) | 126 (95.45) | 6 (4.55) | 17 (89.47) | 2 (10.53) |
| Ciprofloxacin (5) | 114 (86.36) | 18 (13.64) | 16 (84.21) | 3 (15.79) |
| Ofloxacin (5) | 124 (93.94) | 8 (6.06) | 17 (89.47) | 2 (10.53) |
| Gentamicin (10) | 126 (95.45) | 6 (4.55) | 18 (94.74) | 1 (5.26) |
| Tobramycin (10) | 125 (94.70) | 7 (5.30) | 19 (100) | 0 (0) |
| Kanamycin (30) | 125 (94.70) | 7 (5.30) | 19 (100) | 0 (0) |
| Amikacin (30) | 127 (96.21) | 5 (3.79) | 19 (100) | 0 (0) |
| Triméthoprim-sulfamethoxazole (25) | 105 (79.55) | 27 (20.45) | 15 (78.95) | 4 (21.05) |
| Tetracycline (30) | 99 (75) | 33 (25) | 16 (84.21) | 3 (15.79) |
| Chloramphenicol (30) | 124 (93.94) | 8 (6.06) | 18 (94.74) | 1 (5.26) |

**Table 6. Distribution of multi-antibiotic resistance index for *E. coli* and *Salmonella* spp. isolates.**

| **MAR Index Range** | **Number (%) of *E. coli* isolates (n=132)** | **Number (%) of *Salmonella* spp. isolates (n=19)** |
|---|---|---|
| 0 (Sensitive to all) | 21 (15.9%) | 8 (42.1%) |
| 0.01 - 0.20 | 51 (38.6%) | 6 (31.6%) |
| > 0.20 | 60 (45.5%) | 5 (26.3%) |
| **Highest MAR Index** | **0.53** | **0.41** |

MAR, Multi-Antibiotic Resistance index; MDR, multi-drug resistant.