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THE HYGIENIC QUALITY OF MEAT PRODUCED IN ALGERIA: META-ANALYSIS

Nadjah Guergueb[1, 2]
[1]Department of Veterinary Medicine, the University of Batna 1, 05000 Batna
[2]Department of Agricultural Sciences, the University of Biskra, 07000 Biskra
Algeria

g.nadjah@yahoo.fr
nadjah.guergueb@univ-batna.dz

ABSTRACT

This meta-analysis aims to provide a comprehensive overview of the hygienic quality of meat in the context of Algerian meat production. A systematic literature search was conducted across various databases, yielding a pool of studies assessing the microbial contamination levels in different types of meat, including: poultry, beef, lamb, camel, sausages, and minced meat, within Algerian slaughterhouses and butcheries. A total of 25 studies met the inclusion criteria, with a combined sample size of 550 meat samples. The selected studies employed standardized methods for microbial enumeration: Total aerobic mesophilic bacteria (TAMB). The collected data were synthesized using random-effects meta-analysis models to estimate the pooled mean bacterial counts, as well as to explore potential sources of heterogeneity. The results of this meta-analysis, revealed considerable variation in bacterial counts across different meat types and sources. The overall pooled, mean bacterial count was 5.15 colony-forming units per gram (CFU.g^{-1}), with significant heterogeneity observed ($I^2 = 87.52$ %, $P < 0.001$). Subgroup analyses indicated that bacterial counts were notably higher in butcher shops, highlighting the need for targeted interventions to improve hygiene practices in these areas. Furthermore, sensitivity analyses were conducted to assess the influence of individual studies on the overall results, and publication bias was evaluated through a funnel plot. In conclusion, this meta-analysis provides valuable insights into the hygienic quality of meat in Algerian meat production, emphasizing the significance of TAMB as an informative indicator. The observed variations in bacterial counts underscored the importance of hygiene practices throughout the meat supply chain, from farm to consumer.

Key words: Algeria; bacterial counts; food safety; hygienic quality; meat production; meta-analysis

INTRODUCTION

Global meat production has increased rapidly over the past 50 years, as the total production has more than quadrupled since 1961. At a global level, the dominant livestock types are: poultry, cattle, pig, and sheep and goat to a lesser extent [38]. The last data of the Food and Agriculture Organization of the United Nations (FAO) indicate that since 2018, poultry has become the most widely consumed meat worldwide, surpassing pig production [21]. However, the distribution of meat types varies significantly across the world; in some countries, other meat types such as wild game, horse, and duck can account for a significant share of total production [38].

This occurrence can be explained by the fact that poultry meat is not a subject of culturally or religiously set limitations, and it is perceived as nutritionally valuable foodstuff with a low content of fat, in which there are more desirable unsaturated fatty acids, than in other types of meat [29]. Unlike beef and dairy fat, chicken meat contains no trans fat, which contributes to coronary heart disease [30]. Red meat is a nutrient dense food that is an important source of complete protein with all essential amino acids, highly bioavailable iron, zinc, selenium, and B vitamins, especially vitamin B_{12} in the diet [28]. Fat is an important part of the diet, providing energy, and fat-soluble vitamins, such as vitamin E [42]. The intake of meat in adequate amounts, which supplies the missing essential micronutrients, can reduce nutrition-related stunting and the consequent cognitive impairment [5].

Meat and meat products can serve as vehicles of many pathogenic organisms. Several pathogens, such as: *Bacillus cereus, Campylobacter jejuni, Clostridium botulinum, Clostridium perfringens, Escherichia coli, Listeria monocytogenese, Salmonella, Staphylococcus aureus,* and *Yersinia enterocolitica,* are known to produce serious foodborne diseases among the consumers [33, 37]. In addition to foodborne pathogens, bacteria responsible for spoilage may lead to large economic losses. Their growth and metabolic activity during shelf life leading to colour, odour, taste, or texture defects are responsible for waste, and losses of food products [39]. The types of microorganisms present on muscle food products and their numbers depend on the sanitary conditions in the environment of origin of the food, the properties and microbiological quality of any added ingredients, the extent of product processing and handling, and the conditions involved in subsequent storage, handling and distribution [40]. Therefore, the occurrence of pathogens on raw meat can be due to different factors, which include poor farm animal management, improper slaughter practices, processing, storage conditions and lack of meat safety knowledge among meat handlers [37]. The slaughtering and butchering process of animals provides bacteria with an opportunity to colonize meat surfaces. Contamination of meat is a continuing possibility from the moment of bleeding until consumption [35].

Resistant bacteria in animals can be transferred to people usually through the consumption of food [1]. In the case of meat products, chicken, turkey, beef, pork, and resulting products are major vehicles for transmission [1, 32]. In addition to transfer of resistant bacteria in the food chain, exchange of mobile genetic elements among commensal and pathogenic bacteria contributes to the emergence of drug resistance [31]. The emergence of several clones of *Salmonella* resistant to multiple antimicrobials worldwide underscores a significant food safety hazard [24].

In Algeria red meat marketed and consumed consists essentially of mutton and beef. The production of Camlin meat is however marginal. Goat meat production is mainly carried out within the steppe mountains areas [25]. Sheep meat production is estimated at 342,000 tons in 2022 followed by poultry production estimated at 258,000 tons while cattle production is estimated at 146,000 tons (Fig. 1) [19]. The average person consumed around 20 kilograms of meat [38].

Over the last few decades, *Hygienic quality of meat produced in Algeria* has been the subject of several studies. However, the findings vary significantly and have been achieved within a wide range of circumstances, such as different methodologies, sample sizes, types of meat, production practices, geographic regions or time periods.

Overall, the objective of a meta-analysis in this context is to provide a more comprehensive and reliable understanding of the hygienic quality of meat in Algeria by systematically examining and synthesizing the existing body of multiple individual studies.

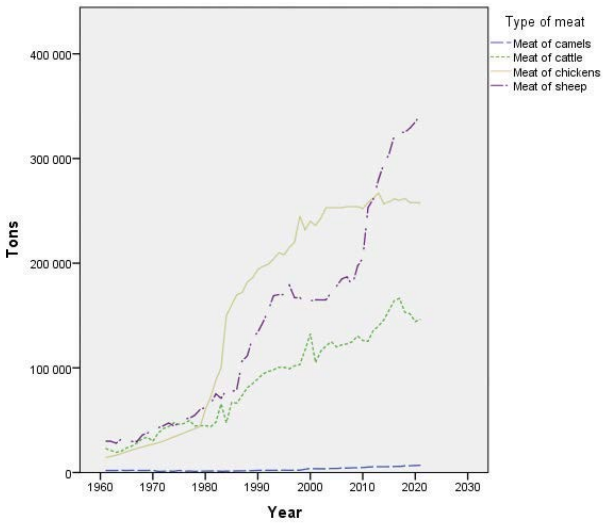


Fig. 1. Annual meat production intended for human consumption, in Algeria (1961–2021).
Source: (FAOSTAT, 2023)

MATERIALS AND METHODS

Defining the search strategy

A comprehensive search strategy was developed using appropriate keywords and database-specific syntax. To conduct this meta-analysis, we adhered to the guidelines provided by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

Inclusion criteria

- Studies conducted in Algeria,
- Studies reporting microbial contamination levels (Total aerobic mesophilic bacteria TAMB),
- Studies reporting total bacterial counts in $CFU.g^{-1}$ of meat,
- Fresh meat of ovine, bovine, caprine or poultry,
- Samples of minced meat or sausages,
- Meat samples collected from slaughterhouses or butcher shops.

Exclusion criteria

- Studies from other countries,
- Studies not specifically focused on meat hygiene,
- Studies with insufficient data on microbial contamination,
- Studies focused solely on frozen or imported meat.

Search terms

The key terms related to the hygienic quality of meat were determined: („meat" OR „beef" OR „bovine" OR „cattle" OR „chicken" OR „poultry" OR „lamb" OR „sheep" OR „camel") AND („minced meat" OR „sausage") AND („microbial contamination" OR „bacterial contamination" OR „hygiene" OR „food safety" OR „total bacterial counts" OR „FMAT") AND („slaughterhouse" OR „abattoir" OR „butcher shop").

Search execution

The search strategy was executed in August 2023 in Google scholar and Algerian University databases. The search results were screened and selected based on relevance to the research question and inclusion criteria.

Statistical analysis

Data was extracted for each included study. Overall effect size was calculated using a random-effects model, which considers both within-study and between-study variability. Heterogeneity among the studies was assessed through Cochran's Q statistic, which evaluates whether the variation in effect sizes is statistically significant beyond what would be expected due to chance. Additionally, the I^2 statistic was computed which measures the proportion of total variation across studies due to heterogeneity rather than chance. High I^2 values indicate substantial heterogeneity. A forest plot was generated to visually represent each individual study along with the overall estimate. Each study's point estimate, represented by a square on the plot, was sized proportionally to its weight in the meta-analysis. The 95 % confidence intervals (CIs) for each study's estimate and the overall estimate were displayed. Subgroup analyses were performed based on meat type and source of the meat samples, to investigate potential variations in hygienic quality. Subgroup-specific effect sizes and 95 % CIs were calculated to examine whether variations in total bacterial counts were influenced by these factors. Publication bias was assessed using funnel plots, which illustrate the relationship between observed outcomes and their standard errors. Additionally, Egger's regression test was conducted to detect potential asymmetry in the funnel plot, which might indicate publication bias.R (version 4.3.0) software was used for all analyses.

RESULTS AND DISCUSSION

The present meta-analysis aimed to comprehensively assess the variations in total bacterial counts in meat samples collected from various sources in Algeria, with a specific focus on total bacterial counts as an indicator. By synthesizing data from multiple studies, we aimed to gain insights into the hygienic quality of meat and the potential implications for food safety practices in the Algerian context.

Study selection

From the initial search, 115 studies were identified as potentially relevant to the meta-analysis of hygienic quality of meat. After applying inclusion and exclusion criteria, 25 studies were considered eligible for the analysis. Fig. 2 outlines the study selection process.

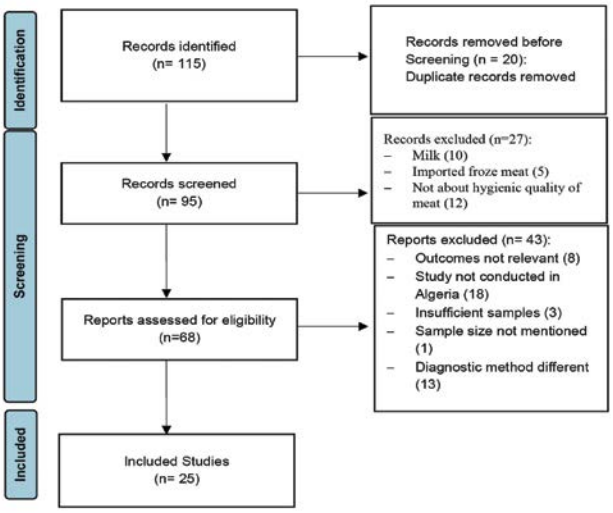


Fig. 2. Flow chart summarizing the process of study selection

Study characteristics

Table 1 presents the characteristics of the included studies. Studies were conducted between 2009 and 2022, with total sample size 550 meat samples. The studies covered various types of meat, including poultry, beef, and lamb, camel, sausages, minced meat from slaughterhouse or butcher shop and were conducted in diverse geographical regions within Algeria (Fig. 3).

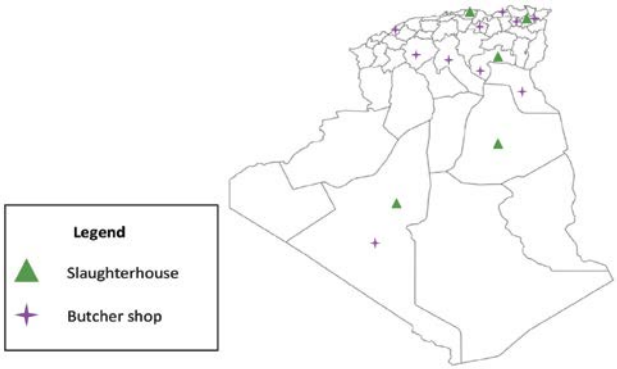


Fig. 3. Map of locations of studies included in the meta-analysis.
Algerian map was downloaded from Vemaps.com.

Heterogeneity

Significant heterogeneity was observed among the included studies (I^2 = 87.52 %, P < 0.001).

Publication bias

Egger's test indicated no publication bias (P = 0.80). The Funnel plot showed a relatively symmetrical distribution of studies, suggesting no significant publication bias (Fig. 4).

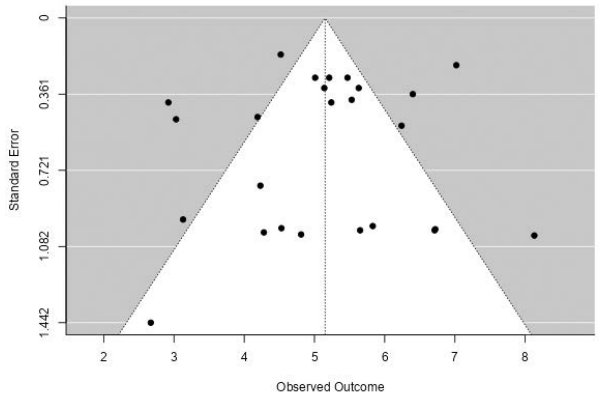


Fig. 4. Funnel plot for the total aerobic mesophilic bacteria (TAMB) level in meat

Overall hygienic quality of meat products

The overall weighted mean total bacterial count was 5.15 $\log_{10}$ CFU.g^{-1} (95 % CI: 4.66–5.64).

Forest plot

Figure 5 displays the forest plot of individual study along with the overall random-effects estimate. The studies are labelled numerically [2], [3], [4], [6], [7], [8], [11], [12], [13], [14], [15], [16], [17], [18], [20], [21], [23], [26], [27], [36], [41].

Table 1. Summarized results of the meta-analysis

Variable	Level	Number of Studies/Samples	I2 (%)	TAMB (log10 CFU.g^{-1})	IC 95 %	P- value
Type of meat	Cow meat	5/38	58.16	5.42	4.08–6.77	0.620
	Camel meat	5/110	83.56	4.19	3.36–5.03	
	Sheep meat	2/29	–	–	–	
	Poultry meat	5/227	60.85	5.60	4.09–7.09	
	Minced meat	4/112	0	5.28	4.81–5.74	
	Sausage	4/34	86.55	5.81	4.67–6.95	
Source of meat	Slaughterhouse	10/184	86.20	4.27	3.61–4.94	0.001
	Butcher shop	15/366	69.04	5.81	5.33–6.29	

I^2 – Heterogeneity; TAMB – Total aerobic mesophilic bacteria; IC 95 %–95 % confidence intervals; P- value – probability value

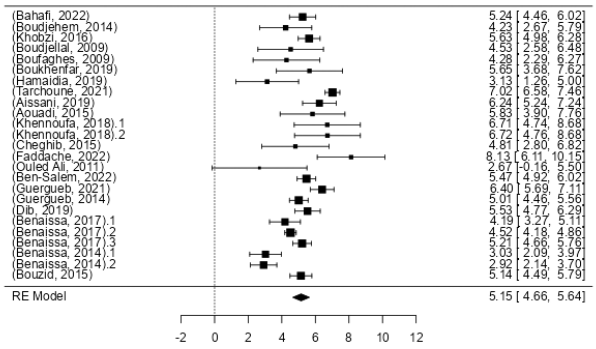


Fig. 5. Forest plot of the overall studies

Subgroup analysis

The subgroup analysis on meat type (poultry, beef, lamb,…), revealed no significant differences in the hygienic quality of meat samples from different sources (P = 0.615). The subgroup analysis by slaughterhouse or butcher shop revealed significant differences in the hygienic quality of meat samples from different sources.

Slaughterhouse: Meat samples from slaughterhouses exhibited a lower weighted mean total bacterial count (4.27 $\log_{10}$ CFU.g^{-1}) (Fig. 6).

Butcher Shop: The samples from this butcher shop had the highest weighted mean total bacterial count, indicating a potential need for improved hygienic practices (5.81 $\log_{10}$ CFU.g^{-1}) (Fig. 7).

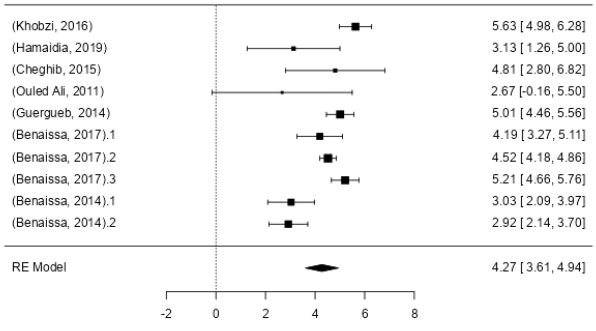


Fig. 6. Forest plot of the bacterial load of meat at slaughterhouses

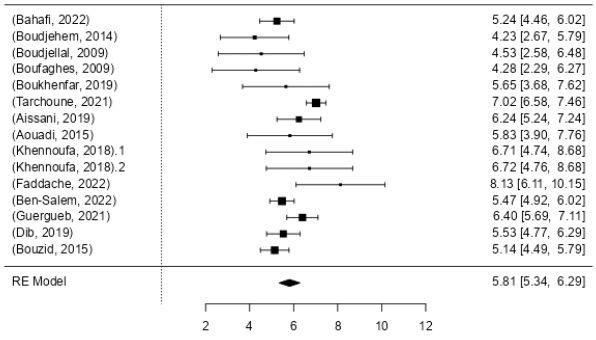


Fig. 7. Forest plot of the contamination level in meat at butcher shops

Variability in total bacterial counts

The results of our meta-analysis reveal notable variability in total bacterial counts across the included studies. This variation suggests that the hygienic quality of meat in Algeria is not uniform, with some samples exhibiting higher bacterial counts than others. The aggregated weighted mean total bacterial count of 5.15 $\log_{10}$ CFU.g^{-1} underscores the need for continued vigilance in the implementation of effective hygiene measures throughout the meat production and distribution chain.

The criteria for TAMB contamination of meat are similar in Algeria and in Europe. However, there are some differences in terms of quality control and monitoring. In Europe, Commission Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs sets a maximum limit of 100,000 CFU.g^{-1} for TAMB in fresh meat. This limit is also in force in Algeria, in accordance with the provisions of Executive Decree 10-2005 of 17 January 2005 on the hygiene of foodstuffs.

Sources of heterogeneity

Significant heterogeneity was observed among the studies included in this meta-analysis (I^2 = 87.52 %). This heterogeneity could be attributed to several factors, including variations in sampling methods, processing practices, and origin source. The variations observed in meat types, such as beef, chicken, lamb, and sausage,… could also contribute to the observed heterogeneity. Subgroup analyses were conducted to explore potential sources of heterogeneity. Subgroup analyses provided valuable insights into the variations in bacterial counts among different meat types and sources. For instance, higher bacterial counts were noted in butcher shops, suggesting that this particular segment of the meat supply chain may warrant special attention to improve hygienic practices. This finding aligns with previous research [9, 10, 22, 34] highlighting the impact of various factors, including inadequate sanitation, cross-contamination, and suboptimal processing conditions, on microbial contamination levels in specific meat sources.

Implications for food safety

The findings of our meta-analysis have important implications for food safety practices in Algeria. The observed variability in total bacterial counts highlights the need for consistent adherence to proper hygiene practices in slaughterhouses, butcheries, and throughout the supply

chain. High bacterial counts in meat samples pose a potential risk to consumers, as consumption of contaminated meat may lead to foodborne illnesses. Addressing this issue requires a concerted effort to implement and enforce stringent hygiene standards at all stages of meat production and distribution.

Limitations

Several limitations of our meta-analysis warrant consideration. First, the availability of data from studies specifically focusing on total bacterial counts in Algerian meat samples was limited, which could have impacted the comprehensiveness of our findings. Additionally, variations in study methodologies and reporting practices could have introduced bias and contributed to the observed heterogeneity. The availability of relevant studies specifically focusing on total bacterial counts in Algerian meat samples was limited, potentially affecting the comprehensiveness of our analysis. Future research should aim to address these limitations by conducting well-designed studies with standardized methodologies and transparent reporting.

CONCLUSIONS

In conclusion, this meta-analysis highlights the variability in total bacterial counts in meat samples obtained from various sources in Algeria. The findings underscore the need for continuous efforts to improve hygiene practices in slaughterhouses and butcheries, thereby enhancing the overall hygienic quality of meat products. Implementing and enforcing rigorous food safety measures is crucial to safeguarding public health and meeting international standards. Addressing these challenges will require collaboration among stakeholders, including regulatory authorities, meat producers, and consumers, to ensure the provision of safe and wholesome meat products in Algeria.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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