Journal of Food Safety and Food Quality
Archiv für Lebensmittelhygiene

J. Food Saf. Food Qual. **2025**; 76(6): 44343
https://doi.org/10.31083/JFSFQ44343

Original Research

Investigation of the Antibacterial Effect of Curcumin Against *Staphylococcus aureus* in Chicken Meat

Zahra Farahmand[1], Goknur Terzi Gulel[1,*]

[1]Department of Food Hygiene and Technology, Faculty of Veterinary Medicine, University Ondokuz Mayis, 55100 Samsun, Türkiye
*Correspondence: goknurterzi@yahoo.com (Goknur Terzi Gulel)
Academic Editors: Corinna Kehrenberg and Maria Schirone
Submitted: 28 June 2025 Revised: 13 October 2025 Accepted: 10 November 2025 Published: 23 December 2025

Abstract

Purpose: Food poisoning caused by *Staphylococcus aureus* is among the most common foodborne illnesses worldwide. Thus, this study aimed to evaluate the antibacterial effect of curcumin against *S. aureus*. **Methods**: Chicken breast samples were inoculated with *S. aureus* at a concentration of 2.0×10^8 CFU/mL and subsequently immersed in a 1%, 2%, or 3% curcumin solution for 15 minutes. The subsequent bacterial load in the chicken samples was quantified on storage days 0, 2, 4, and 6 according to the EN ISO 6888-1 standard. **Results**: The number of *S. aureus* decreased by 2.43, 2.70, and 3.49 log CFU/g by the end of the sixth day following the 1%, 2%, or 3% curcumin treatments, respectively. The minimum inhibitory concentration (MIC) of curcumin against *S. aureus* was 125 µg/mL. A 3% concentration solution of curcumin demonstrated the strongest antibacterial activity, whereas the sensory evaluation revealed that the consumers preferred the 1% and 2% concentrations. **Conclusion**: These findings suggest that curcumin has antibacterial properties and can be used as a natural preservative in food products to control *S. aureus* contamination.

Keywords: antibacterial activity; chicken; curcumin; *S. aureus*

1. Introduction

Chicken meat is an affordable source of high-quality protein that is easily digestible and contains low levels of saturated fats. In addition, chicken contains essential minerals such as calcium, phosphorus, zinc, iron, and copper, as well as vitamins from the B-complex [1].

Staphylococcus aureus (*S. aureus*) is a Gram-positive, common opportunistic pathogen responsible for significant nosocomial and community-acquired diseases worldwide. The bacteria can cause a range of symptoms in humans, ranging from minor skin lesions to serious, life-threatening diseases [2]. Consuming foods containing staphylococcal enterotoxin may lead to symptoms such as hypersalivation, nausea, abdominal cramps, and vomiting. Although these symptoms typically resolve within 24–48 hours, they can be severe in infants, the elderly, and individuals with immunocompromised conditions [3]. In Türkiye, *S.aureus* has been frequently isolated from poultry meat, beef, meat products [4], milk, and dairy products [5].

Various food preservation techniques, such as pasteurization, freezing, drying, salting, smoking, and irradiation, are used to combat foodborne pathogens. Although these methods offer several advantages, they also have disadvantages, such as nutrient loss. Today, consumers increasingly prefer natural and additive-free products, hence the need for alternative preservation agents derived from natural sources [6,7].

Curcumin is a golden-yellow polyphenolic compound and the principal bioactive constituent of turmeric (*Curcuma longa* L.), a rhizomatous plant widely used in food and traditional medicine [8]. Curcumin exhibits a broad range of biological effects, including anti-inflammatory, antioxidant, anticancer, antibacterial, antiviral, and antifungal activities [9]. Despite its low water solubility and bioavailability, curcumin's antimicrobial potential has attracted attention in food preservation research [10].

According to the European Union's EC Directive 94/36/EC [11], curcumin (E100) has been approved as a food colorant. It is permitted in certain foods at levels between 50 and 500 mg/kg or in amounts sufficient to achieve the desired effect, following the principle of quantum satis [12]. Curcumin exhibits antibacterial activity against both Gram-positive and Gram-negative bacteria. Its antimicrobial mechanisms include damaging bacterial DNA, cell walls, and membranes; inhibiting the bacterial quorum sensing (QS) system; preventing bacterial biofilm formation, and photosensitizing activity against bacteria [13].

This study aims to (i) evaluate the antibacterial effect of curcumin against *S. aureus* in chicken meat, (ii) determine its minimum inhibitory concentration (MIC), and (iii) assess the impact of curcumin treatment on the sensory quality of the meat.

2. Materials and Methods

In the present study, chilled chicken breast meat samples were collected from various retail outlets in Samsun, Türkiye. The antibacterial activity of curcumin against *S. aureus* was evaluated both *in vitro* (medium) and in the chicken meat samples. The curcumin solution (Sigma, C

1386, CAS No: 458-37-7, St. Louis, MO, USA) was prepared at final concentrations of 1%, 2%, and 3% using 20% dimethyl sulfoxide (DMSO, Isolab, CAS No: 67-68-5, Eschau, Germany). The inertness of DMSO was confirmed using a negative control. *S. aureus* ATCC 25923 was utilized as the positive control.

2.1 Determination of Antibacterial Activity

The *in vitro* antibacterial efficiency of curcumin on *S. aureus* was determined using the disk diffusion method [14]. The bacteria were initially incubated on Mueller-Hinton Agar (MHA, Merck 103872, Darmstadt, Germany) at 37 °C for 18–24 hours. After incubation, 3–5 bacteria were selected and transferred into tubes containing 5 mL of Mueller-Hinton Broth (MHB, Merck 110293, Darmstadt, Germany), followed by incubation at 35 °C for 2–6 hours until visible turbidity developed. The bacterial suspension was adjusted to 0.5 McFarland (approximately 1.5×10^8 CFU/mL) using a compact benchtop densitometer (DEN-1, Biosan, Riga, Latvia). The concentration was adjusted to a final value of 1×10^6 CFU/mL. A volume of 100 µL of this suspension was evenly spread onto the surface of MHA plates. Sterile 6 mm diameter discs were placed on the agar surface, and 25 µL of curcumin solution was applied to each disc at four different concentrations: 200 mg (5000 µg/disc), 100 mg (2500 µg/disc), 50 mg (1250 µg/disc), and 25 mg (625 µg/disc). Dimethyl sulfoxide (DMSO; 25 µL) served as the negative control, while gentamicin (10 µg/mL) was used as the positive control. The inoculated plates were incubated at 35 °C for 16–20 hours [8]. The diameters of the inhibition zones were measured following the incubation. Zones were classified as follows: $<$9 mm, inactive; 9–12 mm, partially active; 13–18 mm, active; and $>$18 mm, very active. Inhibition zones $\geq$9 mm indicated that the bacteria were affected and that the antibacterial agent (curcumin) was effective [15]. All experiments were conducted in triplicate.

2.2 Determination of the Minimum Inhibition Concentration (MIC)

The microdilution method was used to determine the MIC values in accordance with the guidelines of the Clinical and Laboratory Standards Institute (CLSI) [14]. For this purpose, the bacterial suspension was adjusted to 0.5 McFarland standard (1.5×10^8 CFU/mL). Then, the final inoculum was adjusted to 1×10^5 CFU/mL. The dilutions of curcumin were prepared at concentrations ranging from 500 µg to 1.95 µg. The MIC value was defined as the lowest concentration of curcumin at which visible bacterial growth was inhibited. All MIC measurements were performed in triplicate [16].

2.3 Experimental Contamination of Chicken Meat

S. aureus ATCC 25923 was grown in Tryptic Soy Broth (TSB, Merck 105459, Darmstadt, Germany) at 37 °C for 18–24 hours. The bacterial concentration on Baird-Parker Agar (BP, Merck 105406, Darmstadt, Germany) was measured as 2.0×10^8 CFU/mL. A total of 1000 g of chicken meat was divided into four groups: control, 1% curcumin, 2% curcumin, and 3% curcumin (all prepared in 20% DMSO). The chicken samples were initially contaminated by immersion in 100 mL of TSB that included 2.0×10^8 CFU/mL *S. aureus* and kept at room temperature for 15 minutes to facilitate the attachment of the bacteria. The samples were removed from the bacterial suspension and immersed in 100 mL of 1%, 2%, and 3% curcumin solution (in 20% DMSO). The control group was treated similarly but immersed in 20% DMSO without curcumin. Following treatment, microbiological analysis was performed immediately on the day 0 samples. The remaining samples were stored at +4 °C, and further analyses were conducted on days 2, 4, and 6 of storage.

2.4 Microbiological Analyses

We enumerated *S. aureus* following the procedure described in EN ISO 6888-1. Briefly, 10 g of chicken meat sample was placed into a sterile plastic bag, to which 90 mL of Maximum Recovery Diluent (MRD; Merck 112535, Darmstadt, Germany) was added. The mixture was homogenized for three minutes using a stomacher, and tenfold serial dilutions were prepared. The dilutions were inoculated onto the Baird-Parker agar via the drop plate method and incubated at 37 °C for 24–48 hours. Colonies exhibiting typical morphology (black to dark brown in color, convex, smooth edges, 1–3 mm in diameter, and surrounded by a halo) were counted as *S. aureus* [17]. The isolates were biochemically confirmed by Gram staining, catalase, coagulase, hemolysis, glucose, mannitol, DNAse, and Staphaurex Plus Latex tests. All analyses were performed in triplicate to ensure accuracy.

2.5 Sensory Analyses

Sensory evaluation was conducted to assess the organoleptic acceptability of curcumin-treated chicken meat. For this purpose, chicken samples treated with 1%, 2%, and 3% curcumin were portioned into 100 g servings and cooked in a pan until they reached an internal temperature of 72 °C. A panel of ten healthy individuals, aged between 22 and 45 years, with balanced gender representation, evaluated the samples using a nine-point hedonic scale. None of the panelists had known taste or smell disorders. Although their prior experience with sensory analysis varied, all panelists were trained on the evaluation procedure before testing to ensure consistency and reliability. The evaluation criteria included color, odor, flavor, texture, appearance, and overall acceptability. On the scale, 9 indicated “I like it very much”; 8 meant “I like it much”; 7 meant “I like it moderately”; 6 meant “I like it a little”, and 5 meant “I neither like nor dislike it”. Lower scores indicated increasing dislike: 4 meant “I dislike it a little”; 3

Table 1. Number of *S. aureus* in chicken meat treated with curcumin on storage days of 0, 2, 4, and 6.

Treatment group (*S. aureus*) (CFU/mL)	Storage duration (day)	*S. aureus* counts (CFU/mL)				Treatment group (*S. aureus*) (log CFU/g)	Storage duration (day)	*S. aureus* counts (log CFU/g)			
		Control	1% Curcumin	2% Curcumin	3 % Curcumin			Control	1% Curcumin	2% Curcumin	3% Curcumin
2.0×10^8	0 day	2.6×10^6	2.4×10^6	1.9×10^6	4.0×10^5	8.30	0 day	6.41 ± 0.01^{a}	6.38 ± 0.01^{b}	6.27 ± 0.01^{c}	5.60 ± 0.01^{d}
	2 day	2.8×10^6	1.9×10^6	4.9×10^5	3.9×10^5		2 day	6.44 ± 0.01^{e}	6.27 ± 0.01^{f}	5.69 ± 0.01^{g}	5.59 ± 0.01^{d}
	4 day	2.0×10^6	8.0×10^5	8.1×10^5	6.0×10^5		4 day	6.30 ± 0.01^{h}	5.90 ± 0.01^{i}	5.90 ± 0.01^{i}	5.77 ± 0.01^{i}
	6 day	2.3×10^6	7.5×10^5	4.0×10^5	6.6×10^4		6 day	6.36 ± 0.01^{j}	5.87 ± 0.01^{k}	5.60 ± 0.01^{l}	4.81 ± 0.01^{m}

Superscript letters (a, b, c…m) indicate statistically significant differences ($p < 0.05$) between mean *S. aureus* counts across different curcumin concentrations and incubation times.

Table 2. Log reduction in *S. aureus* counts on storage days of 0, 2, 4, and 6.

Storage duration (day)	Reduction in bacterial count (log CFU/g)			
	Control	1% Curcumin	2% Curcumin	3% Curcumin
0	1.89 ± 0.01^{ab}	1.92 ± 0.01^{c}	2.03 ± 0.01^{d}	2.70 ± 0.01^{e}
2	1.86 ± 0.01^{a}	2.03 ± 0.01^{f}	2.61 ± 0.01^{g}	2.71 ± 0.01^{e}
4	2.00 ± 0.01^{b}	2.40 ± 0.01^{h}	2.40 ± 0.01^{h}	2.53 ± 0.01^{i}
6	1.94 ± 0.01^{ab}	2.43 ± 0.01^{j}	2.70 ± 0.01^{k}	3.49 ± 0.01^{l}

Superscript letters (a, b, c…l) indicate statistically significant differences ($p < 0.05$) between groups in *S. aureus* counts across different curcumin concentrations and incubation times.

meant “I dislike it moderately”; 2 meant “I dislike it very much”, and 1 meant “I dislike it extremely”. Each panelist scored the samples based on these criteria [18].

2.6 Statistical Analysis

Statistical analysis was performed using the SPSS 21 software package programs (SPSS Inc., Chicago, IL, USA). Differences between groups were assessed by one-way analysis of variance (ANOVA) followed by Tukey’s post-hoc test. A significance level of $p < 0.05$ was applied.

3. Results

In this study, curcumin demonstrated significant antibacterial effects against *S. aureus* in chicken meat, with the 3% concentration achieving a notable reduction of 3.49 log CFU/g; however, sensory evaluation revealed that the 1% and 2% concentrations were more favorably received in terms of organoleptic qualities.

3.1 Antibacterial Activity Assay

At the conclusion of the disc diffusion assay, the average inhibition zone diameters were recorded as 13 mm for curcumin at 200 mg/mL dissolved in DMSO, 11 mm for 100 mg/mL, and 9 mm for 50 mg/mL. The positive control, gentamicin, produced zone diameters ranging between 22 and 23 mm. These findings were interpreted based on the size of the inhibition zones. The results were interpreted based on the size of the inhibition zones: zones smaller than 9 mm were classified as inactive; zones between 9 and 12 mm as partially active; zones from 13 to 18 mm as active; and zones larger than 18 mm as highly active. In this study, the MIC of curcumin against *S. aureus* ATCC 25923 was determined to be 125 µg/mL using the microdilution method.

3.2 Experimental Contamination With S. aureus

The *S. aureus* counts in chicken meat contaminated at 2.0×10^8 CFU/mL and subsequently treated with 1%, 2%, and 3% curcumin during storage periods of 0, 2, 4, and 6 days are presented in Table 1. At the end of the 6th day, the number of *S. aureus* was 2.3×10^6 CFU/mL in the control group, and 7.5×10^5 CFU/mL, 4.0×10^5 CFU/mL, and 6.6×10^4 CFU/mL in the 1%, 2%, and 3% curcumin groups, respectively. Considering the logarithmic reduction levels in the number of bacteria, the number of *S. aureus* decreased by 2.43, 2.70, and 3.49 log CFU/g at the end of the 6th day as a result of the application of 1%, 2%, and 3% curcumin solutions (Table 2).

3.3 Sensory Assessment

Table 3 presents the sensory assessment data for chicken meat samples treated with different concentrations of curcumin. Curcumin is a natural yellow pigment, and as its concentration increased, a more intense yellow coloration was observed in the chicken samples. This pronounced yellow color, especially at 3% curcumin, was associated with decreased acceptability in terms of color and odor, as the panelists found the color unnatural and the taste too strong. In contrast, samples treated with 1% and 2% curcumin showed higher sensory acceptance. There were no significant differences between the groups in terms of texture. The panelists noted that 1% curcumin produced a mild taste, aroma, and odor, while 3% curcumin produced a dominant yellow color and a pungent odor. Although 3% curcumin demonstrated the greatest antibacterial activity by significantly reducing bacterial counts, it negatively affected sensory acceptability. Therefore, the 1% and 2% curcumin concentrations were considered acceptable from an organoleptic perspective.

Table 3. Sensory assessment results of curcumin in chicken meat.

Criterion	Sensory assessment		
	1% Curcumin	2% Curcumin	3% Curcumin
Appearance	6.3 ± 0.80^a	7.5 ± 0.52^b	6.6 ± 0.45^c
Colour	6.3 ± 0.88^a	6.6 ± 0.48^b	4.6 ± 0.49^c
Smell	5.3 ± 0.84^a	5.5 ± 0.48^a	3.6 ± 0.53^b
Taste	5.1 ± 1.40^a	5.3 ± 0.82^a	3.6 ± 0.67^b
Texture	6.5 ± 1.14^a	6.0 ± 0.59^b	6.1 ± 0.45^b

Statistically significant difference at $p < 0.05$ is showed between mean values shown with different letters in the same line.

Superscript letters (a, b, and c) indicate significant differences ($p < 0.05$) in sensory changes between different curcumin concentrations.

Note: Scores are based on a 9-point hedonic scale, where 9 = “like extremely”, 8 = “like very much”, 7 = “like moderately”, 6 = “like slightly”, 5 = “neither like nor dislike”, 4 = “dislike slightly”, 3 = “dislike moderately”, 2 = “dislike very much”, and 1 = “dislike extremely”.

4. Discussion

S. aureus is an opportunistic foodborne pathogen causing significant community and nosocomial diseases worldwide [2]. The development of new food preservation methods utilizing the antibacterial activity of curcumin, the primary active compound derived from the turmeric plant, is crucial for public health. Although curcumin has low water solubility, limited bioavailability, and pharmacokinetic characteristics, it possesses powerful antibacterial activities [10].

In this study, the active dose of curcumin was determined as 200 mg/mL. The effectiveness of curcumin’s antibacterial activity may differ based on the solvents used and the particular *S. aureus* strains examined. Similarly, Gupta *et al.* [8] reported that 50 mg/mL curcumin benzene extract created a zone diameter of 9 mm (less effective), but that it was made more effective by using a methanol extract, resulting in a 15 mm diameter zone. Negi *et al.* [19] ob-

served inhibition zones of 9 mm and 21 mm with curcumin in ethanol and hexane extracts, respectively. These findings suggest that curcumin's activity increases with concentration and varies depending on the extraction method. It was also reported by researchers that curcumin prepared from a methanol extract is more effective than that prepared from petroleum ether, chloroform, and benzene [8].

Curcumin's antibacterial effect depends on several mechanisms, including bacterial cell membrane damage, inhibition of bacterial DNA replication, modification of gene expression, inhibition of the quorum-sensing system, and decreased motility of microorganisms [6,20]. In this study, the formation of an active inhibition zone by curcumin against *S. aureus* demonstrated its antibacterial effects, which align with the results of other studies [8,19].

In this study, the MIC of curcumin against *S. aureus* ATCC 25923 was determined as 125 µg/mL. This value is consistent with the study by Altunatmaz *et al*. [21], who reported the same MIC using a macro-dilution method. Other studies have reported similar but slightly varying MIC values; for example, Mun *et al*. [22] found MIC values ranging from 125 to 250 µg/mL against different *S. aureus* strains, while Tajbakhsh *et al*. [23] reported a MIC of 187.5 µg/mL against *S. aureus* ATCC 25923 using broth dilution. Variation in MIC values across studies may arise due to differences in bacterial strains, such as Meticillin-resistant *S. aureus* (MRSA) or methicillin-sensitive *S. aureus* (MSSA), sources of isolates (standard strains versus clinical isolates), antibacterial testing methods (disk diffusion versus broth dilution), and the type or purity of curcumin used [24].

It is important to acknowledge several limitations of this study. The use of DMSO as a solvent, although used as a negative vehicle control, may have subtle effects on antibacterial activity. Additionally, the study focused on a single *S. aureus* strain, which limits the generalizability of the findings to other clinical isolates. Future research should consider evaluating curcumin's antibacterial efficacy against a broader range of *S. aureus* strains, including resistant clinical isolates, and investigate the potential synergistic effects of curcumin combined with other antimicrobials.

In our study, the *S. aureus* population was reduced by 2.43, 2.70, and 3.49 log CFU/g after six days of treatment with 1%, 2%, and 3% curcumin, respectively. These findings are in line with the study by Altunatmaz *et al*. [21], who demonstrated that minced meat treated with 2% curcumin showed a reduction of approximately 3 log CFU/g by day 7. Similarly, 0.5% and 1% curcumin led to reductions of about 2 log CFU/g. However, Lourenço *et al*. [25], who used turmeric powder rather than isolated curcumin, found that 1% turmeric did not significantly reduce the counts of *S. aureus* in chicken meat. These results highlight the stronger efficacy of pure curcumin compared to whole turmeric, likely due to higher concentrations of the active compound. Hosny *et al*. [26] reported complete elimination of *S. aureus* from Karishcum cheese after 14 days of treatment with 0.3% curcumin. However, several studies have confirmed that an increasing curcumin concentration enhances antibacterial efficacy but may compromise sensory acceptability [21].

In this study, the 3% curcumin treatment exhibited the highest antibacterial activity but resulted in reduced sensory acceptability due to strong yellow coloration and intense odor. This observation is consistent with that of Altunatmaz *et al*. [21], who reported that as the dose of curcumin increased, its antimicrobial characteristics also increased, but its sensory characteristics decreased, particularly in terms of color. The panelists stated that 2% curcumin was disliked in ground beef, as it spoiled the natural red color of the ground beef. The same researchers found that doses of 0.5% and 1% curcumin were acceptable in terms of sensory factors. Milon *et al*. [27] found that 0.2% turmeric powder was more acceptable in terms of nutritional quality, as well as physicochemical and biochemical characteristics in a study in which the sensory characteristics of meatballs were examined after adding 0.1%, 0.2%, and 0.3% turmeric powder to ground beef. The authors reported that 0.3% turmeric powder was more satisfactory in terms of antimicrobial effects.

In the study conducted by Tangkham [28], the sensory characteristics of ground beef with 0%, 1% and 2% added turmeric powder were investigated following heat treatment at 70 °C. At the end of the study, no significant difference was detected between the three applications in terms of texture or overall taste, although the 1% treatment received high scores for color (7.89) and flavor (7.34). Purwanti *et al*. [29] reported that the application of 2.5% turmeric powder in poultry meat was acceptable as a food additive for increasing the physical and sensory qualities.

Several recent studies have highlighted the promising antimicrobial potential of curcumin against foodborne pathogens. Sharma *et al*. [30] demonstrated enhanced antibacterial activity of curcumin-loaded nanoparticles against *S. aureus*, while Terzi Gulel *et al*. [31] reviewed curcumin's efficacy in meat preservation, emphasizing both microbial inhibition and sensory quality. Patel *et al*. [32] discussed the molecular mechanisms underlying curcumin's antimicrobial effects, supporting our MIC findings. Additionally, Morsy *et al*. [33] evaluated curcumin's role in improving food safety, noting its antioxidant and sensory impacts consistent with our observations. These recent findings further validate the potential of curcumin as a natural preservative in food applications.

As observed in previous studies, while the intense yellow color of curcumin can limit its application in red meat and dairy products, it may enhance the visual and flavor attributes of poultry. Therefore, moderate concentrations of curcumin could be suitable as a natural antimicrobial and coloring agent in chicken meat products.

5. Conclusion

Currently, consumers prefer preservation methods that do not harm human health, and they wish to consume foods that do not contain additives. There is a need to develop natural methods as an alternative to chemical agents for controlling *S. aureus*, an important pathogen that causes food-borne poisoning. This study highlights the potential of curcumin, a natural bioactive compound extracted from the turmeric plant (*Curcuma longa*), as an effective antibacterial agent against *S. aureus*. Given its antimicrobial properties, curcumin is recommended for use in food preservation to help inhibit the growth of harmful bacteria and extend the shelf life of food products.

Availability of Data and Materials

The data mentioned in the article will be available with the corresponding author.

Author Contributions

Conceptualization: GTG. Data curation: ZF, GTG. Formal analysis: ZF, GTG. Methodology: ZF, GTG. Software: ZF, GTG. Validation: ZF, GTG. Investigation: ZF, GTG. Writing — original draft: ZF, GTG. Writing — review & editing: GTG. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

This study constitutes a part of the Master's thesis. Additionally, a summary of this work was presented as a poster at the 5th International Eurasian Conference on Biological and Chemical Sciences (Eurasian Bio Chem 2022), held from November 23 to 25 in Ankara.

Funding

The research was financially supported by the Scientific Research Project Commission of Ondokuz Mayis University (Project Number: PYO.VET.1904.21.019).

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Kralik G, Kralik Z, Grčević M, Hanžek D. Quality of chicken meat. In Yucel B, Taskin T (eds.) Animal husbandry and nutrition (pp. 63–94). IntechOpen: Croatia. 2018.

[2] Paterson GK, Harrison EM, Holmes MA. The emergence of mecC methicillin-resistant Staphylococcus aureus. Trends in Microbiology. 2014; 22: 42–47. https://doi.org/10.1016/j.tim.2013.11.003.

[3] Sergelidis D, Angelidis AS. Methicillin-resistant Staphylococcus aureus: a controversial food-borne pathogen. Letters in Applied Microbiology. 2017; 64: 409–418. https://doi.org/10.1111/lam.12735.

[4] Sahin SE, Mogulkoc MN, Kalin R, Karahan M. Determination of the important toxin genes of Staphylococcus aureus isolated from meat samples, food handlers and food processing surfaces in Turkey. Israel Journal of Veterinary Medicine. 2020; 75: 42–49.

[5] Saka E, Terzi Gulel G. Detection of Enterotoxin Genes and Methicillin-Resistance in Staphylococcus aureus Isolated from Water Buffalo Milk and Dairy Products. Journal of Food Science. 2018; 83: 1716–1722. https://doi.org/10.1111/1750-3841.14172.

[6] Tyagi P, Singh M, Kumari H, Kumari A, Mukhopadhyay K. Bactericidal activity of curcumin I is associated with damaging of bacterial membrane. PloS One. 2015; 10: e0121313. https://doi.org/10.1371/journal.pone.0121313.

[7] Munir Z, Banche G, Cavallo L, Mandras N, Roana J, Pertusio R, *et al*. Exploitation of the Antibacterial Properties of Photoactivated Curcumin as 'Green' Tool for Food Preservation. International Journal of Molecular Sciences. 2022; 23: 2600. https://doi.org/10.3390/ijms23052600.

[8] Gupta A, Mahajan S, Sharma R. Evaluation of antimicrobial activity of *Curcuma longa* rhizome extract against *Staphylococcus aureus*. Biotechnology Reports (Amsterdam, Netherlands). 2015; 6: 51–55. https://doi.org/10.1016/j.btre.2015.02.001.

[9] Aggarwal BB, Sundaram C, Malani N, Ichikawa H. Curcumin: the Indian solid gold. Advances in Experimental Medicine and Biology. 2007; 595: 1–75. https://doi.org/10.1007/978-0-387-46401-5_1.

[10] Adamczak A, Ożarowski M, Karpiński TM. Curcumin, a Natural Antimicrobial Agent with Strain-Specific Activity. Pharmaceuticals (Basel, Switzerland). 2020; 13: 153. https://doi.org/10.3390/ph13070153.

[11] Council Directive. European Parliament and Council Directive 94/36/EC of 30 June 1994 on colours for use in foodstuffs. Official Journal L. 1994; 237: 13–29. Available at: https://faolex.fao.org/docs/pdf/eur18711.pdf (Accessed: 12 November 2025).

[12] European Food Safety Authority. Refined exposure assessment for curcumin (E 100). EFSA Journal. 2014; 12: 3876. Available at: https://www.efsa.europa.eu/en/efsajournal/pub/3876 (Accessed: 12 November 2025).

[13] Zheng D, Huang C, Huang H, Zhao Y, Khan MRU, Zhao H, *et al*. Antibacterial Mechanism of Curcumin: A Review. Chemistry & Biodiversity. 2020; 17: 1–14. https://doi.org/10.1002/cbdv.202000171.

[14] Clinical and Laboratory Standards Institute (CLSI). Performance standards for anti-microbial susceptibility testing. CLSI Supplement M100, 30th ed. Clinical and Laboratory Standards Institute, 2020; M100: 58–68. Available at: https://www.nih.org.pk/wp-content/uploads/2021/02/CLSI-2020.pdf (Accessed: 12 November 2025).

[15] Alves TM, Silva AF, Brandão M, Grandi TS, Smânia E, Smânia Júnior A, *et al*. Biological screening of Brazilian medicinal plants. Memorias do Instituto Oswaldo Cruz. 2000; 95: 367–373. https://doi.org/10.1590/s0074-02762000000300012.

[16] Gunes H, Gulen D, Mutlu R, Gumus A, Tas T, Topkaya AE. Antibacterial effects of curcumin: An in vitro minimum inhibitory concentration study. Toxicology and Industrial Health. 2016; 32: 246–250. https://doi.org/10.1177/0748233713498458.

[17] International Organisation of Standardisation (ISO 6888). Microbiology of the Food Chain-Horizontal Method for the Enumeration of Coagulase-Positive Staphylococci (Staphylococcus aureus and Other Species). Part 1: Method Using Baird-Parker Agar Medium. International Organization for Standardization.

2021. Available at: https://www.iso.org/standard/76672.html (Accessed: 12 November 2025).
[18] Govaris A, Solomakos N, Pexara A, Chatzopoulou PS. The antimicrobial effect of oregano essential oil, nisin and their combination against Salmonella Enteritidis in minced sheep meat during refrigerated storage. International Journal of Food Microbiology. 2010; 137: 175–180. https://doi.org/10.1016/j.ijfoodmicro.2009.12.017.
[19] Negi PS, Jayaprakasha GK, Jagan Mohan Rao L, Sakariah KK. Antibacterial activity of turmeric oil: a byproduct from curcumin manufacture. Journal of Agricultural and Food Chemistry. 1999; 47: 4297–4300. https://doi.org/10.1021/jf990308d.
[20] Trigo-Gutierrez JK, Vega-Chacón Y, Soares AB, Mima EGDO. Antimicrobial Activity of Curcumin in Nanoformulations: A Comprehensive Review. International Journal of Molecular Sciences. 2021; 22: 7130. https://doi.org/10.3390/ijms22137130.
[21] Altunatmaz SS, Aksu FY, Issa G, Kahraman BB, Altiner DD, Buyukunal SK. Antimicrobial effects of curcumin against L. monocytogenes, *S. aureus*, S. Typhimurium and *E. coli* O157: H7 pathogens in minced meat. Veterinární medicína. 2016; 61: 256–262. https://doi.org/10.17221/8880-VETMED.
[22] Mun SH, Joung DK, Kim YS, Kang OH, Kim SB, Seo YS, *et al*. Synergistic antibacterial effect of curcumin against methicillin-resistant Staphylococcus aureus. Phytomedicine: International Journal of Phytotherapy and Phytopharmacology. 2013; 20: 714–718. https://doi.org/10.1016/j.phymed.2013.02.006.
[23] Tajbakhsh S, Mohammadi K, Deilami I, Zandi K, Fouladvand M, Ramedani E, *et al*. Antibacterial activity of indium curcumin and indium diacetylcurcumin. African Journal of Biotechnology. 2008; 7: 3832–3835.
[24] Teow SY, Liew K, Ali SA, Khoo ASB, Peh SC. Antibacterial Action of Curcumin against *Staphylococcus aureus*: A Brief Review. Journal of Tropical Medicine. 2016; 2016: 2853045. https://doi.org/10.1155/2016/2853045.
[25] Lourenço TC, Mendonça EP, Nalevaiko PC, Melo RT, Silva PL, Rossi DA. Antimicrobial effect of turmeric (Curcuma longa) on chicken breast meat contamination. Brazilian Journal of Poultry Science. 2013; 15: 79–82. https://doi.org/10.1590/S1516-635X2013000200002.
[26] Hosny IM, El-Kholy WI, Murad HA, El-Dairouty RK. Antimicrobial activity of Curcumin upon pathogenic microorganisms during manufacture and storage of a novel style cheese 'Karishcum'. The Journal of American Science. 2011; 7: 611–618.
[27] Milon M, Kabir MH, Hossain MA, Rahman M, Azad MA, Hashem MA. Value added beef meatballs using turmeric (Curcuma longa) powder as a source of natural antioxidant. International Journal of Natural and Social Sciences. 2016; 3: 52–61.
[28] Tangkham W. Sensory characteristics of three different levels of turmeric powder on beef stick product. Acta Scientific Nutritional Health. 2020; 4: 14–18.
[29] Purwanti S, Zuprizal Z, Yuwanta T, Supadmo S. Physical and sensory quality of broiler meat as influenced by dietary supplementation of turmeric (Curcuma longa), garlic (Allium sativum) and in combinations as a feed additive. Animal Production. 2018; 20: 61–69. http://doi.org/10.20884/1.jap.2018.20.1.633.
[30] Sharma J, Panwar D, Bhushan J, Mehta M, Sidhu K, Jhamb S, *et al*. An *in vitro* evaluation of antibacterial effect of curcumin-loaded chitosan nanoparticle-coated gutta-percha against *Staphylococcus aureus*. Journal of Conservative Dentistry and Endodontics. 2023; 26: 560–563. https://doi.org/10.4103/jcd.jcd_302_23.
[31] Terzi Gulel G, Kanat S, Kucukgoz E. Antibacterial effect of curcumin on *Salmonella* Typhimurium: *In vitro* and food model studies. Veterinarni Medicina. 2024; 69: 115–122. https://doi.org/10.17221/114/2023-VETMED.
[32] Patel SS, Acharya A, Ray RS, Agrawal R, Raghuwanshi R, Jain P. Cellular and molecular mechanisms of curcumin in prevention and treatment of disease. Critical Reviews in Food Science and Nutrition. 2020; 60: 887–939. https://doi.org/10.1080/10408398.2018.1552244.
[33] Morsy MK, Al-Dalain SY, Haddad MA, Diab M, Abd-Elaaty EM, Abdeen A, *et al*. Curcumin nanoparticles as a natural antioxidant and antimicrobial preservative against foodborne pathogens in processed chicken fingers. Frontiers in Sustainable Food Systems. 2023; 7: 1267075. https://doi.org/10.3389/fsufs.2023.1267075.