

Detection of coliform bacteria in some ready-to-eat foods

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Abstract

Each year, many people around the world fall ill and even die through the consumption of contaminated food. In various countries, records of foodborne microbial diseases are kept in detail, which makes it possible to obtain information about the microorganism and the food responsible for the disease. Coliform bacteria are commonly found in the intestines and in nature, and therefore they are considered indicators of sanitation. In the current study, the coliform bacteria content of chicken döner, salad and çiğ köfte samples sold in Fethiye, a popular tourist destination, was analyzed. In total, 60 samples were obtained from buffets, cafés, and restaurants. The samples were transported to the laboratory in their sales packaging under aseptic conditions with cold storage maintained and they were analyzed on the same day. The samples were tested using violet red bile (VRB) agar medium. As a result of the analyses, the mean presumptive coliform counts were found to be 1.13 log colony-forming units (CFU)/g in chicken döner, 4.37 log CFU/g in salad, and 0.86 log CFU/g in çiğ köfte. For confirmed coliform counts, verification tests were performed using brilliant green bile broth (BGBB) medium. The confirmed coliform counts were determined to range from < 1.00 to 4.48 log CFU/g in chicken döner, from 1.54 to 7.53 log CFU/g in salad and from < 1.00 to 3.70 log CFU/g in çiğ köfte. Among the tested food samples, confirmed coliforms were found in 20% of the chicken döner, 95% of the salad and 25% of the çiğ köfte samples.

Citation: Aslan G, Çiftçi M, Öncül N. 2026. Detection of coliform bacteria in some ready-to-eat foods. *Food Materials Research* 6: e009 <https://doi.org/10.48130/fmr-0026-0009>

Introduction

As the consumption of ready-to-eat foods becomes more widespread worldwide, the microbial load of these foods, which provide a favorable environment for the growth of microorganisms, should be considered a priority. To ensure a safe food chain, it is necessary to guarantee food safety at every step, from production to consumption. In this regard, the authorities involved in all stages of food production, up until the product reaches the consumer, must work in cooperation^[1,2]. If adequate hygiene and sanitation are not applied to foods during the production, preparation, or storage of foods, or during their presentation to the consumer, various microorganisms can contaminate the food. It is known that contaminated foods cause more than 200 diseases^[2].

Coliform bacteria are non-spore-forming, Gram-negative, rod-shaped bacteria that are commonly found in the intestinal systems of humans and animals. They make up a facultative anaerobic bacterial group that can ferment lactose and produce gas and acid when incubated at 35–37 °C for 48 h^[3,4]. This group primarily includes bacteria belonging to the genera *Escherichia*, *Enterobacter*, *Citrobacter*, and *Klebsiella*. Only *Escherichia coli* uses the intestinal tract as its primary habitat. The others can be found in other environments such as vegetation and soil^[5]. Since coliform bacteria are members of the *Enterobacteriaceae* family, regulations regarding their presence and quantity have been established within the framework of the microbiological standards defined in food safety legislation^[6]. In this context, coliform bacteria detected in foods indicate that sanitation conditions are inadequate, that heat treatment is insufficient or improperly applied, or that recontamination may have occurred after heat treatment. In addition, the detection of *E. coli* in foods indicates that direct or indirect fecal contamination has occurred and that other enteric pathogens may also be present^[7].

Döner kebab is one of the most popular fast-food items in Türkiye and is also consumed worldwide. Depending on preference, lamb,

mutton, beef, chicken, or turkey meat is used in its production. In the Turkish Food Codex Communiqué on Raw Red Meat and Prepared Red Meat Mixtures, it is defined as a meat product obtained by horizontally or vertically rotating and cooking mixtures made from bovine or ovine carcass meats or minced meats that have been brought to a ready-to-cook state through the addition of certain ingredients such as flavor enhancers, animal fats, milk, and eggs^[8]. The microbiological quality of döner kebab is directly affected by the microbiota of the meat used; contamination occurring during preparation, cooking and serving; and the garnishes served alongside it. In studies conducted in Türkiye to determine the microbiological quality of döner kebab, microorganisms such as the coliform group of bacteria, *Salmonella* spp., *Staphylococcus aureus*, *Bacillus cereus*, *Listeria monocytogenes*, *Clostridium perfringens*, and *E. coli* O157:H7 have been detected^[9].

Çiğ köfte is a traditional food widely consumed in Türkiye. It is prepared using the traditional method, in which raw meat, bulgur, tomato paste, and various spices are kneaded by hand for a long time. Although çiğ köfte recipes vary by geographical region and by consumer or producer preferences, the Turkish Standards Institute defines meatless çiğ köfte as "A product prepared by kneading bulgur, red pepper, onion, garlic, various spices, tomato/pepper paste, vinegar, sugar, pomegranate syrup, water and certain vegetable oils together with additives permitted by legislation by hand or machine until a specific consistency is achieved and made ready for consumption either frozen or unfrozen." Since çiğ köfte is offered for consumption without any heat treatment, it can spoil easily during storage. Because of the ingredients used in its production, the preparation conditions, personal hygiene, possible contamination during transportation and storage and the fact that it is consumed raw, it is considered to be among the high-risk foods for public health^[10,11].

Salad is a food produced by mixing raw fruits and vegetables such as cucumber, pepper, tomato, onion, carrot, lettuce, spring onion,

and radish^[12]. Because of its beneficial effects on health and in line with the recommendations of various organizations (World Health Organization [WHO], European Food Safety Authority [EFSA], Food and Agriculture Organization [FAO] and US Department of Agriculture [USDA]), it has become quite popular among consumers in recent years^[13]. In many countries, raw fruits and vegetables are commonly consumed as salad. Consuming these products raw increases the risk of foodborne diseases^[12]. These products, which act as carriers of pathogens, also lead to outbreaks of foodborne diseases worldwide^[14,15]. The fresh products used in the preparation of salads can become contaminated with microorganisms at many stages from field to fork^[14]. Many factors threaten the quality and safety of salads, such as irrigation with contaminated water, fertilization, contact with farm or wild animals before harvest, improper storage conditions and packaging materials, contaminated wash water, unhygienic tools and equipment used during processing, sick food handlers, and exposure to cross-contamination during food preparation after harvest^[16–20].

Despite the difficulties involved in the identification of the conditions that lead to foodborne diseases and their consequences, it is quite clear that most of these diseases are caused by microorganisms (bacteria)^[21]. Seen from this perspective, preventing foodborne diseases, which cause both economic and social problems such as issues in the health system, economy, tourism, and trade in both developed and developing countries, is extremely important^[22,23]. Today, as interest in healthy eating continues to increase, the demand for fresh, unprocessed, or minimally processed nutritious food products is also rising accordingly. When combined with the lack of knowledge during the processing stages, döner made from poultry meat, which carries a high risk of contamination, and çiğ köfte and salad samples that are offered to consumers without any heat treatment can pose a serious threat to public health. It is important to assess the situation to reduce and prevent foodborne outbreaks that can harm individuals' health, the country's health-care system, and commercial enterprises' economic wellbeing. In the current study, the presence of coliform bacteria was investigated to determine the microbial quality of potentially risky ready-to-eat products such as chicken döner, çiğ köfte, and salad.

Materials and methods

Materials

In the current study, ready-to-eat chicken döner, çiğ köfte, and salad samples sold in the Fethiye district of Muğla Province (Türkiye) were used as materials. The samples used in the study were obtained from several local buffets, cafés, and restaurants in Fethiye, with 20 samples from each sample group, making a total of 60 samples. The samples were collected in the same form in which they were served to customers and transported under aseptic conditions to the Research Laboratory of the Department of Nutrition and Dietetics at Fethiye Faculty of Health Sciences of Muğla Sıtkı Koçman University. Samples were transferred in a thermobox with ice packs, maintaining a temperature of approximately 4 °C, and analyzed on the same day within a maximum of 2 h after purchase.

Preparation of samples for microbiological analyses

From the chicken döner, çiğ köfte, and salad samples, 25 g each was weighed and homogenized for 3 min in a stomacher device with 225 mL of peptone water (0.1%) (Oxoid, LP0037, England)

in sterile sample bags. From the homogenate obtained, 10-fold dilutions were prepared using 1 mL of the sample and 0.1% peptone water, and these dilutions were used for determining the coliform bacteria counts^[24].

Coliform bacteria and confirmed coliform bacteria were enumerated according to the FDA's *Bacteriological Analytical Manual* (BAM) and the American Public Health Association (APHA) *Compendium of Methods for the Microbiological Examination of Foods*^[25,26].

Coliform bacteria count

Coliform bacteria were counted using the pour plate method (1 mL) with violet red bile agar (VRBA, Biokar, BK152HA, France) as the culture medium. From the prepared dilutions, 1 mL was transferred into parallel sterile petri dishes and 15–20 mL of the medium, previously melted and cooled to 40–45°C, was poured over them in a thin layer. The sample was mixed with the medium by gently rotating the plate. After the medium solidified, the petri dishes were inverted and incubated aerobically at 35–37 °C for 18–24 h (Daihan scientific, Thermo Stable IG-105, Korea)^[25,26].

Confirmed coliform bacteria count

After incubation, red colonies surrounded by a reddish precipitate zone measuring 1–2 mm in diameter on the plates were counted. For the confirmation test, 10 colonies were inoculated with a loop into brilliant green bile broth (BGBB; Merck KgaA, 1.05454.0500, Germany) containing Durham tubes and then incubated at 35–37 °C for 24–48 h. At the end of the incubation period, tubes showing gas production and membrane formation were identified, and Gram staining was performed. Tubes that were Gram-negative according to the Gram staining results were evaluated as confirmed coliforms^[26]. Based on the results obtained, the calculation was performed as follows:

$$CCC = SC \times PPT \times DF$$

CCC = Confirmed Coliform count (CFU/g)

SC = Count of suspect colonies in VRBA

PPT = Percentage of positive tubes in BGBB

DF = Dilution factor

Statistical analysis

The study was conducted with two replicates and two parallels. When incubation was completed, the plates containing between 10 and 250 colonies were evaluated, and the results were expressed as log colony-forming units (CFU)/g. The statistical analysis of the data was carried out using analysis of variance (ANOVA) with the SPSS Statistics software package (IBM SPSS Statistics Version 22; USA) at a 95% confidence level. The differences between the means were determined using the Duncan test.

Results

The coliform bacteria results for the chicken döner, çiğ köfte, and salad samples are presented in Tables 1, 2, and 3, respectively. Presumptive coliforms were detected in 33 of the tested samples (55%). In 27 samples (45%), the presumptive coliform count was below the detectable limit ($< 1.00 \pm 0.00$ log CFU/g). Among the samples in which presumptive coliforms were detected (33 samples), confirmed coliforms were found in 28 samples (84.85%) according to

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Table 1. Results for coliform bacteria in chicken döner kebab samples (log CFU/g)*.

Samples	Presumptive coliforms	Confirmed coliforms
1	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
2	2.81 ± 0.81 ^c	2.00 ± 0.11 ^c
3	3.91 ± 0.14 ^d	3.39 ± 0.14 ^d
4	1.95 ± 0.13 ^b	0.94 ± 0.14 ^b
5	1.73 ± 0.18 ^b	< 1.00 ± 0.00 ^a
6	5.13 ± 0.03^f	< 1.00 ± 0.00 ^a
7	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
8	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
9	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
10	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
11	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
12	4.58 ± 0.05 ^e	4.48 ± 0.05^e
13	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
14	2.47 ± 0.02 ^c	< 1.00 ± 0.00 ^a
15	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
16	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
17	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
18	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
19	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
20	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
Maximum value	5.13 ± 0.03	4.48 ± 0.05
Minimum value	< 1.00 ± 0.00	< 1.00 ± 0.00
Mean value	1.13	0.54

* $n = 4$, (\pm , standard deviation); different lowercase letters indicate that the values in the same column are significantly different from each other ($p > 0.05$). Values in bold indicate the highest and lowest values among the samples in each column; bold formatting is also used to highlight the summary rows.

Table 2. Results for coliform bacteria in çiğ köfte (raw meatball) samples (log CFU/g)*.

Samples	Presumptive coliforms	Confirmed coliforms
1	3.70 ± 0.01^d	3.49 ± 0.01^e
2	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
3	3.65 ± 0.09 ^d	< 1.00 ± 0.00 ^a
4	3.46 ± 0.10 ^d	3.23 ± 0.10 ^d
5	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
6	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
7	2.91 ± 0.08 ^c	2.57 ± 0.08 ^c
8	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
9	1.95 ± 0.25 ^b	1.63 ± 0.25 ^b
10	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
11	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
12	1.60 ± 0.36 ^b	1.56 ± 0.36 ^b
13	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
14	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
15	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
16	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
17	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
18	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
19	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
20	< 1.00 ± 0.00 ^a	< 1.00 ± 0.00 ^a
Maximum value	3.70 ± 0.01	3.49 ± 0.01
Minimum value	< 1.00 ± 0.00	< 1.00 ± 0.00
Mean value	0.86	0.62

* $n = 4$, (\pm , standard deviation); different lowercase letters indicate that the values in the same column are significantly different from each other ($p > 0.05$). Values in bold indicate the highest and lowest values among the samples in each column; bold formatting is also used to highlight the summary rows.

the confirmation test. Of these 28 samples, 4 were chicken döner (6.67%), 5 were çiğ köfte (8.33%), and 19 were salad samples (31.67%).

Table 3. Results for coliform bacteria in salad samples (log CFU/g)*.

Samples	Presumptive coliforms	Confirmed coliforms
1	4.47 ± 0.15 ^g	4.31 ± 0.15 ^l
2	5.28 ± 0.01 ^k	5.04 ± 0.03 ^{lm}
3	5.68 ± 0.01 ^l	5.46 ± 0.01 ⁿ
4	4.68 ± 0.03 ^{hi}	< 1.00 ± 0.00^a
5	3.79 ± 0.04 ^f	2.79 ± 0.04 ^{de}
6	5.82 ± 0.08 ^l	5.12 ± 0.08 ^m
7	2.60 ± 0.13 ^c	2.60 ± 0.13 ^d
8	7.53 ± 0.02^m	7.43 ± 0.03^o
9	5.23 ± 0.04 ^k	5.23 ± 0.04 ^m
10	3.93 ± 0.11 ^f	3.71 ± 0.12 ^g
11	4.99 ± 0.13 ^j	4.89 ± 0.13 ^{kl}
12	4.65 ± 0.08 ^{ghi}	4.55 ± 0.08 ^j
13	1.54 ± 0.08^a	1.45 ± 0.09 ^b
14	3.47 ± 0.02 ^e	3.31 ± 0.02 ^f
15	4.51 ± 0.00 ^{gh}	4.12 ± 0.01 ^h
16	4.47 ± 0.17 ^g	4.32 ± 0.18 ⁱ
17	1.98 ± 0.04 ^b	1.68 ± 0.04 ^c
18	5.05 ± 0.15 ^j	5.05 ± 0.15 ^{lm}
19	4.75 ± 0.01 ⁱ	4.71 ± 0.02 ^{jk}
20	2.97 ± 0.10 ^d	2.93 ± 0.10 ^e
Maximum value	7.53 ± 0.02	7.43 ± 0.03
Minimum value	1.54 ± 0.08	< 1.00 ± 0.00
Mean value	4.37	3.93

* $n = 4$, (\pm , standard deviation); different lowercase letters indicate that the values in the same column are significantly different from each other ($p > 0.05$). Values in bold indicate the highest and lowest values among the samples in each column; bold formatting is also used to highlight the summary rows.

In 35% of the chicken döner samples, presumptive coliforms were detected, and confirmed coliforms were found in 20% of them. In samples numbered 5, 6, and 14, where presumptive coliforms were detected, the confirmed coliform count was < 1.00 ± 0.00 log CFU/g. In the chicken döner samples, the highest confirmed coliform level was calculated in Sample 12 as 4.48 ± 0.05 log CFU/g (Table 1).

In six (30%) of the çiğ köfte samples, presumptive coliforms were detected, and in five (25%) of them, confirmed coliforms were found. Coliforms were not detected in any samples except Samples 1, 4, 7, 9, and 12. The highest coliform counts were calculated in Sample 1 (Table 2).

Presumptive coliforms were found in all the salad samples (100%), and the mean value was 4.37 log CFU/g. The lowest confirmed coliform count was detected in Sample 4 and the highest in Sample 8. Among all the salad samples, only Sample 4 showed no confirmed coliforms (Table 3).

Discussion

Providing reliable data on food safety worldwide is important for both protecting public health and preventing economic losses. WHO/Foodborne Disease Burden Epidemiology Reference Group (FERG) reports that approximately 35% of the global burden of foodborne diseases is caused by foods of animal origin^[27]. In recent years, it has become important to investigate the presence of bacteria defined as food safety indicators in ready-to-eat foods, which have rapidly become widespread worldwide^[28]. In this connection, many researchers in their respective countries are conducting studies on the microbiological quality of ready-to-eat foods and salads, and their results are being reported^[9–11,20,29–32].

If hygiene is inadequate during the slaughtering of poultry, personal and environmental contamination occurs; as a result, the

microbial load of the product, especially that of the skin, increases. For example, the use of contaminated skin in producing döner negatively affects the microbiological quality of the final product, even if heat treatment is applied. It has been determined that döner made from poultry meat has a higher microbial load compared with those made from red meat^[33]. In the current study, the confirmed coliform values of the 20 different chicken döner samples were found to range from $< 1.00 \pm 0.00$ to 4.48 ± 0.05 log CFU/g. The obtained data were found to be statistically different from each other ($p < 0.05$) (Table 1).

Alçay^[9] examined 30 cooked chicken döner samples to determine the microbiological quality of chicken döner sold in Istanbul. *Enterobacteriaceae* were detected in 12 of these samples (ranging from < 10 to 4×10^2 CFU/g), and *E. coli* was found in 6 of the samples (20%) (ranging from < 10 to 2×10^1 CFU/g). Vazgeçer et al.^[29] conducted a study in the city center of Ankara to examine the microbiological quality of chicken döner kebabs (72 samples) offered for consumption and evaluate their reliability in terms of public health. In the study, coliform group microorganisms were detected in 44% of the samples, with values reported to less than 10.0 CFU/g. Coliform group microorganisms were observed in 17% of the chicken döner samples, with values ranging from 10 to 10^2 CFU/g. It was reported that coliform bacteria were detected in 11%, 17%, and 11% of the döner samples in the range of 10^2 – 10^3 , 10^3 – 10^4 , and 10^4 – 10^5 CFU/g, respectively. In a study conducted to determine the microbiological characteristics of chicken and meat döner offered for consumption by eight enterprises in Sinop Province, 54 döner samples were examined. Coliform group bacteria were detected in all except one sample, with counts ranging from 0.389 to 1.079 log CFU/g^[34]. In a study of 60 raw or cooked beef or chicken döner samples collected in Tekirdağ, the mean value of coliform group bacteria was detected to be 4.66 log CFU/g in raw chicken döner and 2.42 log CFU/g in cooked ones^[35]. In a study investigating the presence of *Clostridioides difficile* in chicken döner samples sold in Istanbul, 12 out of 128 samples were identified as suspected *C. difficile* and two were confirmed^[36]. In a study examining the microbiological quality of 50 chicken döner samples collected from 15 different sales areas in various parts of Antakya, *E. coli* was detected in 24% of the samples and *Salmonella* spp. was found in seven samples^[37]. Türkmen and Tiske-İnan^[38] examined a total of 20 raw and cooked döner kebab samples collected from 20 different restaurants in Karaman. They determined total coliform bacteria counts ranging between 1.00 and 764 pieces per gram (pcs/g), with an average of 96.16 pcs/g for raw samples and 1.04 pcs/g for cooked ones.

Chicken döner is a heat-treated food. Its microbiological quality is negatively affected if hygiene and sanitation conditions are not properly maintained. The presence of microorganisms observed in the results can be explained by factors such as insufficient cooking during the process starting from the raw material; the use of contaminated raw materials, additives, and packaging materials; and personnel lacking adequate training.

In the current study, the confirmed coliform counts of the 20 different çiğ köfte samples ranged from $< 1.00 \pm 0.00$ to 3.49 ± 0.01 log CFU/g. The results were found to be statistically different from each other ($p < 0.05$) (Table 2).

Yurttaş^[11] aimed to determine the microbiological quality of çiğ köfte offered on the market in Çorum. For this reason, 20 çiğ köfte samples were examined in both the winter and summer months. The coliform counts of the samples were reported to range from 1.56 to 5.61 log CFU/g. Although *E. coli* was not detected in any of the samples, it was reported that the microbial quality of çiğ köfte sold during the summer period was lower. As a result of the study, it was suggested that the raw materials and additives used in the

products, as well as the ambient temperature, influenced the results. In the study by Külcü et al.^[10] 120 çiğ köfte samples collected in several cities (Trabzon, Giresun, Ordu, and Samsun) of the Black Sea region of Türkiye were examined microbiologically. In the study, the average count of coliform bacteria was found to be a minimum of 2.09 most probable number (MPN)/g and a maximum of 40.66 MPN/g. The *E. coli* count was determined to be an average of 1.25, 24.40, 38.90, and 25.11 MPN/g, respectively, for Trabzon, Giresun, Ordu, and Samsun. In another study, 50 çiğ köfte samples were collected from different retail outlets at various times in Ankara. As a result of the evaluation, it was reported that coliform bacteria were present in 86% of the samples, ranging from 2.78 to 5.71 log CFU/g^[39]. In a study conducted between 2015 and 2016 to determine the microbiological quality of çiğ köfte offered for consumption in the city centre of Ankara, 168 çiğ köfte samples were examined. Twenty-four samples were prepared with beef, and the rest were vegetarian ones (144 samples) without meat. Coliform bacteria counts were found to be < 2.30 – 6.58 log CFU/g in beef çiğ köfte, whereas the coliform counts were reported to range from < 2.30 to 5.73 log CFU/g in vegetarian çiğ köfte^[40]. The microbiological quality of çiğ köfte samples (a total of 100) obtained from various markets and restaurants in Bursa was investigated. In the analyses, the mean value of coliform bacteria in çiğ köfte samples were reported to be 2.9×10^3 CFU/g. Coliforms were detected in 77% of the çiğ köfte samples^[41].

The results of the previous studies are consistent with those of the current study, indicating that the overall microbiological quality of çiğ köfte is low. This situation can be explained by factors such as the absence of heat treatment during the production process of çiğ köfte and constant hand contact during production and sale. Moreover, the raw materials, spices, sauces, and other additives used in production are also thought to affect the microbiological quality.

In the current study, coliform group bacteria were found at a higher rate in the salad samples compared with the other sample groups. For confirmed coliforms, the results range from $< 1.00 \pm 0.00$ to 7.43 ± 0.03 log CFU/g. In 5% of the examined salad samples, confirmed coliform bacteria were found to be below the detectable level. The results are statistically different from each other ($p < 0.05$) (Table 3).

In a study conducted in Baghdad, 25 ready-made vegetable salad samples randomly collected from local restaurants, along with swab samples from the hands of the staff involved in preparation, were examined for the presence of coliforms. The total coliform counts in the examined salads ranged from 1.35 to 4.78 log CFU/g, whereas the coliform counts in the swab samples taken from the hands of the staff in the same areas ranged from 1.10 to 3.90 log CFU/g^[20]. In a study investigating the microbiological quality of commercially sold ready-made salads in Tunisia, coliform group bacteria were detected in all the 100 samples, with total coliform counts ranging from 4 to 8.57 log CFU/g. *E. coli* was detected in 11% of the samples, with counts ranging from 1.62 to 3.15 log CFU/g^[30]. In a study aiming to determine the microbial quality of freshly cut salads in restaurants located in various districts of Istanbul, 180 salad samples were analyzed. The mean total coliform counts of the collected samples were calculated according to districts, with values found to range from 1.046.5 to 3.588.1 MPN/g. In addition, *E. coli* was detected in 7.22% of all the samples^[42]. In a study examining ready-to-eat salad samples sold in supermarkets (especially leafy green vegetables), coliform group bacteria were found in all the salad samples, with counts ranging from 5.00 to 6.39 log CFU/g^[43]. Another study investigated the microbiological quality of salads and sprouts in Mexico City. In total, 200 samples were collected from supermarkets and street vendors. The mean value of coliform

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group bacteria was higher in salad samples obtained from street vendors (1,000 MPN/g) than supermarkets (56 MPN/g). Fecal coliforms were detected in 32% of the salad samples. Coliform bacteria were identified in all sprout samples, and fecal coliforms were confirmed in 69% of them. As was the case with coliform group bacteria, the fecal count was higher in samples from street vendors than in those from supermarkets^[31]. In another study, 50 salad samples were purchased from restaurants and street vendors in Alexandria District, Egypt. The mean value of total and fecal coliform bacteria was higher in samples from restaurants than from street vendors. Total and fecal coliform counts in restaurant samples ranged from 4.15 log MPN/100 g to 1.60–6.15 log MPN/100 g, respectively, whereas street vendor samples showed ranges of 2.98–4.15 log MPN/100 g for total coliforms and 1.60–4.15 log MPN/100 g for fecal coliforms^[32].

Salad products are exposed to microbiological risks during the washing, cutting, and/or grating stages of the raw materials. Before being served to consumers, the products are stored under refrigeration and, during this process, preservatives such as salt and vinegar are generally avoided because of their wilting effects. During low-temperature storage, microorganisms belonging to the *Enterobacteriaceae* family, including pathogens, can grow^[44,45].

Conclusions

Ready-to-eat meals include foods that are either consumed directly, such as desserts, salads, and cold dishes, or foods that require heating. According to Regulation (EC) No 2073/2005 and the Turkish Food Codex Microbiological Criteria Regulation, microbiological criteria for coliform bacteria are defined for certain food categories as food safety criteria; however, no specific numerical limits are established for coliform bacteria in ready-to-eat foods. In this context, coliform bacteria are primarily used as hygiene indicator microorganisms rather than food safety criteria. Therefore, elevated coliform counts observed in the examined ready-to-eat foods reflect inadequate hygienic conditions and may increase the potential risk to public health^[46,47]. Under normal conditions, coliform group bacteria are not expected to be present in heat-treated foods such as chicken döner. The detection of coliform groups in the chicken döner samples examined in the current study is thought to be caused by the high initial microbial load of the product, insufficient heat treatment, or violations of sanitation rules during serving. The results in the çiğ köfte samples were attributed to the raw materials such as vegetables and spices used in production, as well as equipment, personnel and serving utensils. The high levels of coliform bacteria detected in salads are believed to result from soil contamination or inadequate hygiene and sanitation practices throughout the process up to serving. Establishing a food safety system based on hygiene and sanitation practices is important for reducing food-borne diseases and protecting public health. Thus, by ensuring that all stakeholders in the food chain take an active role in the production and delivery of safe food, the microbiological quality of ready-to-eat foods can be improved.

Author contributions

The authors confirm their contributions to the paper as follows: study conception and design, methodology: Öncül N; data collection: Aslan G, Çiftçi M; analysis and interpretation of results, draft manuscript preparation, writing – review and editing: Aslan G, Öncül N. All authors reviewed the results and approved the final version of the manuscript.

Data availability

All data obtained during this study are included in this published article. Further information may be requested from the corresponding author.

Acknowledgments

Part of this study was presented as an oral presentation and abstract under the title "Determination of Coliform Group Bacteria in Some Foods" at the MSKU National Interdisciplinary Student Congress held on May 12–14, 2022 (Muğla, Türkiye).

Conflict of interest

The authors declare that they have no conflict of interest.

Dates

Received 9 January 2026; Revised 22 February 2026; Accepted 26 March 2026; Published online 12 June 2026

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