Comparative Evaluation of the Quality of Local and Imported Frozen Chicken Meat in Sulaymaniyah Markets, Iraq

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Abstract

In this study, the quality of domestically produced and imported frozen chicken meat available in the market in Sulaymaniyah, Iraq, for six commercial brands was evaluated. A total of 60 samples of breasts and thighs were examined for assessment quality. All the brands conformed to Iraqi standard requirements, but there were significant differences noticed. Imported brands exhibited improved appearance traits with no difference in the packaging and freezer method. However, local brands (TP and BP) excelled over imported ones in major indicators of quality: they possessed higher water-holding capacity (WHC), lower cooking loss, and the lowest total volatile nitrogen (TVN), indicating fresher protein with minimal spoilage. Conversely, imported samples (TS and BS) exhibited higher TVN, a sign of more mature protein degradation. Lipid oxidation revealed by TBARS was higher in imported brands, while local samples exhibited significantly lower readings, indicating improved fat stability. Free fatty acid (FFA) content corresponding to hydrolytic rancidity content was the highest in imported chicken and lower in local brands. Microbiologically, the lowest total plate count (TPC) was exhibited by the local brand TP, while imported TC exhibited the highest psychrotrophic bacteria number. Coliform bacteria were only identified in local brand TR but not in TP. Generally, the local frozen chicken meat exhibited improved rancidity and lower microbial risk possibilities, perhaps owing to the shorter supply chains and quicker turnovers. However, variability between local and imported brands again underlines the necessity to boost and put uniform quality control measures in place for all poultry products on the market.

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Introduction

Poultry meat plays a crucial role in meeting global protein demands and ensuring food security [1-3]. It provides essential nutrients, including protein, vitamins, and minerals, and is associated with reduced risks of obesity, cardiovascular diseases, and type 2 diabetes when consumed as part of a balanced diet [4-6]. With the increasing demand for high-quality and safe poultry products, a significant portion of chicken meat in many regions, including Sulaymaniyah city in the Kurdistan Region of Iraq, is imported from international producers [7].

Frozen chicken has become increasingly popular due to changing consumer lifestyles and its longer shelf life [8]. These changes can ultimately affect the appearance, texture, flavor, nutritional value, and safety of the final product. Therefore, a comprehensive evaluation of physical, chemical, and microbial quality is crucial for maintaining consumer trust and regulatory compliance [9]. Frozen chicken meat quality highlights the impact of temperature and processing methods. [10]. Studies on imported frozen chicken meat have revealed significant microbial contamination and potential health risks. High prevalence of coliforms was found in samples from various countries [11].

Recent research has focused on improving appearance evaluation methods for frozen chicken meat. Color is a critical factor in assessing meat quality and influencing consumer selection [12]. Color directly relates to meat freshness and influences consumer purchase decisions [13] Research on frozen chicken breast meat quality has examined various aspects of storage and thawing. Freezing duration affects meat quality, with longer storage periods leading to increased drip loss, color changes, and reduced sensory properties [14].

The pH of frozen chicken meat tends to decrease over time, with lower storage temperatures resulting in lower pH values [15]. Freezing and thawing processes significantly impact the physical quality parameters of poultry meat. During frozen storage, meats experience changes in water content, pH, color, electrical conductivity, and water absorption, with poultry showing higher water loss and increased lightness [16, 17].

Chemical spoilage indicators are crucial for assessing the quality of frozen poultry meat. TVN and TBARS are key indicators that increase with storage time and correlate strongly with microbial growth, particularly *Pseudomonas spp*.[18]. The development of secondary lipid oxidation products is indicated by a rise in TBARS value during storage. During storage, pro-oxidant chemicals such as ferric ions are released, speeding up the rate of lipid oxidation [19]. Recent studies have examined the microbial quality of frozen and fresh chicken meat. Frozen chicken generally exhibits lower bacterial counts and is considered microbiologically safer than fresh chicken [20, 21].

This study aims to conduct a comprehensive evaluation of the quality of local and imported frozen chicken meat available in Sulaymaniyah markets, Iraq, to provide valuable insights into consumer health implications, inform regulatory standards, and support quality control measures for poultry meat in both local and international supply chains.

Materials and Methods

Collection Sample : This study was conducted to assess the label, appearance evaluation, physical, chemical, and microbial quality of frozen chicken meat from 6 different brands that are produced locally and abroad and available in the markets of Sulaymaniyah city: (R, P, C, S, Q, B).

A total of 60 chicken samples were collected, consisting of 30 breast and 30 thigh samples (5 breast (B) and 5 thigh (T) samples from each brand). The samples were collected using a random selection method to avoid bias in choosing specific products or brands. This means that poultry products were bought without prior preference from a variety of markets and retail stores in Sulaymaniyah that sell local and imported chicken. Samples were selected within a similar production period (not exceeding 30 days apart) to reduce variability due to extended frozen storage. Immediately after purchase, the samples were transported to the laboratory in an insulated cooler box containing dry ice to maintain proper temperature and prevent thawing. Upon arrival at the Animal Sciences Laboratory in the College of Agricultural Engineering Science, University of Sulaimani, samples were stored in a deep freezer (-18°C) until further analysis.

Evaluation Parameter

Brand labeling and packaging: The labeling information available on sample covers had been read for the purpose of compliance with Iraqi Standard regulation, which deals with food labeling [22].

Appearance Evaluation: Visible color, overall appearance, ice spots, and packaging condition were evaluated visually. Ice spots and packaging condition were assessed directly upon removing the samples from the freezer, while visible color and overall appearance were evaluated after thawing at 4 ± 1°C for 12–16 hours. Assessments were performed under standardized white lighting using a 5-point scale (1 = poor, 5 = excellent) by a panel of 3–5 members who were not informed of the origin of the products.

Physical Analysis:

Water-Holding Capacity (WHC): WHC was measured by modifying a method described previously by Szmańko, et al. [23]. WHC was measured by modifying a method described previously by [23]. Briefly, 2 g of the meat samples were put in a 15 mL conical tube with gauze underneath. The tube was then centrifuged at 3000 rpm for 10 min at room temperature. WHC was calculated by comparing the weight of the samples before and after centrifugation, using the following formula:

$$WHC\ (\%) = [(w1 - w2) / w1] \times 100$$

where, w1= weight of meat samples before centrifugation (g), and w2 = weight of meat samples after centrifugation (g).

Thawing Loss: The frozen sample was weighed, then left to thaw completely in a plastic bag at a refrigerated temperature (4°C) for 24 hours [24]. The drip liquid was removed, then the samples reweighed, the thawing loss was determined as a percentage by using the equation below:

Thawing Loss (%) = [(w1 – w2) / w1] × 100

where, w1 = Frozen sample before thawing (g) and w2 = Frozen sample after thawing (g).

Cooking loss: Cooking loss is determined according to the method of Xia, et al. [25] with some modifications. Briefly, 10 g of thaw samples are placed in heat-stable foil paper and keep in a water bath at 80°C for 30 until the center temperature reached 70 ˚C. Weighing the samples before and after cooking was used to assess the cooking loss:

Cooking loss (%) = [(w1 – w2) / w1] × 100

where, w1 = meat weight before cooking (g) and w2 = meat weight after cooking (g).

pH Measurement: The pH of meat samples was determined using a digital pH meter (Hanna Instruments, USA), calibrated with standard pH 4.0 and pH 7.0 buffers before measurement. A homogenized suspension of 10 g of meat in 90 mL of distilled water was prepared, and the pH was recorded [21].

Chemical indicators

Total volatile nitrogen (TVN): TVN was determined by extracting the Ten grams of minced meat were blended with 25 ml of 7.5% Trichloroacetic Acid (TCA), filtered, and 12.5 ml of the filtrate was distilled with 2.5 ml of 10% NaOH using a macro-Kjeldahl apparatus. The distillate was collected in 7.5 ml of 4% boric acid and titrated with 0.05 N H_2SO_4 using methyl red–red-bromocresol green as an indicator according to the method of Malle and Poumeyrol [26] with slight modifications. The TVN value was estimated as follows:

$$TVN(mg/100\,gm) = \frac{V * 14 * \left(100 + \left(\frac{M}{100}\right) * 100\right)}{12.5 * 50}$$

Where: V=ml of 0.05 0f H_2SO_4, M=moisture content

Thiobarbituric Acid Reactive Substances (TBARS): Lipid oxidation in chicken meat samples is determined using TBARS according to the method described by by Xia, et al. [25] with slight modifications. 10 g of each meat canning sample is weight out and homogenize. Then, 50 mL of 7.5% (w/v) trichloroacetic acid (TCA) solution is added and the mixture is a vortex for 30 min. The sample solution is filtered through Whatman No.1 filter paper, and then 5 mL of 20 mM 2-thiobarbituric acid is added and the mixture is boiled in a water bath for 40 min. The sample is cool to 20-25 ˚C for 30 min and centrifuged at 5500 rpm and 25 ˚C for 25 min. The absorbance of the supernatant is measure at 532 nm. The TBARS values are express as mg malonaldehyde/kg sample (mg MA/kg) and calculated as follows:

TBA = (A532 / w) × 9.48

where w is the sample weight and A532 is the absorbance.

Free fatty acids (FFA): Weights of 10 gm of the sample were placed in a mechanical blender, and 25 ml of chloroform was added, the mixture was blended for 2-3 min and filtered immediately through a large filter paper. This was then re-filtered through a paper containing a small amount of anhydrous sodium sulfate [27]. Portions of the filtrate were used for the determination of free fatty acids as follows: Five ml of 95% ethanol neutralized with

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drops of 0.1 N NaOH after adding phenolphthalein. The solution was added to 5 ml of the filtered and the mixture was tittered with 0.1 N NaOH until the pink color persists for 15 seconds. The FFA calculates oleic acid as a percentage of the sample:

$$FFA\% = \frac{\text{ml of 0.1 NaoH} \times 0.0282 \times \text{dilution factor}}{\text{sample weight}} \times 100$$

Microbiological Analysis: Meat samples were microbiologically analyzed by homogenization in peptone water, serial dilution, and pour plate inoculation, followed by incubation and colony counting to determine bacterial load (CFU/g) based on standard methods.

Ten grams of the meat sample were aseptically homogenized in 90 mL of peptone water for 2 minutes. Serial dilutions (10^{-1} to 10^{-8}) were prepared, and 1 mL from each dilution was inoculated using the pour plate method with 20 mL of sterile culture medium at 40–45°C. Plates were gently swirled for uniform mixing, allowed to solidify, and incubated. Colony counts were visually recorded, and bacterial counts were calculated as CFU/g, considering dilution factors (Baumgart et al., 1986; Harrigan & McCance, 1976). The samples were analyzed for various microbiological parameters. The meat samples prepared for microbiological analyses were examined for the following parameters:

Total Plate Count (TPC): Nutrient Agar medium was used. Plates inoculated with the prepared dilutions using the pour plate method were incubated aerobically at 35°C for 2 days. At the end of the incubation, the colonies formed on the plates were counted and expressed as the total plate bacterial count.

Coliform Bacteria Count: MacConkey agar medium was used. Plates inoculated with the prepared dilutions using the pour plate method were incubated aerobically at 35°C for 2 days. After incubation, pink-colored colonies were counted [17].

Psychrotrophic Bacteria Count (PST): The level of psychrotrophic bacteria in the samples was determined according to the method described by Anonymous (2001). Plates inoculated with the prepared dilutions using the pour plate method were incubated aerobically at 4±1°C for 7, and at the end of the incubation period, the microorganisms growing on the plates were counted.

Statistical Analysis:

All data were subjected to one-way analysis of variance (ANOVA) using the XL Stat program for Windows. The level of significance was chosen at $P \leq 0.05$, and the results are presented as mean ± standard error (SE). Duncan's multiple range tests were used to determine the significance of differences among means (Duncan, 1955).

Results and Discussion

Labeling

Table 1 shows the label information of different inspected frozen chicken samples (thighs and breasts) of six brands. The results revealed that all marks had the required label information. It should be noted that labels of Brazil-sourced products have been written in English and Arabic, which was required in Iraq, while the Turkish-sourced Gedik mark has been written in Arabic, English, and Turkish. All of these brands are acceptable by the Iraqi standard regulations [28].

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Table 1: The differences between different trademarks of frozen chicken (thigh and breast)

	Frozen chicken breasts and thighs samples					
Information	B and T (R)	B and T (P)	B and T (C)	B and T (S)	B and T (Q)	B and T (B)
Trade Mark	+	+	+	+	+	+
Origin	Iraq	Iraq	Brazil	Brazil	Turkey	Brazil
Pro. Date	+	+	+	+	+	+
Exp. Date	+	+	+	+	+	+
Net Weight	+	+	+	+	+	+
Batch no.	+	+	+	+	+	+
Storage Condition	+	+	+	+	+	+
Using Language	Arabic, English, Kurdish	Arabic, English, Kurdish	Arabic, English	Arabic, English	Arabic, English, Turkish	Arabic, English

Appearance Evaluation

The appearance characteristics of frozen chicken were evaluated separately for thighs and breasts, as presented in Tables 2 and 3, respectively.

For chicken thighs (Table 2), visible color and overall appearance for imported brands scored higher (ranging from 3.50 to 4.50 and 3.50 to 4.66, respectively) than locals. The variation in meat color can be attributed to several pre- and post-slaughter factors. The color of poultry meat is primarily determined by the concentration of myoglobin, which can be influenced by the chicken's age, sex, diet, and level of physical activity [29]. Similarly, imported thigh samples like BS showed smaller ice spots (score 4.66) than local ones with no significant differences, possibly due to extended storage and repeated freezing cycles that encourage ice crystal growth and surface dehydration [30].

Table 2: Appearance evaluation of frozen chicken thigh meat from different brands

Brands	Visible color	Overall appearance	Ice spots (Ice masses)	Packaging condition
TR	3.83±0.31abc	4.00±0.26 b	4.00±0.27 a	5.00±0.00 a
TP	3.33±0.18 c	2.83±0.31 c	3.83±0.13 a	5.00±0.00 a
TC	3.66±0.21 bc	3.66±0.24 b	4.16±0.21 a	5.00±0.00 a
TS	4.16±0.17 ab	4.16±0.31 ab	4.33±0.22 a	5.00±0.00 a
TQ	3.83±0.23 abc	4.16±0.17 ab	3.50 ±0.16 a	5.00±0.00 a
TB	4.50±0.29 a	4.83±0.19 a	4.00±0.17 a	5.00±0.00 a

The numbers in the table represent the mean and SE. Means with different letters are significantly different ($p \leq 0.05$).

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For chicken breasts (Table 3, a similar pattern was observed. Imported brands again outperformed local samples in appearance scores, particularly in color and general visual appearance. However, the differences in ice spot scores between breast samples were minimal and statistically insignificant ($p > 0.05$), with all samples scoring within an acceptable range (3.50–4.33). This suggests that while structural appearance differed, most brands maintained acceptable storage conditions. Packaging condition, across both cut types, consistently received top scores (5.00), indicating well-sealed and intact packaging. Nonetheless, it is worth noting that packaging alone does not prevent internal quality changes if freezing and storage practices are not properly managed [31, 32].

Table 2: Appearance evaluation of frozen chicken breast meat from different brands

Brands	Visible color	Overall appearance	Ice spots (Ice masses)	Packaging condition
BR	3.50±0.22 bc	3.83±31 bc	4.16±0.22 ab	5.00±0.00 a
BP	2.83±0.31 c	2.83±31 d	4.00±0.17 ab	5.00±0.00 a
BC	4.16±0.31 ab	4.33±0.21 ab	4.50±0.17 a	5.00±0.00 a
BS	4.33±0.33 ab	4.66±0.21 a	4.66±0.21 a	5.00±0.00 a
BQ	3.50±0.22 bc	3.50±0.22 cd	3.50±0.24 b	5.00±0.00 a
BB	4.50±0.34 a	4.50±0.22 ab	4.50±0.26 a	5.00±0.00 a

The numbers in the table represent the mean and SE. Means with different letters are significantly different ($p \leq 0.05$).

Physical Analysis

Table 4 presents the physical characteristics of frozen chicken thigh meat samples, including thawing loss, water holding capacity (WHC), cooking loss, and pH key parameters used to assess meat quality.

The TP local chicken samples exhibited superior physical quality, showing the lowest thawing loss and cooking loss values at 11.68% and 21.26%, respectively. These results indicated an improvement in water-holding capacity (WHC), which was also highest in TP (49.38%) ($p \leq 0.05$), compared to all other samples. The enhanced WHC in local products may be attributed to shorter cold chain durations, minimizing protein denaturation during freezing [33]. In contrast, imported samples such as TQ, TC, and TS demonstrated significantly higher cooking losses (up to 35.72%), likely due to extended storage, fluctuating freezing conditions, or repeated freeze/thaw cycles, all of which contribute to muscle fiber damage [34, 35]. Additionally, local brands TR and TP recorded the lowest pH values (5.90 and 6.13), whereas imported brand TQ had the highest pH (6.40), indicating potential differences in freshness and biochemical stability [36]. Elevated pH may result from stress prior to slaughter or bacterial activity during extended storage [37], more likely in imported meat due to longer handling times.

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Table 4: Physical analysis of frozen chicken thigh meat from different brands

Brands	Thawing loss (%)	WHC (%)	Cooking loss (%)	pH
TR	12.45±1.70 b	46.29±3.64 a	24.83 ±1.65 b	5.90±0.06 d
TP	11.68±3.79 b	49.38±3.71 a	21.26±1.76 b	6.13±0.03 c
TC	14.15 ±2.41 ab	43.90±2.46 ab	35.72±2.56 a	6.26±0.03 b
TS	10.93±1.79 b	36.67±1.62 c	35.30±3.91 a	6.30±0.00 ab
TQ	17.78± 1.24 a	38.00±1.18 bc	34.64±2.20 a	6.40± 0.06 a
TB	9.34 ±2.16 b	43.83±3.22 ab	25.25±1.98 b	6.13±0.03 c

The numbers in the table represent the mean and SE. Means with different letters are significantly different ($p \leq 0.05$).

Table 5 presents the physical characteristics of frozen chicken breast meat samples, including thawing loss, water holding capacity (WHC), cooking loss, and pH key parameters used to assess meat quality. In this study, imported sample BS exhibited the highest thawing loss (21.61%), while local samples BP and imported sample BB had significantly lower losses (15.11% and 13.96%, respectively). High thawing loss is commonly associated with ice crystal growth during slow or repeated freezing, which damages muscle fibers and promotes fluid leakage upon thawing [38].

It is plausible that the local carcasses, for example, the BP goat carcass, were semi-frozen immediately after slaughter and experienced less structural damage, which contributed to the lower thawing loss. Similarly, BP had the highest water-holding capacity (WHC) of 44.66%, while BS had the lowest at 32.04%. WHC plays a big role in juiciness and texture and suffers if the freezing process is slow or if the meat is left storing for too long because it breaks down the muscle structure (Kim et al., 2015). Cooking loss also followed the same trend, with BS higher (38.34%) and BP the lowest (25.30%).These losses reflect protein denaturation and impaired WHC, often resulting from ice crystal-induced damage [34]. Moreover, pH values are important indicators of freshness and biochemical stability, were lowest in BP (5.90) and highest in imported BQ (6.33), likely due to microbial activity or proteolytic degradation during long-term storage [37]. These findings are consistent with Mawlood and Khidhir [35], Shorbagy, et al. [39], who reported pH values around 5.63 after two months of freezing, supporting the link between pH and meat shelf life. Compared to the safe permissible pH limits established by the Egyptian Organization for Standardization [40], which range from 5.5 to 6.5, all the analyzed samples (thigh and breast) were found to be within the acceptable range.

Table 5: Physical analysis of frozen chicken breast meat from different brands

Brands	Thawing loss (%)	WHC (%)	Cooking loss (%)	pH
BR	12.86±1.74 b	42.38±2.72 a	26.37±2.12 d	5.96±0.07 c
BP	15.11±1.55 b	44.66±3.13 a	25.30±2.13 d	5.90±0.12 c
BC	15.07±1.81 b	36.55±1.68 b	34.04±2.83 b	6.23±0.03a
BS	21.61±1.54 a	32.04±2.06 c	38.34±2.14 a	6.20± 0.06ab
BQ	20.06±1.90 a	37.21±2.11 b	31.32±1.18 bc	6.33±0.03 a
BB	13.96±2.37 b	40.40±3.22 ab	27.49±1.20 cd	6.00±0.06 bc

The numbers in the table represent the mean and SE. Means with different letters are significantly different (p≤ 0.05).

Chemical Analysis

Table 6 presents the chemical quality indices (TVN, TBARS, and FFA) for frozen chicken Thigh samples. The local samples (TR and TP) recorded lower TVN values (6.09 - 5.07 mg/100 g, respectively) compared to imported samples, suggesting fresher initial quality and reduced protein breakdown or more microbial activity. This finding aligns with the results reported by [35], who indicated that the TVN values were somewhat comparable to those observed in our study. Similarly, [41] highlighted the role of microbial activity and endogenous enzymes in increasing TVN levels during prolonged storage periods.

The TBARS values were also notably lower in TP (0.38 mg MDA/kg), compared to TQ and TS (both around 0.73 mg MDA/kg). According to Anfal A. Obeed in 2025, TBARS values below 1 mg MDA/kg characterize barely any oxidation, referring to the possibility of local products possessing higher oxidative stability. Present results may also resonate with those of (Kumar et al., 2014), who reported similar ranges of TBARS from 0.42 to 0.81 MDA/kg during storage. Also, the high TBARS for TS and TQ indicate severe oxidation due to long-term frozen exposure or temperature fluctuations.

The FFA levels were somewhat similar to the rest of the parameters whereby the imported samples, being TS (1.40%) and TQ (1.36%), registered the highest values, showing some degree of lipolysis; whereas, the local samples, namely TR (0.85%) and TP (0.75%), showed smaller values. The statement supported the view that FFA increases as enzyme action and microbial lipase activity propagate during prolonged freezing storage, as claimed by Anfal.A. Obeed [42]. Also, some authors claim that the high values of imported samples are due to long storage time or temperature fluctuation. This indicates that TVN, TBARS, and FFA are all related markers of biochemical degradation, whereby a high reading could indicate loss of freshness with possible spoilage.

Table 6: Chemical analysis of frozen chicken thigh meat from different brands

Brands	TVN (mg/100 g)	TBARS mg (MDA/kg)	FFA (%)
TR	6.09±0.66 cd	0.40±0.04 b	0.85±0.06 b
TP	5.07±0.34 d	0.38±0.05 b	0.75± 0.05b
TC	7.48±0.46 c	0.48±0.07 b	0.95±0.07 b
TS	12.56±0.44 a	0.73±0.06 a	1.40±0.12 a
TQ	10.78±0.51 b	0.73±0.06 a	1.36± 0.14a
TB	6.85±0.22 c	0.46±0.10 b	0.90± 0.07b

The numbers in the table represent the mean and SE. Means with different letters are significantly different (p≤ 0.05).

Consequently, Table 7 shows the analyses for chemical quality indicators for frozen breast samples, considered in relation to differences between local and imported brands. The local brand BP reported the lowest TVN value (3.04 mg/100 g), indicating the highest freshness. Conversely, imported BS and BQ showed significantly

($p \leq 0.05$) higher TVN values (8.37 and 7.61 mg/100 g, respectively), which usually indicate protein and nitrogenous compound degradation or microbial activity. Such variation occurs due to temperature fluctuations, enzyme activity, or microbial activity even under freezing conditions, in the longer and more complex distribution chains of imported product samples [43].

In the TBARS analysis, local BP and BR samples gave the lowest values of 0.34 and 0.37 mg MDA/kg, while the imported samples of BS and BQ yielded similar values of 0.62 mg MDA/kg, indicating the commencement of oxidative rancidity. This is supported by the statement of Connell [44] that TBARS value is an accepted index of the extent of lipid oxidation and the degree of flavor deterioration. Our study findings agree with those of Shorbagy et al. (2019), who reported TBARS levels of about 0.57 mg MDA/kg in frozen chicken stored for two months.

Similarly, FFA values were lowest in BP (0.58%) and highest in BS (1.20%) and BQ (1.15%). These high levels of free fatty acids in imported samples indicate advanced lipolysis, which suggests the possibility of prolonged storage and high enzyme activity, whether endogenous or microbial contamination and activity [45] .Overall, the results indicate that locally produced frozen samples maintained better chemical stability, possibly due to shorter supply chains and faster post-slaughter processing compared to imported samples.

Table 7: Chemical analysis of frozen chicken breast meat from different brands

Brands	TVN (mg/100 g)	TBARS (mg MDA/kg)	FFA (%)
BR	4.06±0.46 bc	0.37±0.03 b	0.65±0.05 bc
BP	3.04±0.58 c	0.34±0.06 b	0.58±0.07 c
BC	5.20±0.55 b	0.40±0.07 b	0.80±0.06 bc
BS	8.37±0.88 a	0.62±0.03 a	1.20±0.11 a
BQ	7.61±0.22 a	0.62±0.08 a	1.15±0.09 a
BB	5.71±0.58 b	0.39±0.06 b	0.85±0.06 b

The numbers in the table represent the mean and SE. Means with different letters are significantly different ($p \leq 0.05$).

Microbial Analysis

Tables 8 and 9 summarize the microbial quality of frozen chicken thigh and breast samples, highlighting clear differences between local and imported brands in TPC, coliforms, and PST.

In thigh meat (Table 8), the local brand TP demonstrated the lowest TPC (2.33 log CFU/g). In contrast, imported brands TC and TS recorded higher TPC values (3.01 - 3.13 log CFU/g). A similar trend was observed in breast meat (Table 9), BP exhibited the lowest TPC (2.40 log CFU/g), significantly lower than the imported brands BQ and BS (both at 3.41 log CFU/g), with significant differences between brands ($p \leq 0.05$). These findings are consistent with Liu, et al. [46] and Zhao [47], who reported that prolonged cold-chain logistics in imported meat increases microbial contamination risks due to cumulative exposure to fluctuating ambient temperatures and cross-contamination during distribution. The TPC level in all samples was still below acceptable limit (5×10^5 CFU/g), indicating acceptability [48].

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Coliform bacteria, used as hygiene indicators of fecal contamination, in thigh samples (Table 8), were detected at the highest levels in the local TR samples (1.7 log CFU/g) compared to the other samples. At the same time, the results showed the absence of coliform bacteria in the TB and TP samples. For breast samples (Table 9), BR had the highest coliform count (1.81 log CFU/g), whereas BP and BB showed no detection. However, the coliform level in all samples was still below the Codex Alimentarius acceptable limit (<2 log CFU/g), indicating acceptable but improvable hygiene [49]. The presence of coliforms, even at acceptable levels, can indicate processing lapses, such as equipment contamination or inadequate worker hygiene [50]. Coliform bacteria, particularly Escherichia coli, serve as important hygiene indicators in chicken meat processing and retail [51]. Proper hygiene practices during processing, including thorough cleaning of surfaces and handlers' hands, are crucial for ensuring the microbiological safety of the final product [52].The results of the psychrotrophic bacteria showed that local thigh samples (Table 8), especially TP samples, had lower microbial loads (2.31 log CFU/g) compared to imported samples, especially TC samples, which showed higher microbial loads (3.28 log CFU/g). In breast meat (Table 9), imported BC reached 3.69 log CFU/g, while local BP remained lowest at 2.39 log CFU/g, with significant differences between most brands ($p \leq 0.05$). These results align with Koutsoumanis [53], who indicated that cold-tolerant bacteria such as Pseudomonas spp. are prevalent in chilled and frozen meats and can grow even at the lowest refrigeration temperatures, especially when storage exceeds the optimal duration or temperatures fluctuate. Psychrotrophic bacteria are spoilage microorganisms that thrive at refrigeration temperatures, making them a key concern for the shelf-life and quality of chilled and frozen meat products [47].

In general, the results obtained in this study are consistent with those of [35, 54], those indicated that frozen storage results in an overall decrease in microbes due to several factors such as dehydration, ice crystal formation, and decreased water activity, although some spoilage organisms may persist and grow once thawed.

Table 8: Microbial analyses (log CFU/g) of frozen chicken thigh meat from different brands

Brands	TPC	Coliform	PST
TR	2.96±0.17 bc	1.7±0.11 a	2.76±0.08 bc
TP	2.33±0.15 d	1.26±0.10 cd	2.31±0.13 c
TC	3.01±0.30 ab	1.25±0.19 cd	3.28±0.11 a
TS	3.13±0.12 a	1.49±0.07 bc	3.14±0.13 ab
TQ	2.89±0.11 bc	1.60±0.11 ab	2.78±0.08 bc
TB	2.87±0.11 cd	0.00 d	2.68±0.07 bc

The numbers in the table represent the mean and SE. Means with different letters are significantly different ($p \leq 0.05$).

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Table 9: Microbial analyses (log CFU/g) of frozen chicken breast meat from different brands

Brands	TPC	Coliform	PST
BR	2.74±0.13 bc	1.81±0.03 a	2.68±0.04 c
BP	2.40±0.11 d	0.00±0.00 d	2.39±0.07 c
BC	3.25±0.23 ab	1.09±0.10 c	3.69±0.03 a
BS	3.41±0.13 bc	1.53±0.10 b	3.31±0.06 b
BQ	3.41±0.14 a	1.28±0.07 c	3.26±0.05 b
BB	2.71±0.13 cd	0.00±0.00 d	2.65±0.04 c

The numbers in the table represent the mean and SE. Means with different letters are significantly different ($p \leq 0.05$).

This study revealed a clear contradiction between the superior visual appearance of imported frozen chicken and the better physicochemical and microbial quality of local products. Visual traits such as color and general appearance were higher in imported brands, largely reflecting advanced glazing and packaging practices rather than actual freshness [29]. By contrast, local samples showed significantly lower cooking loss, higher water-holding capacity, and reduced spoilage indicators such as TVN, TBARS, and FFA, suggesting shorter storage times and more stable protein and lipid integrity [14, 34, 55].

Microbiological results followed the same pattern, with imported brands presenting higher total counts and psychrotrophic bacteria, though still within Codex permissible limits [56, 57]. These findings emphasize that attractive appearance is not a reliable indicator of internal quality. Local chicken, despite its less appealing visual characteristics, exhibited superior freshness and stability. Improving the packaging and presentation of local products, alongside consumer awareness, could enhance competitiveness against imported alternatives.

Conclusion:

This study looked at six different brands of frozen chicken (two local and four imported) and found clear differences in quality. Overall, the local brands (especially TP and BP) performed much better. They held more water, lost less during cooking, and showed fewer signs of damage from freezing, meaning their texture and protein structure were better preserved. In contrast, the imported brands had higher levels of spoilage indicators like TVN (a sign of protein breakdown), TBARS (a sign of fat oxidation), and free fatty acids, which suggest they may have been exposed to longer storage times or poor temperature control during shipping. For example, the imported TS brand had nearly double the rancidity level of the local TP brand. with respect to bacteria, the imported products also had higher microbial counts. Still, all the samples (including those with coliforms) were within safe limits. In short, locally produced frozen chicken not only held up well but, in many cases, outperformed the imported options. The study highlights how crucial good cold chain management and regular quality checks are, and it shows that with proper handling, local meat can meet or even exceed international standards, it is recommended that strict monitoring of cold chain storage and transportation be enforced to reduce the deterioration of frozen chicken quality. Regular quality control testing, including microbiological and chemical analysis, should be applied to ensure

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compliance with international standards. Training of workers in hygienic handling and raising consumer awareness about safe storage and cooking practices are also essential. Furthermore, strengthening local poultry production can help reduce dependence on long-term imported frozen chicken, thereby improving freshness and safety.

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