In recent years, the consumer demand for ready-to-eat meat products is rising because of socio-economic factors. This has triggered innovations including the production of restructured meat products in the meat industry (10, 21). Restructured meat is a product transformed into a similar or different form by ensuring the integrity of the chopped meat (21). It is a technological approach for recreating low-value meat preparations (5, 18) and constitutes added value for the meat industry (10, 26).

Meat loaf is a restructured product with a high nutritional value, allowing the usage of trimmed meat and meat by-products. Specific and nonspecific meat loaves prepared by varied formulations are available (36). Their production steps are often similar (1), and the raw materials are generally low economic value meat, fat and meat by-products. Trimmed meat and meat by-products produce a high connecting tissue, low tenderness and juiciness. However, the associated cooking loss adversely affects the product quality (17, 35).

Tumbling, which involves the combined use of impact and friction energies (45, 48), is an effective mechanical process for producing tender and juicy meat (25), characterised by homogenous penetration of curing agents (24, 40). The main purpose of the process is to enable sufficient extraction of salt-soluble

Effect of the tumbling process and kappa-carrageenan usage on the quality characteristics of meat loaf1)

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Summary

In this study the authors aimed to determine the effects of the tumbling process and carrageenan usage on the physicochemical, microbiological and sensory properties of meat loaves, which are uncommon in Turkey and only produced at a sub-industrial level. The meat loaves were produced from beef (rib and chuck regions) and layer hen meat and partitioned equally into three groups. The first group served as a control group, whereas the second and third groups were processed by tumbling for 1 and 2 h, respectively. The tumbling programme involved 20 millibar pressure, with 3 min of operation and 1 min of stoppage. After tumbling, each group was divided into two equal parts, followed by the addition of 1% carrageenan to one part of each. This production was repeated, and the meat loaves were stored at 4°C. Physicochemical, microbiological and sensory analyses of the final products were performed on the 0th, 3rd, 7th, 12th and 15th day of storage for assessing the product quality. The utilisation of carrageenan increased the beef and chicken meat loaves by 0.69% and 1.85%, respectively. The carrageenan reduced cooking loss by an average of 5% relative to the control group. The cutting and sensory properties of the groups produced by both tumbling and the addition of carrageenan exhibit higher scores than the other groups (P < 0.05). The average of the pH, aw, salt%, dry matter%, ash% and fat% in the beef meat loaves are 6.26, 0.938, 0.988, 31.52, 2.30 and 4.64, respectively, whereas corresponding values for chicken meat loaves are 6.26, 0.927, 1.23, 35.80, 2.18 and 7.38, respectively for the control groups.

Yeast-mould growth was absent in all samples, containing 2.90-6.05 log10 CFU/g TMAB, 2.00-4.27 log10 CFU/g Micrococcus–Staphylococcus and 0-3.62 log10 CFU/g Enterobacteriaceae.

Keywords: meat loaf, kappa-carrageenan, tumbling

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proteins for improving the tenderness, juiciness and slicing properties (21). Because of its hydrocolloidal structure, carrageenan is utilised for gel formation, water retention and imparting desired textural properties for meat products (29, 34). Carrageenans are sulfated polymers of galactose and anhydrogalactose extracted from red seaweeds. Although the three main types of carrageenans are iota, kappa and lambda, the kappa type is that commonly used in food technology (4, 8, 12, 37).

In this study, the effects of tumbling and adding carrageenan on the quality characteristics of meat loaves are examined.

**Material and methods**

**Production of meat loaves and experimental groups.** In producing the meat loaves, trimmed ribs from beef meat and layer chicken ribs and forearms meat were used as the raw materials. The meat (beef and layer hen meat), oil, spices and other additives used as raw materials were obtained from retail markets in Konya, Turkey. The production occurred at two different times, forming experimental production groups (Tab. 1). The loaf dough compositions were determined as presented in Table 2. The tumbling programme involved 20 millibar pressure, with 3 min of operation and 1 min of stoppage in tumbling machine (Scharfen Tumbler HR2530).

The prepared loaf dough was stored stainless steel containers measuring 11 × 8.5 × 3.5 cm. After covering the loaf dough with an aluminium lid, the product was baked in an air-conditioning furnace (Fessmann/Microprocessor MC-3) until the core temperature reached 75°C. After baking, 3 mm slices were produced, vacuum packed (Kramer + Grebe Compack Tabletop Packager) and stored at 4°C. Physico-chemical, microbiological and sensory analyses of the final products were performed on the 0th, 3rd, 7th, 12th and 15th day of storage for assessing the product quality.

**Physicochemical analysis.** The yield (%) was calculated by weighing the samples before heat treatment and before packing after cooling as previously described (19, 36). Following the cooking stage, all samples were cooled to 50°C and then weighed by removing the excess liquid. The cooking loss (%) for the samples were calculated considering the weights before heat treatment as detailed in the past (1). Meat loaf samples cutting properties were evaluated as good or bad according to whether the knife cutting was clean, sticky or crumby, with details reported previously (35). The pH of the samples was determined by a digital pH metre (InoLab pH 720 model, WTW, GmbH), whereas the a₁ was determined by a water activity device (Novasina LabSwift-aw). Dry matter analyses were performed using an AND MX-50 moisture analyser, whereas the salt contents were determined according to a modified Mohr method (6) and the ash content was measured according to the TS 1746 standard established by the Turkish Standards Institute (50).

**Microbiological analysis.** About 10 g of samples were weighed into sterile specimen bags and homogenised with 90 ml of ¼ strength Ringer (Oxoid BR0052) solution in a mixer (Stomacher Lab. Blender 400), with serial dilutions up to 10⁻⁷ and 1 ml dilutions were transferred to petri dishes. After media [Plate Count Agar (PCA, Oxoid CM325), Violet Red Bile Agar (VRBA, Oxoid CM0978), Mannitol Salt Agar (MSA, Oxoid CM0085) and Potato Dextrose Agar (PDA, Oxoid CM0139)] addition, these were incubated at 30°C for 48 h for total mesophilic aerobic bacteria (TMAB), 30°C for 24 h for Enterobacteriaceae, 37°C for 36 h for Micrococcus–Staphylococcus and 22°C for 5 days for yeast and moulds. At the end of the incubation period, the colonies were calculated in petri plates as previously reported (7, 22).

**Sensory analysis.** The samples were evaluated by a panel group (four males and three females aged 24-35) for colour, flavour, appearance and texture. The samples were presented in white plates to the panel in the sensory evaluation room with good lighting. In the sensory evaluation, a hedonic type scale with the highest score of 10 representing the liked features, and the lowest score of 1 denoting disliked features was used (47).

**Tab. 1. Produced experimental groups**

| Raw material          | Experimental Groups | Tumbling | Carrageenan (1%) |
|-----------------------|--------------------|---------|-----------------|
| Beef rib meat         | I                  | –       | –               |
|                      | II                 | –       | –               |
|                      | III                | 1 h     | –               |
|                      | IV                 | 1 h     | –               |
|                      | V                  | 2 h     | +               |
|                      | VI                 | 2 h     | –               |
| Chicken rib meat      | I                  | –       | –               |
|                      | II                 | –       | –               |
|                      | III                | 1 h     | –               |
|                      | IV                 | 1 h     | –               |
|                      | V                  | 2 h     | +               |
|                      | VI                 | 2 h     | –               |

**Tab. 2. Composition of meat loaf dough**

| Ingredients              | Beef meat loaf | Chicken meat loaf |
|--------------------------|----------------|------------------|
| Beef rib meat           | 460 g          | –                |
| Cattle forearm           | 460 g          | –                |
| Chicken breast meat (skinned) | –          | 438 g            |
| Chicken thigh meat (skinned) | –          | 438 g            |
| Bovine oil              | 48 g           | 96 g             |
| Ice                     | 280 g          | 280 g            |
| Dry bread               | 106 g          | 106 g            |
| Milk powder             | 38 g           | 38 g             |
| Salt                    | 19 g           | 19 g             |
| Chopped onions          | 48 g           | 48 g             |
| Black pepper            | 2.5 g          | 2.5 g            |
| Cumin                   | 1.2 g          | 1.2 g            |
| Allspice                | 0.6 g          | 0.6 g            |
| Sodium nitrite          | 0.1 g          | 0.1 g            |
Statistical analysis. The one-way ANOVA test was used after the SPSS Statistics 21.0 package programme for determining normal distribution in the data. Significant differences were then determined by introducing the Duncan Test (46).

Results and discussion

The yield of beef and chicken meat loaves increased by 0.69% and 1.85%, respectively, with an overall yield increase of 1.27% for experimental production groups with carrageenan applied (II, IV and VI) compared with the control groups (I, III and V). The yield increase and cutting properties of the groups (IV and VI) involving tumbling and carrageenan addition are better than those for the other groups. The cutting properties of beef and chicken meat loaves that were not subjected to tumbling and carrageenan treatment are the worst for samples groups. The cutting properties of some experimental groups involving carrageenan treatment is better than those for the control groups (Tab. 3). When both production averages are considered for all groups, carrageenan appears to reduce cooking loss by an average of 5.00%. The carrageenan addition reduced beef meat loaves cooking loss by 7.27% between the 1st and 2nd groups, 3.36% between the 3rd and 4th groups, 3.72% between the 5th and 6th groups and 4.76%, 7.2% and 3.73% for chicken meat loaves respectively (Tab. 4).

Data for physicochemical parameters including pH, aw, dry matter, salt, ash and fat content for all storage durations are presented in Table 5.

Yeast–mould growth was absent during storage of the beef and chicken meat loaves for all samples. The TMAB, Micrococcus–Staphylococcus and Enterobacteriaceae concentrations range from 3.76 to 4.56 log₁₀ CFU/g, 3.11 to 3.95 log₁₀ CFU/g and 0.65 to 1.5 log₁₀ CFU/g on the 1st day and 4.55 to 5.25 log₁₀ CFU/g, 2.98 to 3.88 log₁₀ CFU/g and 1.68 to 1.81 log₁₀ CFU/g on the 15th day, respectively, for beef meat loaves. Chicken meat loaves yielded corresponding values of 3.85-4.4 log₁₀ CFU/g, 2.91-3.63 log₁₀ CFU/g and 0-1.10 log₁₀ CFU/g on the 1st day and 3.12-3.75 log₁₀ CFU/g, 2.30-2.65 log₁₀ CFU/g and 0-1.02 log₁₀ CFU/g on the 15th day of storage. The average values for

Tab. 3. Yield and cutting features of beef and chicken meat loaf samples

| Group | Application | Beef meat loaf 1st and 2nd production (Yie (% Mean ± SE)) | Chicken meat loaf 1st and 2nd production (Yie (% Mean ± SE)) |
|-------|-------------|----------------------------------------------------------|----------------------------------------------------------|
| I     | T (–), C (–) | B 98.06 ± 0.73 B 96.91 ± 0.83a B                        | B 98.88 ± 0.65 G G 99.10 ± 0.25a B                        |
| II    | T (–), C (+) | B 98.88 ± 0.65 G G 99.24 ± 1.51 B                        | B 98.46 ± 0.71 G G 99.25 ± 0.49a G                        |
| III   | T 1, C (–)  | G 98.79 ± 0.85 G G 99.28 ± 0.49a G                        | G 98.27 ± 0.43 G G 97.82 ± 0.46a G                        |
| IV    | T 1, C (+)  | G 98.79 ± 0.85 G G 99.28 ± 0.49a G                        | G 98.27 ± 0.43 G G 97.82 ± 0.46a G                        |
| V     | T 2, C (–)  | G 99.19 ± 0.46 G G 98.17 ± 0.45a G                        | G 99.19 ± 0.46 G G 98.17 ± 0.45a G                        |
| VI    | T 2, C (+)  | G 99.19 ± 0.46 G G 98.17 ± 0.45a G                        | G 99.19 ± 0.46 G G 98.17 ± 0.45a G                        |

Explanations: Yie – % yield; Cut – cuttability; B – bad; G – good; T (–) – tumbling not applied; T (+) – tumbling applied; T1 – tumbling applied for 1 h; T2 – tumbling applied for 2 h; C (–) – carrageenan not applied; C (+) – carrageenan applied; SE – standart error; values within a row with different letters are significantly different (p < 0.05)

Tab. 4. % Cooking loss for beef and chicken meat loaf samples (% Mean ± SE)

| Group | Application | Beef meat loaf | Chicken meat loaf |
|-------|-------------|----------------|-------------------|
| I     | T (–), C (–) | 11.87 ± 3.47   | 10.19 ± 1.91     |
| II    | T (–), C (+) | 11.24 ± 1.34   | 10.01 ± 1.02     |
| III   | T 1, C (–)  | 8.04 ± 0.59    | 7.88 ± 0.31      |
| IV    | T 1, C (+)  | 8.04 ± 0.59    | 7.88 ± 0.31      |
| V     | T 2, C (–)  | 7.86 ± 0.38    | 7.70 ± 0.26      |
| VI    | T 2, C (+)  | 7.86 ± 0.38    | 7.70 ± 0.26      |

Explanations: SE – standart error; values within a row with different letters are significantly different (p < 0.05)

Tab. 5. Physicochemical parameters of meat loaves (Mean ± SE)

| Group | Application | pH | DM (%) | Ash (%) | Salt (%) | Fat (%) |
|-------|-------------|----|--------|---------|----------|---------|
| I     | T (–), C (–) | 6.26 ± 0.12 | 31.52 ± 1.00 | 2.30 ± 0.26 | 0.988 ± 0.15 | 4.64 ± 0.21 |
| II    | T (–), C (+) | 6.33 ± 0.83 | 29.66 ± 1.27 | 2.50 ± 0.35 | 1.07 ± 0.16 | 4.60 ± 0.14 |
| III   | T 1, C (–)  | 6.28 ± 0.10 | 30.65 ± 1.00 | 2.23 ± 0.36 | 1.03 ± 0.12 | 5.10 ± 0.99 |
| IV    | T 1, C (+)  | 6.33 ± 0.06 | 30.53 ± 1.28 | 2.40 ± 0.21 | 1.10 ± 0.14 | 5.03 ± 0.30 |
| V     | T 2, C (–)  | 6.24 ± 0.03 | 30.28 ± 1.88 | 2.15 ± 0.33 | 0.99 ± 0.11 | 4.73 ± 0.19 |
| VI    | T 2, C (+)  | 6.33 ± 0.04 | 29.40 ± 1.56 | 2.30 ± 0.19 | 1.01 ± 0.15 | 4.82 ± 0.14 |

Explanations: DM – dry matter; T (–) – tumbling not applied; T (+) – tumbling applied; T1 – tumbling applied for 1 h; T2 – tumbling applied for 2 h; C (–) – carrageenan not applied; C (+) – carrageenan applied
the microbial counts during storage (0th, 3rd, 7th, 12th and 15th days) are also displayed in Figure 1.

For both meat types, groups (IV and VI) that involved tumbling and carrageenan application are rated higher by the panellists. Although the carrageenan application (for both meat types) produced a higher score, the difference between the groups was not statistically significant (p > 0.05). The sensory evaluation scores for loaves subjected to tumbling surpassed those for meat groups without tumbling (p < 0.05, Tab. 6 and 7).

The increased yield of all groups treated with carrageenan (1%) compared with control groups is attributed to improved water retention capacity associated with carrageenan. Data on the optimum effect and additives use levels are lacking, with variations observed according to the raw material, produced food, other additives, carrageenan type, composition and concentration. However, the use of 2% kappa-carrageenan is reported to positively affect the yield and textural properties of meatballs with low-fat content (23) and increase the water retention capacity of sausages (32) and the water retention capacity characteristics of salt present in food (38).

The highest cooking loss values are displayed by the 1st group of beef meat loaves and the 1st and 3rd groups of chicken meat loaves. The effect of carrageenan addition on the cooking loss is evident (2nd, 1st and

**Fig. 1. Microbiological values of meat loaves during storage (log₁₀ CFU/g)**

**Tab. 6. Sensory analysis results of beef meat loaves**

| Group | Application | Flavor | Texture | Appearance | Colour |
|-------|-------------|--------|---------|------------|--------|
| I     | T (–), C (–) | 7.67 ± 0.30° | 7.21 ± 0.26° | 8.14 ± 0.31° | 7.85 ± 0.40° |
| II    | T (–), C (+) | 7.85 ± 0.27° | 7.85 ± 0.27° | 8.07 ± 0.28° | 7.87 ± 0.29° |
| III   | T 1, C (–)  | 7.64 ± 0.32° | 8.28 ± 0.32° | 8.14 ± 0.31° | 8.50 ± 0.31° |
| IV    | T 1, C (+)  | 8.85 ± 0.27° | 8.78 ± 0.21° | 8.78 ± 0.23° | 9.07 ± 0.19° |
| V     | T 2, C (–)  | 7.85 ± 0.31° | 8.71 ± 0.28° | 8.71 ± 0.22° | 9.00 ± 0.27° |
| VI    | T 2, C (+)  | 8.71 ± 0.28° | 9.00 ± 0.25° | 8.92 ± 0.19° | 9.28 ± 0.22° |
| Average of Applications | | 7.46 ± 0.21° | 7.53 ± 0.19° | 8.10 ± 0.20° | 8.32 ± 0.26° |

| Group | Application | Flavor | Texture | Appearance | Colour |
|-------|-------------|--------|---------|------------|--------|
| T (–) | 7.28 ± 0.26° | 7.71 ± 0.26° | 8.28 ± 0.22° | 8.92 ± 0.24° |
| T (1) | 8.25 ± 0.23° | 8.53 ± 0.19° | 8.46 ± 0.20° | 8.78 ± 0.18° |
| T (2) | 8.28 ± 0.22° | 8.85 ± 0.19° | 8.82 ± 0.14° | 9.14 ± 0.17° |
| C (–) | 7.52 ± 0.18 | 8.07 ± 0.19 | 8.33 ± 0.16 | 8.32 ± 0.26 |
| C (+) | 8.47 ± 0.17 | 8.54 ± 0.16 | 8.59 ± 0.20 | 8.78 ± 0.14 |

Explanations: differences between groups with different letters in the same column are important (p < 0.05); T (–) – tumbling not applied; T (+) – tumbling applied; T1 – tumbling applied for 1 h; T2 – tumbling applied for 2 h; C (–) – carrageenan not applied; C (+) – carrageenan applied.
control groups), with significant reductions in some produced groups. Generally, the lowest cooking losses are obtained in the 4th groups produced after tumbling for 1 h and carrageenan treatment. Comparing the effects of carrageenan and tumbling on cooking loss, carrageenan is assigned a more significant influence by increasing the water retention capacity of the product. This is because the cooking loss depends on the ability of the protein matrix to immobilise fat and water. However, non-meat components, particularly in low-fat meat doughs, are important for the gelling ability, water retention capacity and storage stability (34). The tumbling process imposes thermal energy to muscle fibres, with the physical effects of falling, crashing and friction on the muscle proteins. Myofibrillar proteins, for example, transform to a soluble form because of the heat generated by the thermal energy in the tissue (21, 30). Combining the water retention properties of carrageenan and the tumbling effect on proteins, the heat generated during these processes is considered to catalyse the water binding effect. In fact, Trius and Sebranek (49) stated that the water binding effect of carrageenan particles in meat products occurs during heat treatment, with the bond converted to gel during the cooling process.

In this study, the 6th groups of beef and chicken meat exposed to 2 h tumbling and carrageenan show higher cooking loss values compared with their corresponding 4th groups. This is probably due to mechanical damage from the tumbling process over time. Moreover, reduced water retention capacity of the proteins with increasing heat is another possible explanation. This highlights dominance of changes occurring in the protein fractions from tumbling over water retention capacity from carrageenan. Schmidt (42) stated that the kinetic energy produced by the tumbling process loosens the sarcosome structure, causing rapid disintegration of actin filaments and Z discs. Demirok et al. (16) reported that the use of tumbling and phosphate influences the moisture amount, water-soluble protein and α-amino groups in cooked döner. Although no application affected the sarcoplasmic and myofibrillar proteins, proteolysis resulted from heat treatment.

For cooking loss, the effect of tumbling is higher in beef meat and decreases as the loss decreases. This is probably because the protein content of a beef loaf surpasses that of a chicken loaf, since thigh and breast meat served as raw materials. We infer that cooking loss in these loaf samples can be reduced by increasing the breast composition and thus the total protein percentage.

The mechanical properties of meat, particularly connective tissue protein, are affected by collagen. The texture is influenced by the collagen amount and solubility with heat treatment. The heat-induced changes in muscle components depend on temperature and time, whereas the hardening or softening of meat depends on the cooking conditions (21). Since the inter-group heat treatment and time mechanisms are identical, observed differences in the cutting properties are assigned to changes in the protein properties and water retention capabilities. The cutting properties of the 4th and 6th groups, processed by tumbling and carrageenan application support this assertion. A protein film is formed around the meat fibres–muscle fibres from extraction of myofibrillar proteins by the tumbling process. Thus, the increased brittleness and juiciness of the product also affects the cutting properties (20, 55), whereas carrageenan also increases the water retention properties. However, Modi et al. (37) stated that different amounts of carrageenan added to the composition of meatballs produced experimentally positively affect the water retention, cooking loss and hardness properties of the products. Similarly, Lin and Mei (33) reported that the addition of 0.41 g/100 g iota carrageenan to meat dough compositions increased the emulsion stability and water retention capacity. These researchers attributed this to the formation of a more stable complex of fat-in-water emulsion by denaturing of meat proteins during the heat treatment. Aktaş and Gençcelep (2) observed that the increase in emulsion viscosity enhanced its stability, and the decrease in cooking loss is associated with the emulsion stability.

The differences in the chemical properties of the meat loaves are influenced by many factors (e.g. type of raw material, size of meat loaf, temperature and heat treatment duration, type of tumbler machine and additives). In this study, the similarity of the basic factors affecting the chemical properties of the meat loaves for all groups likely accounts for the absence of significant differences for the analysed parameters. McIvor et al. (35) reported moisture, fat, ash and protein in chicken meat loaf of 52.6%, 17.10%, 3.50% and 22.81%, respectively. Ubersax et al. (51) reported moisture contents of 73.6%, 73.2%, 73% and 72.6% fat content of 0.36%, 1.59%, 2.80% and 4.53%, and pH values of 5.74, 5.77, 5.81 and 5.86 for turkey meat loaves mechanically deboned at 0%, 10%, 20% and 30% levels, respectively. Also, Acton and Dick (1) observed that the moisture, fat, protein and ash for turkey meat loaves prepared by adding 20% skin are 65.7%, 10.8%, 20.7% and 2.0%, respectively. Furthermore, Sen and Karim (43) concluded that the pH of a product increases with increasing meat piece size for restructured sheep meat. Similarly, Gurikar et al. (21) reported that the pH of a product increases with increasing meat piece size for restructured pork. Gurikar et al. (21) and Vasanthi et al. (53) further suggest that increasing pH values are linked to losses in free acid groups with rising heat treatment time. Sharedeh et al. (44) indicated that a small pilot tumbling device is suitable for static salting, whereas large tumblers were suitable for combining massage and salting. Villalobos-Delgado et al. (54) noted that tumbling is effective only for stickiness of dry-cured lamb leg samples produced from different tumbling times after salting. Mocanu et al. (36) found
higher levels of dry matter and ash in meat loaf samples produced from pork back fat and different vegetable oils compared with the control group.

In this study, yeast-mould growth is undetected in the meat loaf samples; the concentrations of TMAB, Micrococcus–Staphylococcus and Enterobacteriaceae range from 2.90 to 6.05 log$_{10}$ CFU/g, 2.00 to 4.27 log$_{10}$ CFU/g and 0 to 3.62 log$_{10}$ CFU/g, respectively. These findings are consistent with Devatkai et al. (17) who reported aerobic plaques concentrations on buffalo meat loaf stored at 4°C of 2.27, 3.10, 3.94, 5.13 and 6.38 log$_{10}$ CFU/g levels for the 1st, 5th, 10th, 15th and 20th days of storage, respectively. These researchers suggested that the microorganisms may be due to contamination from manual contact during packaging, storage and sampling for analysis after heat treatment. Carroll et al. (13) found that the approximate number of TMAB in turkey meat loaves treated with different marinated combinations was 2 log$_{10}$ CFU/cm$^2$ on the 0th, 1st, 5th and 10th days of storage, 3 log$_{10}$ CFU/cm$^2$ on the 14th day, 4 log$_{10}$ CFU/cm$^2$ on the 20th day and 5.5 log$_{10}$ CFU/cm$^2$ on the 70th day. In microbiological analyses conducted after the cooking process, McIvor et al. (35) attributed the absence of coliform bacteria, yeast-mould, Salmonella spp. and S. aureus growth and the low-level aerobic colony number of 8 × 10$^2$ CFU/g to the efficacy of the heating process. The preference of layer hens associated with high contamination levels and trimming meat residues in this study makes microbiological controls compulsory (27). Although heat treatment is applied during the production phase, avoiding contamination during storage is vital. Chow (15) indicated that the presence of a routine heat treatment step in producing different meat loaves prevents the development of pathogenic microorganisms in the meat loaves from meat with expected high contamination level.

For the 1st day of storage, the TMAB, Micrococcus–Staphylococcus and Enterobacteriaceae loads for both meat loaves are similar. The average TMAB and Enterobacteriaceae loads of the beef loaves, however, increased in the final days of storage. In contrast, TMAB, Micrococcus–Staphylococcus and Enterobacteriaceae average values decreased for chicken meat loaves. This is possibly because the average $a_w$ in the chicken loaves are relatively low and the salt ratios are higher. The increase in salt in the compositions of the foods also decreases the $a_w$. This factor, which is considered as the water binding property of salt, also accounts for the salt-induced antimicrobial effect (3, 11). Similarly, many studies (28, 31, 52) suggest that the gradual decrease of $a_w$ and increasing salt content for different meat products are due to bacterial inhibition and/or their synergetic effects.

Considering the averages of the applications for both meat types for sensory analyses, it is important for the carrageenan addition and tumbling process to produce higher sensory scores. Bharti et al. (9) suggested that 45 min tumbling for small chicken pieces marinated in spices and yoghurt increases the physicochemical and sensory quality characteristics of the products. Hullberg et al. (24) indicated that the tumbling process produces better texture and more uniform cured meat colour for smoked meat. They further stated that tumbling reduced the undesirable pores, and no difference was noted in sensory preferences, but many palinellists preferred meat samples processed without tumbling. Modi et al. (37) suggested that added carrageenan groups are more favourable than the control group, whereas Prabhu and Monge (41) concluded the effect of carrageenan use on the hardness, stickiness, chewability and slicing characteristics of turkey breast meat was significant. Also, Mohan and Singh (38) reported that the beef steaks using 0.5% kappa-carrageenan yield better sensory results for colour, hardness, juiciness and overall acceptability. Furthermore, Chareonthaikij et al. (14) stated that the use of 0.3% transglutaminase and 1% kappa-carrageenan improved the sensory and textural properties in fish meatballs.

This study revealed that effective data were to prepare appropriate formulations for the consumers like their sensory properties, by enhancing the textural properties and quality of meat loaves constituting problems in production technology. For cooking loss, the least loss was observed in Group 4 for beef and chicken meat loaves, which were treated with carrageenan and processed by tumbling for 1 h. The tumbling process and carrageenan used in the meat industry exhibit positive effects on the technological improvement of the meat loaf.

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