

Effects of vacuum packaging on the quality of frozen cooked döner kebab

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Abstract: Döner kebab is a traditional Turkish dish, recognized worldwide. It is an important fast-food meal sold by its local name in many countries. Döner kebab is consumed as a fresh dish and should be served immediately after cooking. Raw döner kebab can be stored by freezing, but there is not enough knowledge about the storage of cooked döner kebab. This study was conducted to investigate the effect of vacuum packaging on the meat quality of frozen cooked döner kebab. Packaged döner kebabs were stored at $-18 \pm 1^\circ\text{C}$ for up to 12 months and examined monthly for microbiological (total aerobic mesophilic bacteria and *Pseudomonas* spp.), physicochemical (pH, moisture, fat, TBARS, and instrumental color L^* , a^* , b^* , and ΔE^*), and sensorial characteristics during the storage period. As a result, the quality and shelf-life of vacuum-packaged and frozen cooked döner kebabs were preserved throughout the storage period of 12 months. Microbial growth in döner meat was delayed due to the lack of O_2 in the package, which prevented the increase of lipid oxidation and improved the consumer acceptance for up to 9 months. However, loss of color and leakage of fat during long storage may adversely affect consumer preferences.

Key words: Döner kebab, frozen storage, microbiological quality, shelf-life, sensory evaluation

1. Introduction

Döner kebab is a traditional Turkish dish. The name comes from its preparation, where the meat is roasted vertically on a spit. Döner kebab, which is recognized worldwide, is an important fast-food meal sold in many countries by its local name (döner kebab, donair, dona-kebab, etc.). To prepare a döner kebab, thinly sliced meat is marinated by adding different ratios of salt, various spices, onion, onion juice, grated tomatoes, tomato juice or tomato sauce, olive oil, lemon juice or vinegar, milk or milk powder, yogurt, egg, and marinated grape juice or white sugar. The meat is then kept for 1 night in cold chain and compressed vertically onto a spit. The alignment process is completed by shaping the mixture like a shuttle, cone, or egg. Döner prepared as described above is roasted in front of an electrical, gas, or charcoal heater by slowly rotating it. After roasting, it is cut into thin slices to serve.

Döner kebab is consumed as a fresh dish and should be served immediately after cooking. Raw döner kebab can be stored by freezing; on the other hand, there is not enough research about the storage of cooked döner kebab. Presentation of frozen cooked döner kebab for consumption will provide convenience for both manufacturers and consumers.

Sometimes, uncooked meat pieces can be offered to consumers due to incomplete cooking during rush hours or improper slicing (1). Recent studies demonstrated that, occasionally, the microbiological quality of ready-to-eat döner kebab is not good for consumption and the meat can contain pathogenic microorganisms (2–9). Although it is not common, there have been reported cases of food poisoning caused by döner kebab consumption in the past years (10–12).

Freezing döner kebab after controlled and proper cooking at production places is important in preventing consumption of uncooked döner kebab at consumption points (e.g., buffets or restaurants). Otherwise, the “heat and eat” concept provides great convenience for the consumer.

Although there is not a predictable microbial risk of frozen storage of döner kebab, a potential risk of rancidity is present due to its fat content. Vacuum packaging helps to store food for a long time by preventing oxygen exposure and water loss. The effect of vacuum-packing has been studied in a number of food materials; however, such research associated with döner kebab is not available.

This study was therefore carried out to investigate the effect of vacuum packaging on the meat quality of frozen cooked döner kebab.

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2. Materials and methods

2.1. Production of döner kebabs

Experimental döner kebabs were made using traditional methods. The minced beef meat was mixed in a tumbler (Boğaziçi, İstanbul, Turkey) with salt and seasonings (onion, spice, tomato, yogurt, etc.) and kept at 4 °C for marination. After 12 h, raw döner material was fixed on a spit to give a cylinder shape and cooked by rotating in front of a heating element (Gas burners, Pimak, İstanbul, Turkey). During the cooking process, the roasted surfaces were cut continually using an electric döner knife (Tekin T-1 / 0706, İstanbul, Turkey). The experimental döner samples were produced at room temperature in triplicate on different dates.

2.2. Packaging of döner kebabs

Döner kebabs were divided into portions of 250 ± 5 g for each pack, placed on individual barrier foam trays (LLDPE/EVOH multilayer), and wrapped with a polyethylene film for aerobic packaging (air) or heat-sealed with a Multivac packaging unit (Multivac, Germany) for vacuum packaging (VAC) with multilayer polyolefin with PVDC film.

2.3. Storage conditions of döner kebabs

Packaged döner kebabs (air and VAC packs) were held under refrigerated display conditions at 4 ± 1 °C for 12 h and then were stored at -18 ± 1 °C for up to 12 months. Samples were examined monthly for their microbiological, physicochemical, and sensorial characteristics during storage.

2.4. Analysis of döner kebabs

Analysis of microbiological (total aerobic mesophilic bacteria and *Pseudomonas* spp.) physicochemical (pH, moisture, fat, lipid oxidation), instrumental color (L^* , a^* , b^* , ΔE), and sensorial properties (appearance, off-odor, flavor intensity, texture, chewiness, and general appearance acceptability) of döner samples were conducted at the beginning and at every month of the frozen storage period.

2.5. Microbiological analyses

Portions of döner samples (25 g) were homogenized with 225 mL of 0.1% peptone water (Oxoid CM0009, UK) for 2 min and serial decimal dilutions were prepared. Appropriate dilutions were spread on plate count agar (PCA, Oxoid, CM0325) and incubated at 35 °C for 48 h to determine the total aerobic plate counts (TAPC). *Pseudomonas* spp. were enumerated on *Pseudomonas* agar (Oxoid, CM0559) with a cetrimide, fucidin, and cephaloridine supplement (Oxoid, SR0103) by incubating at 25–30 °C for 48 h (13).

All microbiological tests were carried out in duplicate at 3 independent times, and the results were expressed as log₁₀ CFU/g.

2.6. Physicochemical analyses

2.6.1. pH

The pH levels of the döner kebabs were measured at room temperature using a Hanna pH meter (Hanna HI-9321, USA) calibrated with standard buffers, and the means were recorded after 3 readings (14).

2.6.2. Moisture content

The moisture content of döner samples was defined by drying a homogeneous mixture at 105 ± 2 °C until a constant weight was obtained according to AOAC procedures (14).

2.6.3. Fat content

The total fat content of the döner kebabs was determined by the Soxhlet method according to AOAC procedures (14).

2.7. Thiobarbituric acid reactive substances (TBARS) values

The TBARS values of döner samples were evaluated according to the method of Shrestha and Min (15) by measuring the absorbance of color developed at 530 nm using a UV visual spectrophotometer (Chebios Optimum-One) and mixing 20% trichloroacetic acid in 2 M phosphoric acid solution at 4 °C with a 0.005 M thiobarbituric acid solution (TCA/TBA). Results were calculated according to the percentage of malondialdehyde (MDA), which has a molecular weight of 72.06.

The TBARS value was calculated as follows:

$$\text{TBARS value} = [(\text{absorbance} - 0.0121) / 0.1379] \times [72.06 / 94] \text{ mg MDA/kg döner kebab.}$$

2.8. Surface color analyses

The color of döner kebabs (CIE L^* (lightness), a^* (redness), and b^* (yellowness) values) was measured at 5 different areas on the inner part of each sample using a Colorflex HunterLab Spectrophotometer (Hunter Associates Laboratory Inc., USA). At each sampling day, samples were taken immediately after opening each package, using a color difference meter (16). From these coordinates, the total color difference (ΔE^*) was calculated using the following equation:

$$\Delta E^* = [(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2]^{1/2}.$$

2.9. Sensorial examination

Eight semitrained panelists were requested to score the appearance, off-odor, flavor intensity, texture, chewiness, and general appearance acceptability on the basis of a 9-point hedonic rating scales (17,18). The scales were composed of 1, extremely unacceptable, to 9, extremely acceptable (19). The panelists were trained in 3 separate sessions (approximately 2 h) for the evaluation of selected attributes and the usage of the scale.

The panel members scored a set of 6 samples in a randomized order in a temperature- and light-controlled room. Each sample was coded with a 3-digit number

and unsalted crackers and water were used to freshen the panelists' mouths between each subsample assessment. Sensory analysis was performed in duplicates in 3 sessions.

2.10. Statistical analysis

Analysis of variance was carried out for each variable to determine the effect of storage time and packaging type. The trial was performed in triplicate and microbial counts were expressed as log₁₀ CFU/g. The mean separations were calculated by using Duncan's multiple range tests and the significance of differences was defined as P < 0.05.

3. Results

Changes in microbial populations are shown in Table 1. Days of storage at controlled chilling conditions for 12 months affected the bacterial populations of döner kebabs. Microbial growth in each group decreased during whole storage time with a magnitude greater in vacuum packaging than in air.

The initial mean pH value was 5.94 for both groups and increased rapidly to 6.28 and 6.18 for air and VAC packaged döner samples respectively until the 4th month of storage, then continued to increase slightly until the end of storage (Table 1).

Table 1. Changes in microbiological and physicochemical properties of döner kebabs packaged in different atmospheres during storage at $-18 \pm 1^{\circ}\text{C}$.

| Attributes | Package type | Time (months) | | | | | | | | | | | | P | |
|--|--------------|--------------------|----------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|----------------------|---------------------|-----|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| TAPC (log CFU/g) (SD = 0.054) | Air | 4.936 ^A | 4.873 ^{aAB} | 4.808 ^{aBC} | 4.742 ^{aBC} | 4.548 ^{aDE} | 4.430 ^{aEF} | 4.662 ^{aCD} | 4.805 ^{aABC} | 4.672 ^{aCD} | 4.560 ^{aDE} | 4.427 ^{aEF} | 4.273 ^{aFG} | 4.253 ^{aG} | *** |
| | VAC | 4.936 ^A | 4.715 ^{bB} | 4.609 ^B | 4.350 ^{bC} | 4.049 ^{bD} | 3.981 ^{bDE} | 3.945 ^{bDE} | 4.001 ^{bD} | 3.952 ^{bDE} | 3.901 ^{bDE} | 3.812 ^{bE} | 3.641 ^{bF} | 3.306 ^{bG} | *** |
| | P | NS | * | NS | * | * | * | *** | *** | *** | *** | *** | *** | *** | *** |
| <i>Pseudomonas</i> spp. (log CFU/g) (SD = 0.086) | Air | 4.064 ^A | 3.967 ^{aB} | 3.936 ^{aBC} | 3.888 ^{aBCD} | 3.865 ^{aCD} | 3.817 ^{aDE} | 3.768 ^{aE} | 3.671 ^{aF} | 3.555 ^{aG} | 3.354 ^{aH} | 3.072 ^{aI} | 2.935 ^{aJ} | 2.835 ^{aK} | *** |
| | VAC | 4.064 ^A | 3.702 ^{bB} | 3.595 ^{bC} | 3.549 ^{bC} | 3.217 ^{bD} | 3.132 ^{bD} | 2.899 ^{bE} | 2.710 ^{bF} | 2.630 ^{bF} | 2.472 ^{bG} | 2.319 ^{bH} | 2.059 ^{bI} | 1.725 ^{bJ} | *** |
| | P | NS | *** | *** | ** | *** | *** | *** | *** | *** | *** | ** | *** | *** | *** |
| pH (SD = 0.021) | Air | 5.94 ^I | 5.97 ^I | 6.15 ^{aH} | 6.22 ^{aG} | 6.28 ^{aF} | 6.30 ^{aEF} | 6.31 ^{aDEF} | 6.31 ^{aDEF} | 6.33 ^{aCDE} | 6.34 ^{aBCD} | 6.36 ^{aABC} | 6.37 ^{aAB} | 6.39 ^{aA} | *** |
| | VAC | 5.94 ^G | 5.95 ^G | 6.08 ^{bF} | 6.10 ^{bE} | 6.18 ^{bD} | 6.20 ^{bCD} | 6.22 ^{bBCD} | 6.24 ^{bABC} | 6.26 ^{bAB} | 6.28 ^A | 6.27 ^{bAB} | 6.25 ^{bAB} | 6.26 ^{bAB} | *** |
| | P | NS | NS | ** | *** | ** | * | ** | * | * | * | * | ** | ** | ** |
| Moisture (%) (SD = 1.301) | Air | 66.50 ^A | 55.00 ^{bB} | 51.33 ^{bC} | 48.47 ^{bCD} | 47.00 ^{bDE} | 45.49 ^{bDE} | 44.98 ^{bE} | 43.88 ^{bEF} | 41.14 ^{bFG} | 38.75 ^{bGH} | 37.92 ^{bH} | 37.31 ^{bH} | 36.22 ^{bH} | *** |
| | VAC | 66.50 ^A | 62.95 ^{aB} | 56.90 ^{aC} | 55.05 ^{aD} | 54.72 ^{aD} | 54.17 ^{aD} | 53.98 ^{aD} | 50.08 ^{aE} | 49.15 ^{aE} | 44.45 ^{aF} | 41.73 ^{aH} | 41.41 ^{aH} | 40.98 ^{aH} | *** |
| | P | NS | ** | *** | *** | *** | ** | * | * | ** | ** | ** | ** | ** | ** |

a,b: Means within a column with different letters are significantly different (P < 0.05).

A-F: Means within a row with different letters are significantly different (P < 0.05).

*: P < 0.05, **: P < 0.01, ***: P < 0.001.

The moisture and fat content of döner kebabs decreased during the entire storage time (Table 1; Figure 1). The initial mean moisture content was 66.50% and initial fat content was 18.20% for air and VAC packages, and these values tended to decrease depending on packaging conditions.

TBARS values of döner samples showed differences (P < 0.05) with storage time within and between groups (Figure 2). Döner kebabs packaged with air had higher mean TBARS values during the 12 months of storage compared to döner in VAC packages. Initial TBARS values were 0.055 mg MDA/kg, while the values were 0.439 and 0.288 mg MDA/kg at the end of storage for air and VAC packages, respectively.

Color properties (CIE L*, a*, b*) were different (P < 0.05) between air and vacuum packaging during storage. The initial values of each group decreased day by day during the entire storage time (Table 2).

The results of the sensory analysis of döner kebab samples for appearance, off-odor, flavor intensity, texture, chewiness, and general acceptance are presented in Table 3. The attributes showed differences for package condition and storage time. Significant differences were recorded after the 6th month of storage (P < 0.05) and a leakage of fat after the 9th month was observed in VAC packages.

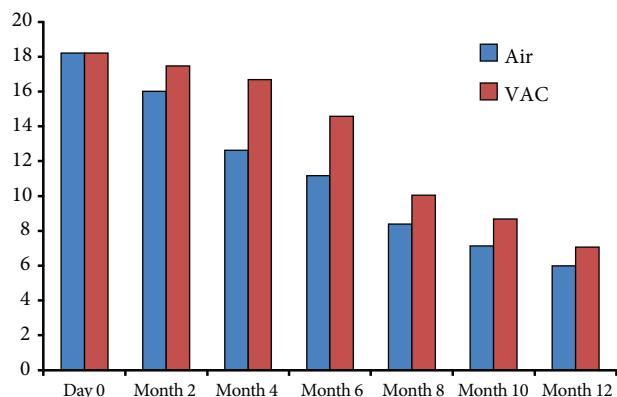


Figure 1. Changes in fat content of doner kebabs during storage time at -18°C (%).

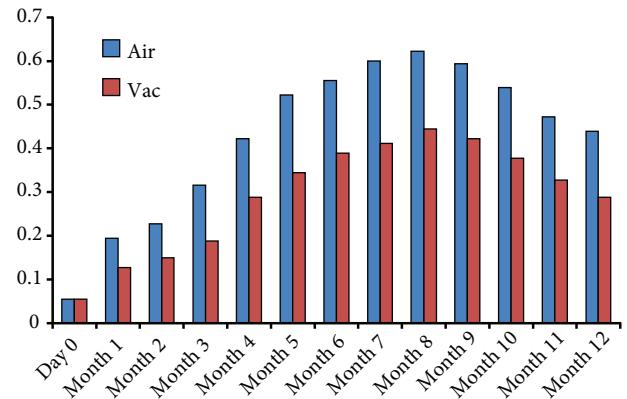


Figure 2. Changes in TBARS values of doner kebabs during storage time at -18°C (MDA/kg).

Table 2. Changes in color properties of doner kebabs packaged in different atmospheres during storage at $-18 \pm 1^{\circ}\text{C}$.

| Color attributes | Package type | Time (months) | | | | | | | P |
|--|--------------|----------------------|----------------------|-----------------------|-----------------------|----------------------|-----------------------|-----------------------|-----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | |
| L^* (Lightness) (SD = 0.426) | Air | 35.407 ^E | 41.350 ^{aA} | 41.053 ^{aAB} | 40.260 ^{BC} | 39.527 ^{CD} | 39.107 ^{aD} | 38.007 ^{aE} | *** |
| | VAC | 35.407 ^D | 39.590 ^{bA} | 39.913 ^{bA} | 39.090 ^{AB} | 38.013 ^{BC} | 36.777 ^{bCD} | 35.457 ^{bD} | *** |
| | P | NS | ** | * | NS | NS | ** | ** | |
| a^* (Redness) (SD = 0.249) | Air | 8.023 ^A | 6.573 ^B | 5.950 ^{BC} | 5.053 ^{bCD} | 4.343 ^{bDE} | 4.060 ^{bDE} | 3.507 ^{bE} | *** |
| | VAC | 8.023 ^A | 7.307 ^{AB} | 7.010 ^{BC} | 6.847 ^{aBC} | 6.587 ^{aBC} | 6.527 ^{aBC} | 6.343 ^{aC} | ** |
| | P | NS | NS | NS | ** | ** | *** | *** | |
| b^* (Yellowness) (SD = 0.232) | Air | 14.277 ^{BC} | 15.307 ^A | 14.170 ^{BC} | 13.453 ^{aCD} | 12.783 ^{aD} | 13.180 ^D | 14.773 ^{aAB} | *** |
| | VAC | 14.277 ^A | 14.440 ^A | 13.103 ^B | 12.167 ^{bC} | 11.003 ^{bD} | 12.360 ^{BC} | 13.103 ^{bB} | *** |
| | P | NS | NS | NS | ** | * | NS | * | |
| ΔE^* (Total color differences) (SD = 0.435) | Air | 0 ^D | 6.314 ^{aC} | 6.069 ^A | 5.757 ^{AB} | 5.748 ^{aAB} | 5.553 ^{aAB} | 5.291 ^{aB} | *** |
| | VAC | 0 ^C | 4.375 ^{bA} | 4.793 ^A | 4.434 ^A | 4.475 ^{bA} | 2.901 ^{bB} | 2.199 ^{bB} | *** |
| | P | NS | * | NS | NS | * | ** | *** | |

a,b: Means within a column with different letters are significantly different ($P < 0.05$).

A-E: Means within a row with different letters are significantly different ($P < 0.05$).

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$, NS: not significant.

4. Discussion

Microbial loads showed differences between air and vacuum packaging ($P < 0.05$) for total aerobic plate counts. The initial microbial counts at day 0 were $4.936 \log \text{CFU/g}$ for air and VAC packaging. Microbial growth in each group decreased during the whole storage time; however, this decrease was more remarkable in VAC-packaged samples, with a gradual $1.6 \log$ decrease at the end of the storage. A conspicuously significant difference ($P < 0.001$)

was also recorded between the days of storage in the same group, both for air and VAC packaging.

Initial mean *Pseudomonas* spp. counts were $4.064 \log \text{CFU/g}$ for both groups, where a decrease was found during the whole storage period ($P < 0.01$) for air and VAC packaging. Air-packaged doner samples remained nearly constant for up to 6 months. A fractional decrease was seen in doner kebabs from $3.967 \log \text{CFU/g}$ to $3.768 \log \text{CFU/g}$, and then these values decreased distinctly

Table 3. Changes in sensorial characteristics of döner kebabs packaged in different atmospheres during storage at -18 ± 1 °C.

| Attributes | Package type | Time (months) | | | | | P |
|------------------------------------|--------------|--------------------|---------------------|----------------------|---------------------|---------------------|-----|
| | | 0 | 3 | 6 | 9 | 12 | |
| Appearance (SD = 0.542) | Air | 8.563 ^A | 7.573 ^B | 5.093 ^{bC} | 3.487 ^{bD} | 2.540 ^{bE} | *** |
| | VAC | 8.563 ^A | 8.023 ^A | 7.013 ^{aB} | 4.593 ^{aC} | 4.100 ^{aC} | *** |
| | P | NS | NS | ** | * | * | |
| Odor (SD = 0.375) | Air | 8.403 ^A | 7.477 ^B | 6.090 ^{bC} | 5.097 ^{bD} | 3.993 ^E | *** |
| | VAC | 8.403 ^A | 8.010 ^{AB} | 7.547 ^{aBC} | 7.003 ^{aC} | 5.117 ^D | *** |
| | P | NS | NS | ** | ** | * | |
| Flavor (SD = 0.405) | Air | 8.490 ^A | 7.693 ^B | 6.100 ^{bC} | 4.480 ^{bD} | 3.857 ^{bE} | *** |
| | VAC | 8.490 ^A | 7.853 ^B | 7.183 ^{aC} | 6.107 ^{aD} | 5.123 ^{aE} | *** |
| | P | NS | NS | * | ** | ** | |
| Texture (SD = 0.347) | Air | 7.943 ^A | 7.017 ^B | 5.943 ^C | 5.023 ^{bD} | 3.893 ^{bE} | *** |
| | VAC | 7.943 ^A | 7.317 ^B | 6.277 ^C | 5.597 ^{aD} | 4.817 ^{aE} | *** |
| | P | NS | NS | NS | * | * | |
| Chewiness (SD = 0.348) | Air | 8.420 ^A | 7.090 ^{BB} | 5.9170 ^C | 5.137 ^{bD} | 4.347 ^E | *** |
| | VAC | 8.420 ^A | 7.597 ^{aB} | 6.527 ^C | 5.937 ^{aD} | 5.127 ^E | *** |
| | P | NS | * | * | * | * | |
| General acceptance (SD = 0.370) | Air | 8.043 ^A | 7.020 ^{BB} | 6.017 ^{bC} | 4.400 ^{bD} | 3.397 ^{bE} | *** |
| | VAC | 8.043 ^A | 7.460 ^{aB} | 7.040 ^{aC} | 6.063 ^{aD} | 5.013 ^{aE} | *** |
| | P | NS | ** | *** | *** | *** | |

^{a,b}: Means within a column with different letters are significantly different ($P < 0.05$).

^{A-E}: Means within a row with different letters are significantly different ($P < 0.05$).

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$, NS: not significant.

month by month until the end of the storage time (2.835 log CFU/g at the end of storage), while VAC-packaged samples decreased to 3.702 log CFU/g at the first month of storage and continued to diminish during the whole storage time ($P < 0.01$). A significant 2.3 log decrease at the end of the storage was determined for VAC samples with 1.725 log CFU/g in the 12th month (Table 1). PVC-wrapped meats favor faster bacterial growth compared to vacuum-packaged ones. Total viable plate counts decrease with vacuum packaging while lactobacilli tend to increase, whereas pseudomonads usually dominate the spoilage microflora of PVC-wrapped meats (20).

Gonulalan et al. (21) stated that TAPC, coliform, and psychrotrophic bacteria counts of döner decreased during frozen storage at -30 °C for 60 days in both raw and cooked conditions. Generally, it is reported that döner purchased from local fast-food units had an average total

aerobic bacteria count of 10^4 – 10^5 CFU/g (21–25). It is remarkable that the effects of storage, combined with low storage temperature and packaging conditions, increased with time and reduced the microbial count. Similarly, Ergönül and Kundakçı (26) pointed out that lower counts observed in frozen storage might be due to the fact that bacteria become inactive over time.

The pH value of döner samples increased during storage time at -18 ± 1 °C. A significant difference was recorded from the 2nd month of storage, with 6.15 and 6.08 for air- and VAC-packaged samples, respectively, until the end of the storage time ($P < 0.01$). A strong, significant difference was also determined in the pH value of each group during storage ($P < 0.001$).

Ergönül and Kundakçı (27) stated that the initial pH value of döner samples was 6.03; this increased during frozen storage and reached 6.30. The changes in pH value

of frozen döner during 7.5 months significantly varied among the months, as similarly stated in the present study. According to Turkish standards, the pH value of fresh döner should not exceed the value of 6.20 (28). Likewise, Kayisoglu et al. (4) reported that pH values of fresh chicken döner samples were 5.69–6.13, which was parallel to our findings.

A significant decrease was found in the moisture content of döner kebabs for all groups during storage time ($P < 0.05$); the loss of moisture at the end of storage was more remarkable for air-packaged döner samples (36.22%) compared to VAC-packaged ones (40.98%).

Ergönül and Kundakci (27) indicated that the water content of döner was 62.39% after production and decreased to 60.46% at the end of the frozen storage. The loss of approximately 3.1% water was found contrary to the present study, where a significant decrease was determined in both packaging conditions (approximately 25%–30.1%). Additionally, Kayisoglu et al. (4) stated that the water content of raw chicken döner was between 59.61% and 61.61%, while Seeger et al. (29) reported that the amount of water in chicken döner sold in Germany was between 37.9% and 68.1%.

Fat content of döner kebabs decreased during the entire storage time, dependent on the packaging system used (Figure 1). Döner samples packaged in air had lower fat contents during the 12 months of storage compared to döner in VAC packages. A significant change was observed within ($P < 0.001$) and between ($P < 0.05$) the groups during storage, with a fat value of 5.99% and 7.08% for air- and VAC-packaged döner samples at the end of storage times, respectively.

Ergönül and Kundakci (27) pointed out that the initial fat levels in döner varied from 13.91% to 14.26% after 7.5 months of frozen storage. This finding is contrary to the present study, where a dramatic decrease was observed in the fat content of döner samples. This could be due to the initial fat amount of meat types and the percentage of lipolysis during frozen storage. The fat levels of döner kebabs were reported to be between 9.48% and 22.77% (30) and between 1.05% and 2.08% (4) in meat and chicken döner, respectively.

Storage time and packaging conditions were the significant factors for thiobarbituric acid values. The TBARS values of all döner samples increased in up to 8 months of storage time, then decreased until the end of storage; levels in VAC-packaged samples remained lower than those of air-packaged ones during the entire storage time.

Ergönül and Kundakci (27) emphasized that the initial TBA value of döner samples was 0.370 mg/kg, and this increased slowly during frozen storage, reaching 0.894 mg/kg at the end of 7.5 months. However, limited oxidation

occurred during frozen storage and the average TBA value did not exceed the level of 1 mg/kg, which is the critical level for TBA, similar to in the present study. In another study conducted by Ergönül and Kundakci (26), the TBA value varied between 0.278 and 0.462 mg/kg during 3 months of frozen storage. Gonulalan et al. (21) reported that fat and TBA values of sucuk döner tended to increase with storage time, while pH and moisture content of döner decreased during 60 days of frozen storage.

Higher values for lightness and yellowness in air-packaged samples were recorded, while redness was higher in VAC packages (Table 2). Furthermore, the decreases in a^* and b^* values were significantly important after the 4th month of storage ($P < 0.05$), where a remarkable difference was observed in the 2nd month of storage for L^* values between air and VAC packages. Total color differences (ΔE^*) were more substantial in air packages than VAC packages; this difference was more evident for all storage times at -18 °C in air packages with an almost constant difference in color parameters (Table 2). It is recognized that browning occurs in PVC packaging due to oxygen-stimulated metmyoglobin formation even while bacterial numbers are low (20).

Sensory analysis of döner kebab showed differences between package conditions and storage time. Even though the shelf-life was prolonged with VAC packaging, a significant difference was not observed except for chewiness, which influenced the general acceptance until the 3rd month of storage in respect to panelists' preferences ($P > 0.05$). Significant differences were found after the 6th month of storage ($P < 0.05$), where the samples were, in general, not acceptable for air packaging. A leakage of fat was remarkable after the 9th month, which affected the appearance of the vacuum-packaged döner kebabs. However, döner meat stored under vacuum packaging was more acceptable during the entire storage time at -18 °C. Gonulalan et al. (21) determined that the sensory evaluation of sucuk döner had favorable input at the 60th day of storage; therefore, it is applicable in döner production without posing any acceptability problems. Ergönül and Kundakci (27) stated that odor, taste, palatability, and general appearance evaluation scores of döner samples changed significantly ($P < 0.05$) with storage time. They also indicated that consumer choice was not influenced by frozen storage for a period of 7.5 months.

The quality and shelf-life of vacuum-packaged and frozen cooked döner kebabs were preserved throughout the storage period of 12 months. Microbial growth in döner meat was delayed due to the lack of O₂ in the package, which prevented the increase of lipid oxidation and improved consumer acceptance for up to 9 months. Furthermore, loss of color and leakage of fat during long storage may adversely affect consumer preferences.

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