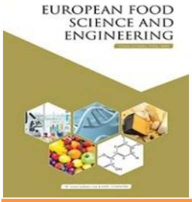


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# The effect of ginger use in chicken meatball production on lipid oxidation, sensory properties and other quality criteria

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ABSTRACT

In this study, ginger was used in different proportions (control, 0.25%, 0.50%, 0.75% and 1%) in the production of chicken meatball and the samples were cooked at different temperatures (175 ℃ and 200 ℃). Total aerobic mesophilic bacteria (TAMB) count, pH, moisture, thiobarbituric acid reactive substances (TBARS), ash, cooking yield and sensory analyses were applied on the samples. Ginger ratio (GR) in the meatballs caused statistically significant differences in TAMB, moisture, TBARS, ash, cooking yield and taste values ($P<0.01$). On the other hand, pH value was affected by this ratio at the level of $P<0.01$. Especially, with the increase in ginger ratio, lipid oxidation decreased while cooking yield increased. Cooking temperature (CT) caused changes in TAMB, TBARS and ash values. High cooking temperature caused a decrease in TAMB count and TBARS values. GR-CT interaction was statistically effective on TAMB, moisture, ash, cooking efficiency and general acceptability from sensory parameters. Considering the sensory analysis results, it was concluded that up to 0.75% ginger could be used in meatballs to increase functional properties and provide antioxidant and antimicrobial effects.

## 1. Introduction

Meatball is a meat product that is consumed worldwide and is usually prepared with minced meat, spices, binding agents and various additives (Kirkyol & Akköse, 2023). Despite the fact that they are prepared using a variety of recipes in different countries and cultures, its basic ingredients and production process are similar to each other. Meatball stands out as a healthy food option in nutrition, especially with their high protein, vitamin and mineral content. In addition, due to the ease of preparation and sensory diversity, meatball is gaining importance as an indispensable food in both homemade meals and industrial production, making it commercially attractive. Especially in the ready-to-eat food sector, meatball is prepared with different types of meat and appeal to a wide range of consumer groups (Meng et al., 2022).

The types of meat used in making meatball have a direct effect on the flavor, texture, nutritional value and cost of the product. While red meats such as goat, lamb (Silva et al., 2023), pork (Madsen et al., 1996; He et al., 2022) and beef (Kirkyol & Akköse, 2023) are generally preferred in traditional recipes; other alternative protein sources (white meats) such as chicken (Racanicci et al., 2004; Kesemen & Akköse 2024), turkey (Karpińska-Tymoszczyk & Draszanowska, 2019) and even fish (Guan et al., 2019) are used in the modern food sector. White meats are preferred especially for lower-cost and low-fat products (Karpińska-Tymoszczyk & Draszanowska, 2019).

White meats stand out as a healthy alternative with their low cost, low saturated fat and high protein content (De Lima et al., 2015; Al-Juhaimi et al., 2018; Karpińska-Tymoszczyk, and Draszanowska, 2019). Chicken and turkey meats have more advantages compared to red meats in terms of polyunsaturated fatty acids (Racanicci et al., 2011; Petcu et al., 2023). This situation makes meatballs containing white meat more attractive, especially for health-conscious consumers. What is more, its low cholesterol level makes chicken meatballs preferable in terms of cardiovascular health (Lima et al., 2016). The neutral taste of chicken meat can be easily blended with spices and herbal extracts. This allows the meatball to be adapted to different palates (Jaworska et al., 2021). The sensory properties of chicken meatballs can be enriched, especially when produced using ginger (Rongsensusang et al., 2005), rosemary (Karpińska-Tymoszczyk & Draszanowska, 2019) and other herbal additives (Racanicci et al., 2004).

As a processed meat product, meatball is susceptible to the problems such as lipid oxidation and microbial spoilage. This

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situation may shorten shelf life, deteriorate sensory properties and increase food safety risks (Lima et al., 2016; Jaworska et al., 2021; Petcu et al., 2023). Antioxidants and antimicrobial agents play a critical role in preventing these problems (Guan et al., 2019; Petcu et al., 2023). Lipid oxidation causes loss of flavor, color change and decrease in nutritional value in the products (Jayasena and Jo, 2014; Karpińska-Tymoszczyk & Draszanowska, 2019). Antioxidants slow down oxidation by neutralizing free radicals. Synthetic antioxidants (e.g. BHA, BHT) have been used as an effective solution for many years, however the demand for natural antioxidants is increasing due to the toxic effects of synthetic ones (Jaworska et al., 2021; Petcu et al., 2023). Microbial spoilage in meatballs increases the risk of foodborne illness (Morsy et al., 2023). Natural antimicrobial agents provide a safe product by preventing the growth of pathogenic microorganisms (Jaworska et al., 2021; He et al., 2022; Petcu et al., 2023). Herbal extracts and natural-sourced components such as ginger and rosemary stand out with both antioxidant and antimicrobial properties (He et al., 2022). In addition, natural components are preferred since they are more suitable for environmentally friendly production processes (Shaukat et al., 2023).

Ginger (*Zingiber officinale*) is one of the most important herbal extracts used in meatball production. It contains phenolic compounds such as gingerol and shogaol which protect the flavor and nutritional value of meatballs by slowing down lipid oxidation (Laelago Ersedo et al., 2023; Shaukat et al., 2023). In addition, ginger increases food safety by preventing the growth of pathogenic microorganisms, which is also crucial in extending shelf life (Beristain-Bauza et al. 2019; Laelago Ersedo et al., 2023; Shaukat et al., 2023) Ginger supports the immune system with its anti-inflammatory and antioxidant properties and turns meatball into a functional food (Laelago Ersedo et al., 2023; Shaukat et al., 2023).

In chicken meatball production, dittany and rosemary herb (Racanicci et al., 2004), mate (Racanicci et al., 2008), argel leaf extract (Al-Juhaimi et al., 2018), moringa leaf powder (Nisar et al., 2020) and ginger (Rongsensusang et al., 2005) were used as antioxidants. In the study conducted by Rongsensusang et al., (2005); 2, 4 and 6% ginger was added to meatballs made from chicken meat and the product was examined in terms of pH, penetrometer values, TBA, microbial load and sensory properties during storage. However, the effects of different cooking temperatures on meatballs with ginger added have not been investigated in the literature. In addition, cooking efficiency, moisture and ash analyzes have not been performed on chicken meatballs with ginger added. In this study, different amounts of ginger (control, 0.25%, 0.50%, 0.75% and 1%) were used in meatballs produced using chicken meat and they were cooked at different temperatures (175 ℃ and 200 ℃). At the end of production, samples were analyzed in terms of total aerobic mesophilic bacteria (TAMB), pH, moisture, thiobarbituric acid reactive substances (TBARS), ash, cooking efficiency and sensory ways (color, appearance, odor, texture, taste and general acceptability).

## 2. Materials and Methods

### 2.1. Materials

The chicken meat, beef fat, salt, onion, breadcrumbs, eggs and spices (hot pepper powder, sweet pepper powder, black pepper, cumin and ginger) used in this study were supplied from the Kastamonu market.

### 2.2. Methods

*Production of meatball*

To start with the ingredients, 71% chicken meat, 12% beef fat, 1% salt, 6% onion, 6% breadcrumbs, 2.5% egg, 0.3% hot pepper powder, 0.6% sweet pepper powder, 0.3% black pepper and 0.3% cumin were used for meatball production. The first group prepared with this formulation was considered as control and ginger was not used in production. In the other groups, ginger was added in addition to this formulation at different rates (0.25%, 0.5%, 0.75% and 1%). 40 g of meatballs were taken and shaped using a metal mold (6.5 cm diameter and 1 cm thickness). The produced meatballs were cooked on a hot plate (Elektromag M4060, Türkiye) at different temperatures (175 ℃ and 200 ℃) and then analyzed for total aerobic mesophilic bacteria (TAMB), pH, moisture, thiobarbituric acid reactive substances (TBARS), ash, and cooking efficiency. Sensory analysis was also applied to the samples.

*TAMB*

PCA (plate count agar) was used for TAMB count. 25 g of meatball samples were weighed; 225 mL of dilution fluid was added and homogenized using the Stomacher device. After that, the homogenate was diluted with the rate of 1:10. Appropriate dilutions were cultured by the spreading method and the petri plates were incubated at 30 ℃ for 2 days. At the end of the period, the TAMB count was determined as log cfu/g.

*pH*

Before determining the pH values of the samples, the pH meter was calibrated using buffer solutions (pH 4.00 and pH 7.00). Then, 100 mL of pure water was added onto 10 g of sample and homogenized using an ultra-turrax device (Velp Scientific, Italy). The pH value of the homogenate was determined using a calibrated pH meter (Isolab, Germany) (Gökalp et al., 2010).

*Moisture*

The nickel containers to be used in the analysis were dried and tared. Then, 10 g of meatball samples were weighed on those containers and dried at 105 ℃ until a constant weight was reached. The moisture content was stated as % at the end of drying (Gökalp et al., 2010).

*TBARS*

To determine lipid oxidation in meatballs, 12 mL of 7.5% TCA solution was added on 2 g of weighed sample; the mixture was homogenized using ultra-turrax (Velp Scientific, Italy) and filtered by Whatman No.1 filter paper. 3 mL of this filtrate and 3 mL of 0.02 M TBA solution were mixed together, kept in a boiling water bath for 40 minutes and cooled. After the mixture was cooled, then it was centrifuged for 5 minutes at 2000 G and the absorbance was determined at 530 nm in a spectrophotometer. The result was expressed as mg malondialdehyde/kg (Lemon, 1975).

$$TBARS\ (\mu molMDA/kg) = \frac{\left(\frac{Absorbance}{Standard} \times 2\right)}{Sample\ \ Weight} \times 6.8 \qquad (1)$$

*Ash*

Ash crucibles were dried and tared before use, 5 g of meatball sample was weighed on these crucibles and placed in a muffle furnace; and the temperature was gradually increased and brought to 525 °C. The burning process was terminated when the color of the samples became gray-white and the results were calculated as ash% on dry matter (Gökalp et al., 2010).

*Cooking yield*

The 40 g meatball samples were weighed before and after cooking. Then, the cooking yield was determined using these results (Pinero et al., 2008).

$$CY = \frac{A}{B} x\ 100 \qquad (2)$$

where CY, cooking yield (%); A, cooked meatball weight (g); B, Raw meatball weight (g)

*Sensory analysis*

In the sensory analysis, 10 semi-trained panelists evaluated the cooked meatball samples in terms of color, appearance, odor, texture, taste and general acceptability using the hedonic type scale (1-9). In the scoring, 1 point was accepted as "undesirable" and 9 points as "typically desirable".

**2.4. Statistical analysis**

Ginger ratio and cooking temperature were selected as factors in the study. The trial was carried out with 2 replications and completely random. TAMB, pH, moisture, ash and cooking efficiency were carried out with two replications. TBARS and sensory analysis were carried out with 3 and 10 replications, respectively. Variance analysis was applied to the data obtained from the analyses and statistically significant results were compared with the Duncan multiple comparison test (IBM SPSS Statistics 2).

## 3. Results and Discussion

Total aerobic mesophilic bacteria (TAMB) counts of meatballs cooked at different temperatures using different amounts of ginger are shown in Table 1. As seen from the table, the TAMB counts of the groups using 1% ginger were found to be higher than the other groups. This result is thought to be due to contamination that occurs especially during the drying of ginger. However it has been stated that the TAMB count decreased with the use of argel leaf extract in chicken meatballs (Al-Juhaimi et al., 2018). At high cooking temperatures, there was a statistical increase in the number of these bacteria and a lower average value was detected in meatballs cooked at 200 °C. In addition, a significant effect of GR-CT interaction on TAMB was determined and while a lower TAMB count was determined in meatballs cooked at 175 °C in the control group, cooking at 200 °C caused higher TAMB counts in the groups using 0.75% and 1% ginger (Figure 1).

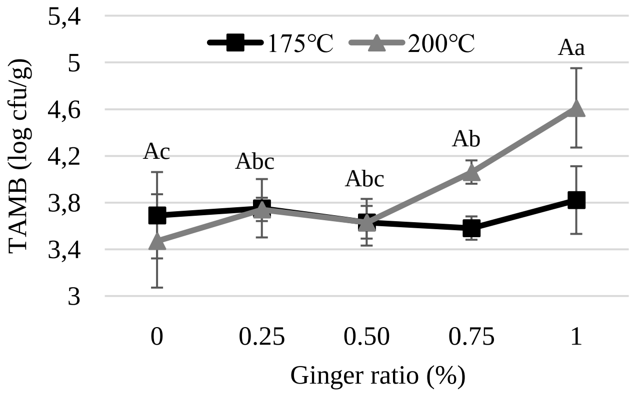


**Figure 1.** The effect of ginger level x cooking temperature interaction on TAMB number (A: Same letters indicate statistical no differences (P>0.05) for meatball cooking at 175 °C; a-c: Different letters indicate statistical differences (P<0.05) for meatball cooking at 200 °C)

The ginger ratio, cooking temperature and the interaction of these factors did not have a significant effect on the pH value of the meatballs (P>0.05) (Table 1). The use of ginger in meatballs produced from pork did not show a significant effect on the pH value as well (He et al., 2022). On the other hand, in the study conducted by Al-Juhaimi et al. (2018) on chicken meatballs, argel leaf extract caused a decrease in the pH value.

**Table 1.** The effect of ginger level and cooking temperature on TAMB, pH, moisture, TBARS, ash and cooking yield of meatball

| | TAMB (log cfu/g) | pH | Moisture (%) | TBARS (mg MDA/kg) | Ash (%) | Cooking Yield |
|---|---|---|---|---|---|---|
| **Ginger ratio (GR) (%)** | | | | | | |
| **0-Control** | 3.58±0.37$^{b}$ | 6.05±0.05 | 58.81±0.73$^{b}$ | 0.841±0.013$^{a}$ | 2.61±0.10$^{a}$ | 85.06±3.43$^{c}$ |
| **0.25** | 3.75±0.17$^{b}$ | 6.10±0.01 | 60.27±0.51$^{a}$ | 0.778±0.014$^{b}$ | 2.55±0.08$^{b}$ | 85.85±1.98$^{bc}$ |
| **0.50** | 3.63±0.16$^{b}$ | 6.08±0.02 | 59.40±2.01$^{ab}$ | 0.766±0.011$^{c}$ | 2.56±0.03$^{b}$ | 85.14±1.80$^{c}$ |
| **0.75** | 3.82±0.28$^{b}$ | 6.10±0.05 | 58.47±0.33$^{b}$ | 0.711±0.009$^{d}$ | 2.53±0.11$^{b}$ | 86.76±2.85$^{b}$ |
| **1** | 4.22±0.52$^{a}$ | 6.14±0.02 | 58.74±0.66$^{b}$ | 0.661±0.012$^{e}$ | 2.36±0.07$^{c}$ | 89.62±1.47$^{a}$ |
| **Sig.** | ** | NS | * | ** | ** | ** |
| **Cooking temperature (CT) (°C)** | | | | | | |
| **175** | 3.69±0.23$^{b}$ | 6.09±0.04 | 59.39±1.15 | 0.760±0.065$^{a}$ | 2.56±0.14$^{a}$ | 86.19±3.31 |
| **200** | 3.90±0.47$^{a}$ | 6.10±0.04 | 58.88±1.12 | 0.743±0.062$^{b}$ | 2.48±0.06$^{b}$ | 86.78±2.38 |
| **Sig.** | * | NS | NS | ** | ** | NS |
| **GRxCT** | * | NS | ** | NS | ** | ** |

$^{a-e}$: Different letters indicate statistical difference (P <0.05) in each column; NS: Not significant; *P < 0.05; **P < 0.01

The ginger ratio and GR-CT interaction caused a statistical change in the moisture value. The moisture value became the highest in the group containing 0.25% ginger (Table 1). On the other hand, He et al. (2022) did not determine a significant effect of ginger use on the moisture value in pork meatballs. According to the GR-CT interaction, cooking at 200 ℃ caused a higher moisture value in the control and 0.25% ginger groups, while the opposite was observed in the other groups (Figure 2).

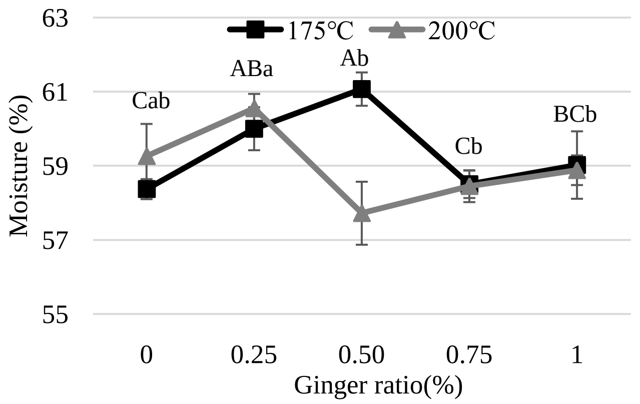


**Figure 2.** The effect of ginger level x cooking temperature interaction on moisture (A-C: Different letters indicate statistical differences (P<0.05) for meatball cooking at 175 ℃; a-b: Different letters indicate statistical differences (P<0.05) for meatball cooking at 200 ℃)

The TBARS value, which is an indicator of lipid oxidation, was significantly affected by all main sources of variation and the interaction of those sources. According to the results, the use of ginger and the application of high cooking temperature caused a decrease in lipid oxidation (Table 1). This result is thought to be due to the antioxidant effect of ginger, since it contains the related phenolic compounds (Shaukat et al., 2023). In a study conducted on chicken meatballs, the use of dittany herb and rosemary caused a decrease in the TBARS value (Racanicci et al., 2004). Bulan & Öz (2022) found that the TBARS value of beef meatballs decreased with the use of tarragon. In addition, this study also concluded that since the internal temperature of the sample group that were applied high-temperature cooking process reached the desired level in a shorter time, it caused a lower TBARS value in these groups (Table 1).

The ginger ratio, cooking temperature and interaction of these two factors had a significant effect on the ash content of the meatball samples. As seen in Table 1, the control group showed a higher ash content than the other samples. Contrary to this study, the use of argel leaf extract in chicken meatballs did not cause a statistical change in the ash value (Al-Juhaimi et al., 2018). On the other hand, this study also provided that the ash content in meatballs cooked at 175 ℃ was found to be higher than other groups. The effect of GR-CT interaction on the ash content is given in Figure 3. As seen in the figure, while the samples cooked at 200 ℃ in the control, 0.25% and 0.75% ginger groups showed lower ash content, the meatballs cooked at 200 ℃ in the 1% ginger group showed higher values (Figure 3).

The cooking yield results of chicken meatballs produced using different ginger ratios and cooking temperatures are shown in Table 1. As it can be understood from the results, the use of 0.75% and 1% ginger had positive effects on cooking yield. The highest average cooking yield value (89.62) was determined in the group containing 1% ginger. In a study conducted on pork meatballs, the use of ginger reduced cooking loss and the lowest value was found in the group using 1.25% ginger (He et al., 2022). In this study, cooking temperature had no significant effect on cooking yield (P>0.05). However, the GR-CT interaction affected cooking yield very significantly. While cooking at 200 ℃ increased cooking yield in the control and 0.25% ginger samples, cooking at 200 ℃ caused lower values in the samples containing 0.75% ginger (Figure 4).

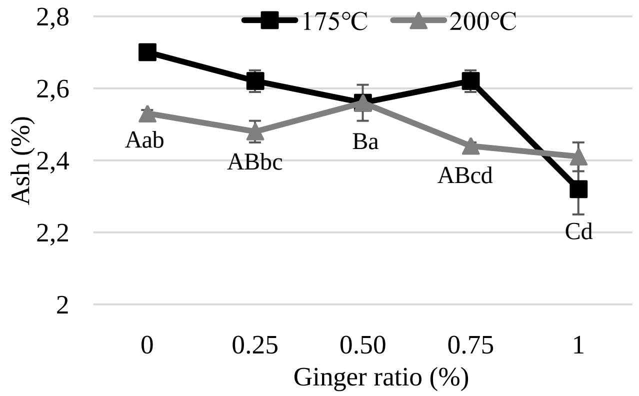


**Figure 3.** The effect of ginger level x cooking temperature interaction on ash (A-C: Different letters indicate statistical differences (P<0.05) for meatball cooking at 175 ℃; a-d: Different letters indicate statistical differences (P<0.05) for meatball cooking at 200 ℃)

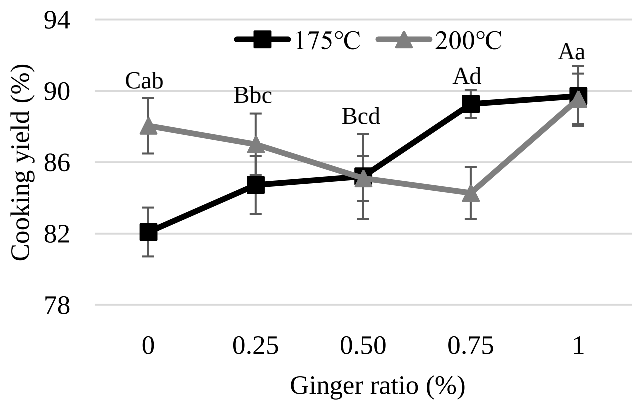


**Figure 4.** The effect of ginger level x cooking temperature interaction on cooking yield (A-C: Different letters indicate statistical differences (P<0.05) for meatball cooking at 175 ℃; a-d: Different letters indicate statistical differences (P<0.05) for meatball cooking at 200 ℃)

The sensory analysis results of meatballs produced with different ginger ratios and cooking temperatures are presented in Table 2. While the ginger ratio statistically affected only the taste of the product, the cooking temperature did not have a significant effect on the average sensory analysis values. In terms of taste, especially the use of 1% ginger received lower scores from the panelists. In the study conducted by Nisar et al., (2020), it was determined that moringa leaf powder application on chicken meatball did not affect the sensory properties. The interaction of these two values had a statistical effect on general acceptability at P<0.05 level. As seen from Figure 5, while cooking at 200 ℃ caused lower general acceptability scores in the control and 0.25% ginger groups, it increased general acceptability in the other groups.

**Table 2.** The effect of ginger level and cooking temperature on sensory parameters of meatball

| | Color | Appearance | Odor | Texture | Taste | General acceptability |
|---|---|---|---|---|---|---|
| **Ginger ratio (GR) (%)** | | | | | | |
| **0-Control** | 7.79±1.32 | 7.67±1.34 | 7.86±1.03 | 7.92±1.41 | 7.88±1.26[a] | 7.83±1.13 |
| **0.25** | 7.75±1.07 | 7.58±1.14 | 7.79±1.28 | 7.58±1.10 | 7.75±1.11[a] | 7.79±0.93 |
| **0.50** | 8.00±1.02 | 7.96±1.12 | 7.96±1.20 | 7.29±1.60 | 7.38±1.44[ab] | 7.75±1.03 |
| **0.75** | 7.63±1.06 | 8.04±1.08 | 8.17±0.76 | 7.58±0.97 | 6.92±1.84[ab] | 7.38±1.31 |
| **1** | 7.96±1.08 | 8.13±0.95 | 7.96±1.27 | 7.96±1.08 | 6.42±2.19[b] | 7.00±1.79 |
| **Sig.** | NS | NS | NS | NS | * | NS |
| **Cooking temperature (CT) (°C)** | | | | | | |
| **175** | 7.82±1.16 | 7.88±1.12 | 7.80±1.22 | 7.57±1.37 | 7.15±1.82 | 7.48±1.42 |
| **200** | 7.83±1.06 | 7.87±1.16 | 8.10±0.99 | 7.77±1.14 | 7.38±1.53 | 7.62±1.17 |
| **Sig.** | NS | NS | NS | NS | NS | NS |
| **GRxCT** | NS | NS | NS | NS | NS | * |

[a-b]: Different letters indicate statistical difference (P <0.05) in each column; NS: Not significant; *P < 0.05

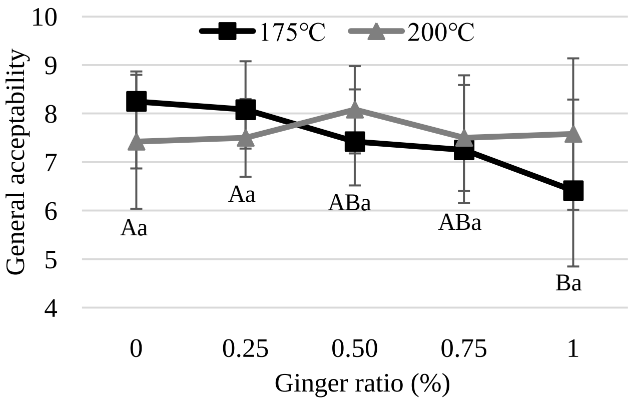


**Figure 5.** The effect of ginger level x cooking temperature interaction on general acceptability (A-B: Different letters indicate statistical differences (P<0.05) for meatball cooking at 175 °C; a-c: Same letters indicate statistical no differences (P>0.05) for meatball cooking at 200 °C)

## 4. Conclusions

The use of ginger in meatballs increased cooking efficiency while limiting lipid oxidation. On the other hand, while the use of 1% ginger caused an increase in TAMB numbers, it decreased the ash value and received lower scores from the panelists in terms of taste. Considering all these outcomes, it is thought that the use of ginger up to 0.75% in meatball production is appropriate. In addition, when the TBARS values were considered in terms of cooking temperature, it was observed that cooking at 200 °C gave more positive results.

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There is no acknowledgement.

## Conflicts of Interest

The authors state that they have no conflicts of interest.

### Declaration of Competing Interest

The authors declare no conflict of interest.

## References

Al-Juhaimi, F. Y., Shahzad, S. A., Ahmed, A. S., Adiamo, O. Q., Mohamed Ahmed, I. A., Alsawmahi, O. N., ... & Babiker, E. E. (2018). Effect of Argel (Solenostemma argel) leaf extract on quality attributes of chicken meatballs during cold storage. *Journal of Food Science and Technology*, *55*, 1797-1805. doi:10.1007/s13197-018-3094-1

Beristain-Bauza, S. D. C., Hernandez-Carranza, P., Cid-Perez, T. S., Avila-Sosa, R., Ruiz-Lopez, I., & Ochoa-Velasco, C. E. (2019). Antimicrobial activity of ginger (*Zingiber Officinale*) and its application in food products. *Food Reviews International*, *35* (5), 407-426. doi:10.1080/87559129.2019.1573829

Bulan, R., & Oz, F. (2022). Impact of tarragon usage on lipid oxidation and heterocyclic aromatic amine formation in meatball. *International Journal of Food Science & Technology*, *57* (2), 942-950. doi:10.1111/ijfs.15430

De Lima, C. B., Racanicci, A. M. C., Oliveira, G. R., Migotto, D. L., Amador, S. A., de Souza, T. C., ... & Vieira, A. (2015). Effects of the dietary supplementation of sucupira (*Pterodon emarginatus* Vog.) and copaiba (*Copaifera langsdorffii*) resinoils on chicken breast and thigh meat quality and oxidative stability. *Brazilian Journal of Poultry Science*, *17*, 47-55. doi:10.1590/1516-635XSPECIALISSUENutrition-PoultryFeedingAdditives047-056

Bradley-Johnson, S. (1994). Psychoeducational assessment of students who are visually impaired or blind: Infancy through high school (2nd ed.). Austin, TX: Pro-ed.

Gökalp, H. Y., Kaya, M., Tülek, Y. & Zorba, Ö. (2010). Et ve et ürünleri kalite kontrolü ve laboratuvar uygulama klavuzu (5[th] ed.). Atatürk University Publishing (Turkish).

Guan, W., Ren, X., Li, Y., & Mao, L. (2019). The beneficial effects of grape seed, sage and arogano extracts on quality and volatile flavor component of hairtail fish balls during cold storage at 4 °C. *LWT-Food Science and Technology*, *101*, 25-31. doi:10.1016/j.lwt.2018.11.024

He, X., Li, B., Yu, X., Zhuang, Y., Li, C., Dong, L., ... & Wang, S. (2022). Inhibiting effects of ginger and rosemary on the formation of heterocyclic amines, polycyclic aromatic hydrocarbons, and trans fatty acids in fried pork balls. *Foods*, *11* (23), 3767. doi:10.3390/foods11233767

Jaworska, D., Rosiak, E., Kostyra, E., Jaszczyk, K., Wroniszewska, M., & Przybylski, W. (2021). Effect of herbal addition on the microbiological, oxidative stability and sensory quality of minced poultry meat. *Foods*, *10* (7), 1537. doi:10.3390/foods10071537

Jayasena, D. D., & Jo, C. (2014). Potential application of essential oils as natural antioxidants in meat and meat products: A review. *Food Reviews International*, *30* (1), 71-90. doi:10.1080/87559129.2013.853776

Karpińska-Tymoszczyk, M., & Draszanowska, A. (2019). The effect of natural and synthetic antioxidants and packaging type on the quality of cooked poultry products during frozen storage. *Food Science and Technology International*, *25* (5), 429-439. doi:10.1177/1082013219830196

Kesemen, A. M., & Akköse, A. (2024). Evaluation of physicochemical, textural, and sensory properties of reduced-fat chicken patties produced with chia flour and κ-carrageenan. *Italian Journal of Food Science/Rivista Italiana di Scienza degli Alimenti*, *36* (3). doi:10.15586/ijfs.v36i3.2490

Kirkyol, M., & Akköse, A. (2023). Effect of animal fat replacement with almond flour on quality parameters of beef patties. *Food Science & Nutrition*, *11*, 7091-7099. doi:10.1002/fsn3.3633

Laelago Ersedo, T., Teka, T. A., Fikreyesus Forsido, S., Dessalegn, E., Adebo, J. A., Tamiru, M., & Astatkie, T. (2023). Food flavor enhancement, preservation, and bio-functionality of ginger (Zingiber officinale): a review. *International Journal of Food Properties*, *26* (1), 928-951. doi:10.1080/10942912.2023.2194576

Lemon, D. W. (1975). An Improved TBA Test for Rancidity New Series Circular, No:51 Halifax-Laboratory, Halifax, Nova Scotia.

Lima, C. B., Migotto, D. L., Oliveira, G. R., Souza, T. C., Santana, R. O., Castejon, F. V., ... & Racanicci, A. M. C. (2016). Dietary supplementation of barbatimão (Stryphnodendron adstringens) and pacari (Lafoensia Pacari) extracts on the oxidative stability and quality of chicken meat. *Brazilian Journal of Poultry Science*, *18*, 669-676. doi:10.1590/1806-9061-2015-0212

Madsen, H. L., Andersen, L., Christiansen, L., Brockhoff, P., & Bertelsen, G. (1996). Antioxidative activity of summer savory (Satureja hortensis L.) and rosemary (Rosmarinus officinalis L.) in minced, cooked pork meat. *Zeitschrift für Lebensmittel-Untersuchung und Forschung*, *203*, 333-338. doi:10.1007/BF01231071

Meng, X., Wu, D., Zhang, Z., Wang, H., Wu, P., Xu, Z., ... & Dabbour, M. (2022). An overview of factors affecting the quality of beef meatballs: Processing and preservation. *Food Science & Nutrition*, *10* (6), 1961-1974. doi:10.1002/fsn3.2812

Morsy, M. K., Al-Dalain, S. Y., Haddad, M. A., Diab, M., Abd-Elaaty, E. M., Abdeen, A., ... & Elsabagh, R. (2023). Curcumin nanoparticles as a natural antioxidant and antimicrobial preservative against foodborne pathogens in processed chicken fingers. *Frontiers in Sustainable Food Systems*, *7*, 1267075. doi:10.3389/fsufs.2023.1267075

Nisar, M. F., Arshad, M. S., Yasin, M., Khan, M. K., Afzaal, M., Sattar, S., & Suleria, H. A. R. (2020). Evaluation of gamma irradiation and moringa leaf powder on quality characteristics of meat balls under different packaging materials. *Journal of Food Processing and Preservation*, *44*(10), e14748. doi:10.1111/jfpp.14748

Petcu, C. D., Mihai, O. D., Tăpăloagă, D., Gheorghe-Irimia, R. A., Pogurschi, E. N., Militaru, M., ... & Ghimpețeanu, O. M. (2023). Effects of plant-based antioxidants in animal diets and meat products: A review. *Foods*, *12*(6), 1334. doi:10.3390/foods12061334

Pinero, M. P., Parra, K., Huerta-Leidenz, N., De Moreno, L. A., Ferrer, M., Araujo, S., & Barboza, Y. (2008). Effect of oat's soluble fibre (β-glucan) as a fat replacer on physical, chemical, microbiological and sensory properties of low-fat beef patties. *Meat science*, *80*(3), 675-680. doi:10.1016/j.meatsci.2008.03.006

Racanicci, A. M., Danielsen, B., & Skibsted, L. H. (2008). Mate (Ilex paraguariensis) as a source of water extractable antioxidant for use in chicken meat. *European Food Research and Technology*, *227*, 255-260. doi:10.1007/s00217-007-0718-5

Racanicci, A. M., Danielsen, B., Menten, J. F. M., Regitano-d'Arce, M. A., & Skibsted, L. H. (2004). Antioxidant effect of dittany (Origanum dictamnus) in pre-cooked chicken meat balls during chill-storage in comparison to rosemary (*Rosmarinus officinalis*). *European Food Research and Technology*, *218*, 521-524. doi:10.1007/s00217-004-0907-4

Racanicci, A. M., Menten, J. F., Alencar, S. M., Buissa, R. S., & Skibsted, L. H. (2011). Mate (Ilex paraguariensis) as dietary additive for broilers: performance and oxidative stability of meat. *European Food Research and Technology*, *232*, 655-661. doi:10.1007/s00217-011-1432-x

Rongsensusang, R., Reddy, K. S., Reddy, K. K., & Lakshmi, K. D. (2005). Effect of ginger on quality of frozen spent hen meat balls. *Journal of Food Science and Technology-Mysore*, *42*(6), 534-539.

Shaukat, M. N., Nazir, A., & Fallico, B. (2023). Ginger bioactives: A comprehensive review of health benefits and potential food applications. *Antioxidants*, *12*(11), 2015. doi:10.3390/antiox12112015

Silva, S. R., Teixeira, A., & Guedes, C. (2023). Sheep and goat meat processing and quality. *Foods*, *12*(10), 2033. doi:10.3390/foods9070960