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Use of Various Chili Powder in Chicken Patties: Effects on Color and Oxidative Stability

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ABSTRACT

In this study, the chicken patties were manufactured using different chili powders such as Bird's eye chili, Jalapeno and Mexican chili. It was found that TBARS values increased over 6 days at 4°C in the chicken patty samples except CP3, with the control group showing the highest increase in lipid oxidation. Among the chili varieties used, Mexican chili (CP3) was the most effective in preventing lipid oxidation, as it maintained stable TBARS values throughout the storage period. The addition of chili powder significantly reduced the pH of chicken patties compared to the control group, with the lowest pH values observed in the CP2 and CP3 groups. Jalapeño maintained pH stability of samples throughout storage. The incorporation of various chili powders into chicken patties resulted in darker-colored patties on days 1 and 2, with Bird's eye chili yielding the closest color to the control on day 6. The CP3 group exhibited the highest *a** values, contributing to a redder and more color-stable appearance, while the addition of Jalapeño did not significantly affect *b** values, while Bird's eye and Mexican chili increased them. In conclusion, the incorporation of different chili varieties into chicken patty formulations was found to be effective in mitigating lipid oxidation, with Mexican chili demonstrating the most pronounced protective effect.

Tavuk Köftelerinde Çeşitli Acı Biber Tozlarının Kullanımı: Renk ve Oksidatif Stabilite Üzerine Etkileri

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ÖZ

Bu çalışmada, tavuk köfteleri Kuş gözü biberi, Jalapeno biberi ve Meksika biberi gibi farklı biber tozları kullanılarak üretilmiştir. TBARS değerlerinin CP3 hariç tavuk köftesi örneklerinde 4°C'de 6 gün boyunca arttığını ve kontrol grubunun lipid oksidasyonunda en yüksek artışı gösterdiği tespit edilmiştir. Kullanılan biber çeşitleri arasında Meksika biberi (CP3), depolama süresi boyunca sabit TBARS değerlerini koruduğu için lipid oksidasyonunu önlemede en etkili olanıydı. Toz biber ilavesi tavuk köftelerinin pH değerini kontrol grubuna kıyasla önemli ölçüde düşürmüş, en düşük pH değerleri CP2 ve CP3 gruplarında gözlenmiştir. Jalapeño, depolama boyunca örneklerin pH stabilitesini korumuştur. Çeşitli acı biber tozlarının tavuk köftelerine eklenmesi, 1. ve 2. günlerde daha koyu renkli köfteler elde edilmesine neden olurken, kuş gözü acı biber 6. günde kontrole en yakın rengi vermiştir. CP3 grubu en yüksek *a** değerlerini sergileyerek daha kırmızı ve daha renk stabil bir görünüme katkıda bulunurken, Jalapeño ilavesi *b** değerlerini önemli ölçüde etkilememiş, kuş gözü ve Meksika biberi ise artırmıştır. Sonuç olarak tavuk köfte formülasyonlarında çeşitli biberlerin kullanımının lipid oksidasyonunun önlenmesinde etkili olduğu, özellikle Meksika biberinin en iyi sonucu verdiği belirlenmiştir.

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1. Introduction

Chicken meat is important in the human diet because it is rich in some nutrients, such as essential amino acids, vitamins and minerals, and low in fat and cholesterol compared to other meat sources. In addition, chicken meat and meat products have high sensory properties, leading to high acceptance, and chicken meat is easy for everyone to prepare, with no social or religious restrictions (Jung et al., 2014; Huo et al., 2021; Hailemariam et al., 2022). Chicken meat is suitable for the production of various meat products such as nuggets, sausages, patties, which are produced by processing chicken meat with various seasonings and non-meat ingredients (Akter et al., 2022). Chicken patties have become a popular meat product as a result of the increased demand for ready-to-eat foods in recent years, associated with the development of food science and technology and the modernisation of lifestyles. Patties are made by mixing minced meat with oil, breadcrumbs, salt and spices and then forming it into balls using a mould (Patriani and Apsari, 2021; Akter et al., 2022). Currently, some bioactive ingredients are being used to enhance the nutritional and functional properties of patties due to increased consumer interest in healthier meat products (Verma et al., 2016; Patriani and Apsari, 2021; Akter et al., 2022).

Meat and meat products can be chemically degraded at different stages, such as production, storage and distribution, resulting in a significant decrease in quality parameters (Domínguez et al., 2019; Alirezalu et al., 2020; Biplob et al., 2024). One important element influencing the safety, shelf life, and quality of meat products is lipid oxidation. The shelf life of meat and meat products was shortened by lipid oxidation, which also caused a decline in organoleptic qualities such as color, flavor, texture, and nutritional value. (Devatkal et al., 2014; Alirezalu et al., 2020; Biplob et al., 2024). It leads to the formation of off-flavors, discoloration, nutrient loss, and potentially harmful compounds. Over the years, various natural and synthetic antioxidants have been used to control lipid oxidation in meat systems. Compounds such as rosemary extract, plant origin polyphenols, tocopherols, and essential oils from spices have demonstrated varying degrees of effectiveness in inhibiting oxidative reactions (Shahidi and Zhong, 2010; Karre et al., 2013; Estevez, 2015; Babaoğlu et al., 2022; Dilek et al., 2025). Because of their high phenolic component concentration and antioxidant capacity, plant-based by-products have garnered increasing attention in recent years as sustainable and useful additives. In order to stop lipid oxidation, natural antioxidants are frequently added to meat products (Lorenzo et al., 2018). Natural antioxidants are abundant in plant materials such as fruits, vegetables, medicinal herbs and spices, which have attracted attention in recent years due to their high content of phenolic and other bioactive components with antioxidant and antimicrobial properties (Akter et al., 2022; Biplob et al., 2024). Natural antioxidants are recognised as GRAS (Generally Recognised as Safe) ingredients and are effective at low levels and non-toxic at high levels (Lorenzo et al., 2018; Munekata et al., 2020).

Pepper (*Capsicum* spp.) is a widely cultivated plant in the world and a popular spice belonging to the *Solanaceae* family, which is widely used in the world's nutrition (Hernández-Pérez et al., 2020;

Awodola-Peters et al., 2021; Zhang et al., 2023). *Capsicum annuum* and *Capsicum frutescens* are most known and used as spices with a pungent and spicy flavour. A number of bioactive compounds in *Capsicum* spp. have protective properties against the microbial developments of spoilage and pathogenic microbial growth and oxidation are alkylamides (capsaicinoids) and polyphenols (Souza et al., 2022; Ivane et al., 2024). The polyphenols in capsicums are flavonoids, phenolic acids and anthocyanins and protect against oxidation. Bioactive compounds in *Capsicum* spp. could be used as natural substitutes for chemical antimicrobials and antioxidants in food technology. The effects of bioactive compounds are related to the food composition, production technology and storage requirements (Baenas et al., 2019; Liu et al., 2023; Ivane et al., 2024). The varieties of *Capsicum* spp. and the degree of ripening caused differences in pepper quality (Awodola-Peters et al., 2021). Bird's eye chilli (*Capsicum frutescens*) is grown commercially in tropical regions, particularly in Thailand, and has a higher spiciness than other chillies (Khanema et al., 2024; Pastsart et al., 2024). Jalapeno pepper (*Capsicum annum*) is one of the well-known and most consumed peppers in Mexico (Sánchez Toledano et al., 2023). The effect of *Capsicum* spp. on the quality of meat and meat products has been observed in the literature (Kim, 2020; Ivane et al., 2024; Ivane and Romeo, 2025).

In this study, Bird's eye chili, Jalapeno, and Mexican chili powders were incorporated into chicken patties at a concentration of 2.5% by replacing an equivalent amount of breadcrumb in the formulation, in order to evaluate their effectiveness in reducing lipid oxidation and improving product stability during storage. Unlike previous studies, which primarily focused on pepper extracts or essential oils, this study utilizes whole fruit powder, promoting a more sustainable and cost-effective approach. The antioxidant properties of the chili powders were also characterized to better understand their functional contribution to oxidative stability. The aim of this study was to determine the effects of Bird's eye chilli, jalapeno and Mexican chilli on the pH, color and thiobarbituric acid reactive substances (TBARS) parameters of chicken patties during the 1st, 2nd and 6th days of chilled storage.

2. Materials and Methods

Chicken breast meat used in the production of chicken patties was procured from a local supplier in Konya and the fresh meat samples were shipped to the lab at 4 °C to maintain a cold environment. Fresh hot chili peppers were purchased from a local market, manually chopped into small pieces using a knife, and dried at ambient room temperature. After drying, the peppers were ground into powder and added to the product formulation. The drying process was carried out under typical room conditions without controlling specific parameters such as temperature or humidity.

The remaining ingredients used in the chicken patties formulation, including olive oil, salt, and breadcrumbs, were sourced from local market in Konya.

2.1. Preperation of Chicken Patties

Using a plate with holes 3 mm in diameter (Kitchen Aid, Classic Model, USA), the fresh chicken meat (not previously frozen) was minced twice in a meat grinder without any trimming (i.e., skin and fat were not removed) and then separated into four batches.

After being weighed separately, all ingredients- breadcrumbs, olive oil, salt, distilled water, and chili powders- were added simultaneously and manually mixed by hand for approximately 4 minutes until a homogeneous mixture was obtained. Four varieties of chicken patties were made in the manner described in Table 1: CP1 (Bird's eye chili), CP2 (Jalapeño), CP3 (Mexican chili), and control C (no chili powder added). Every chicken patty, weighing roughly 40 ± 0.1 g each, was manually molded into a circular form with dimensions of 35 mm in diameter and 10 mm in thickness. To ensure uniformity in sample dimensions, a mold was used during the shaping process, providing consistent diameter and thickness across all samples. Additionally, each sample was individually weighed using a calibrated digital balance to achieve the target weight with a precision of ±0.1 g during manual shaping. They were then individually placed in Styrofoam trays. The samples were packaged under atmospheric conditions using a polyvinyl chloride (PVC) film that allows oxygen transmission. No vacuum packaging or additional sealing method was employed. After shaping and packaging, all patties were immediately stored at 4 ± 1°C (for 6 days). The initial analyses, corresponding to day 1 of storage, were performed after approximately 24 hours of refrigeration. A total of 72 chicken patties were produced: three patties for each treatment x four treatments (C, CP1, CP2 and CP3) x three storage times (1, 2 and 6 days) x two independent replications (using similar manufacturing processes). All samples were analysed on days 1, 2 and 6.

Table 1. Chicken patty formulation of treatments with different chili powder

Ingredients (g)	**Groups**			
	C	**CP1**	**CP2**	**CP3**
Chicken meat	108	108	108	108
Breadcrump	8.4	5.4	5.4	5.4
Olive oil	1.2	1.2	1.2	1.2
Salt	1.2	1.2	1.2	1.2
Distile water	1.2	1.2	1.2	1.2
Bird's eye chili powder	-	3	-	-
Jalapeño powder	-	-	3	-
Mexican chili powder	-	-	-	3

C: Control; CP1: Bird's eye chili powder added chicken patty; CP2; Jalapeño powder added chicken patty; CP3; Mexican chili powder added chicken patty.

2.2. Determination of Total Phenolic Content, Total Flavonoid Content and Antioxidant Activity of Chili Powders

Çetin Babaoğlu et al. (2024) proposed a modified method for obtaining the extract from the chili samples before the TPC, TFC, and DPPH assays. For this purpose, five grams of ground sample were suspended in a 70% methanol (v/v) solution, and they were then incubated in a shaking water bath (250 rpm) at

25°C for an hour. After incubation, centrifugation was used for 10 minutes at 10,000 rpm to collect the supernatant.

According to Lee et al. (1998), DPPH (1,1-diphenyl-2-picrylhydrazyl) was used to assess the extracts' capacity to scavenge free radicals. A spectrophotometer (UV-160 A, UV–Visible Recording Spectrophotometer, Shi-madzu, Tokyo, Japan) was used to measure the absorbance at 517 nm. A percentage of free radical scavenging activity (%) was used to represent the results.

The Folin-Ciocalteu procedure was employed to determine the extracts' total phenolic contents (Yoo et al., 2004). 2.5 mL of 10% Folin reagent (v/v), 0.1 mL of extract, and 0.4 mL of distilled water were put in a tube and left in the dark for two minutes in order to measure the complex's total phenolic content. Two milliliters of a 7.5% NaCO 3 (w/v) solution were then added to the sample tube, and it was incubated for five minutes at 50°C. A spectrophotometer was used to measure the samples' absorbance at 760 wavelengths. Using a gallic acid standard curve, the samples' total phenolic acid concentration was determined on a dry basis.

The total flavonoid concentration of the extracts was ascertained using the technique described by Chen and Chen (2011). 150 µL of 5% NaNO3 (w/v), 2 mL of distilled water, and 0.5 mL of extract were placed in a tube and left in the dark for six minutes in order to measure the total flavonoid content. After that, 200 µL of distilled water, 2 mL of 1 N NaOH, and 150 µL of 10% AlCl3 (w/v) solution were added to the sample tube, and it was allowed to sit for fifteen minutes. A spectrophotometer was used to test the samples' absorbance at 510 wavelengths. Using a catechin standard curve, the samples' total flavonoid concentration was determined on a dry basis.

2.3. pH Values of Chicken Patties

Using a pH meter and the procedure described by Lambooij et al., (1999). A pH meter was used to measure the chicken patties' pH levels at three distinct points on each sample. Prior to the analysis, the pH meter was calibrated using buffer solutions with pH values of 4, 7, and 10. To guarantee accuracy, the readings were obtained right after calibration.

2.4. Lipid Oxidation (Thiobarbituricacid (TBARS) Number) of Chicken Patties

As stated by Tarladgis et al. (1960) method was used to measure the TBARS number, a measure of lipid oxidation. Using a UV-160 A, UV-Visible Recorder Spectrophotometer (Shimadzu, Tokyo, Japan). Briefly, 10 g of sample was homogenized with 97.5 mL of distilled water (50 ◦C), then 2 mL of HCl was added and distilled at 125 ◦C. After approximately 45 ml of distillate was obtained, 5 ml of distillate was kept in a hot water bath (90 ◦C) with 5 ml of TBARS reagent for 35 min. The tubes were then cooled in a cold water bath. The absorbance of the supernatant was recorded at 530 nm. The TBARS number was then computed as mg malonaldehyde/kg sample by multiplying the absorption readings by the coefficient 7.03.

2.5. Color Properties of Chicken Patties

A colorimeter (Konica, Minolta CR 400, Osaka, Japan) with illuminant D65, 2◦ observer angle, diffuse/O mode, 8 mm aperture for illumination, and 8 mm for measurement was used to quantify the samples' L^* (lightness), a^* (redness), and b^* (yellowness) parameters. The mean values (L^*, a^*, and b^*) of each sample were analyzed after color measurements were taken at four distinct sites per sample, all perpendicular to the sample surface (Babaoğlu et al., 2022).

2.6. Statistical Analysis

In a completely randomized factorial design with two independent replications, four treatments (C, CP1, CP2, and CP3) and three storage durations (1, 2, and 6 days) were used. The generalized linear mixed model was used to do an analysis of variance (ANOVA) for the statistical analysis of the pH, TBARS, and color data. Replication was regarded as a random element, whereas the chili powder treatment, storage duration, and interaction were fixed components. To ascertain the differences between the means at a 5% significant level, Tukey Multiple Comparison Tests were employed in conjunction with the chili powder treatment, storage duration, and the interaction between the storage duration and the chili powder treatment.

3. Results and Discussion

3.1. Total Phenolic Content, Total Flavonoid Content and Antioxidant Activity

In Table 2, the DPPH (%), TFC (mg CE/100 mL), and TPC (mg GAE/100 mL) results of different chili varieties are summarized. The DPPH values of the samples range from 66.78 to 69.14%, with no significant statistical difference observed in terms of antioxidant activity ($P > 0.05$). In terms of total phenolic content, both Bird’s eye chili and jalapeno are similar ($P > 0.05$), but have higher TPC values compared to Mexican chili ($P < 0.05$). When evaluated for total flavonoid content, the highest flavonoid content was found in jalapeno (32.95 mg CE/100 mL), while the lowest was observed in Mexican chili (22.35 mg CE/100 mL) ($P < 0.05$).

It is reported that capsaicin and capsaicinoids compounds contained in *Capsicum annuum* peppers have important effects on antioxidant, anti-obesity and other nutritional benefits. In particular, it has been reported that these compounds show anti-obesity effects through mechanisms such as inhibiting lipid oxidation, inhibiting the differentiation of adipocytes and increasing thermogenesis (Martínez et al., 2006). Since Jalapeño and Mexican chili are also included in *Capsicum annuum* species, it is likely that these peppers have similar antioxidant and anti-obesity effects. However, further research on the specific properties and effects of these species is needed.

In a study, the antioxidant activities and bioactive compounds of five different jalapeno pepper varieties (Grande, El Dorido, Red, Yellow, and Orange) were evaluated. The antioxidant capacity was measured using the DPPH radical scavenging assay, with Grande (87%) and El Dorido (83%) showing the highest DPPH radical scavenging activities. Additionally, these two varieties exhibited high reducing power and total phenolic content, reaching levels comparable to BHT. As a result, it was reported that the antioxidant activities of jalapeno peppers are related to the presence of phenolic compounds and other bioactive compounds (flavonoids and vitamins) and these peppers may offer potential health benefits. The study also highlights that there is variability in antioxidant activity among different jalapeno pepper varieties, and their composition should be considered in agricultural production and consumption (Farhoudi et al., 2019).

Table 2. The antioxidant activity (DPPH), total phenolic (TPC) and total flavonoid (TFC) contents of *chili varieties*

Analysis	*Bird's eye chili*	*Jalapeño*	*Mexican chili*
DPPH (%)	66.78±1.19[a]	69.14±1.67[a]	67.28±0.48[a]
TFC (mg CE/100 mL)	25.27±0.46[b]	32.95±0.72[a]	22.35±0.26[c]
TPC (mg GAE/100 mL)	197.06±0.00[a]	192.58±2.17[a]	182.48±1.56[b]

Mean±standard dev. Within the same row values with different superscript letters indicate significant differences ($P < 0.05$) DPPH: The 1,1-diphenyl-2-picrylhydrazyl. TPC: Total phenolic content, TFC: Total flavonoid content

3.2. pH

Table 3 illustrates the pH values of chicken patties during 6 days at 4^0C. On days 1 and 2, the addition of chili powder resulted in a significant reduction in pH levels compared to the control group ($P < 0.05$). On day 1, the highest pH value was observed in the control group (5,22), whereas the lowest values were recorded in treatments CP2 (5.15) and CP3 (5.14) ($P < 0.05$). On day 2, although the control group again exhibited the highest pH value (5.27) ($P < 0.05$), no statistically significant differences ($P > 0.05$) were found among the treatment groups, with pH values ranging between 5.17 and 5.21. On the last day, the highest pH value was measured in CP2 (5.15) and the lowest in the control group (4.94) ($P < 0.05$). While the addition of Jalapeño maintained the pH stability of the chicken patty samples throughout storage, the samples prepared with the addition of Bird's eye chili exhibited higher pH values on days 1 and 2 compared to the final day of the study ($P < 0.05$). Fluctuations in pH levels were observed in both the control group and the CP3 treatment group. The observed fluctuations in pH values during storage can be attributed to multiple factors. Primarily, the metabolic activity of residual microorganisms and enzymatic reactions during storage may lead to the production of acidic or basic compounds, thereby altering the pH. Additionally, the incorporation of different chili varieties could have contributed to these variations due to their distinct phytochemical compositions, including organic acids and phenolic compounds, which can influence the acidity or alkalinity of the chicken patty matrix. The interaction between chili seed components and the meat matrix may also affect buffering capacity, further impacting pH stability during storage. These factors collectively explain the statistically significant differences observed across samples.

In one study, pork sausage samples containing red sweet pepper or cayenne pepper (*Capsicum annuum*) (0.1%, 0.5%, or 2%) or black or white pepper (*Piper nigrum*) (0.1%, 0.5%, or 1%) were packaged in an atmosphere of 80% O_2 and 20% CO_2 and stored in the dark at 2 °C for 16 days. Based on pH measurements conducted every four days, it was reported that the addition of chilli peppers had no significant effect on pH (P > 0.05). These findings are consistent with those observed in the group containing only jalapeño, suggesting that the differing acidic properties of various chilli pepper varieties may result in variable effects on pH (Martínez et al., 2006).

Table 3. The results of physicochemical analyses of chicken patty samples formulated with chili powders

Analyses	Groups	Storage day		
		1	2	6
pH	**C**	5.22 ± 0.01^{aB}	5.27 ± 0.00^{aA}	4.94 ± 0.01^{cC}
	CP1	5.17 ± 0.00^{bA}	5.21 ± 0.02^{bA}	5.10 ± 0.01^{abB}
	CP2	5.15 ± 0.01^{cA}	5.17 ± 0.01^{bA}	5.15 ± 0.02^{aA}
	CP3	5.14 ± 0.00^{cB}	5.19 ± 0.01^{bA}	5.08 ± 0.01^{bC}
L*	**C**	54.71 ± 0.77^{aA}	55.67 ± 0.19^{aA}	55.53 ± 0.29^{aA}
	CP1	47.72 ± 0.21^{bB}	48.63 ± 0.31^{bB}	55.53 ± 0.29^{aA}
	CP2	46.26 ± 0.31^{bcA}	46.73 ± 0.87^{bA}	45.02 ± 2.41^{bA}
	CP3	44.83 ± 0.00^{cA}	43.61 ± 0.14^{cA}	43.23 ± 1.28^{bA}
a*	**C**	8.05 ± 0.24^{cA}	7.66 ± 0.35^{cA}	7.84 ± 0.18^{cA}
	CP1	15.18 ± 0.24^{bA}	12.43 ± 0.32^{bB}	13.21 ± 0.11^{bB}
	CP2	1.59 ± 0.27^{dAB}	0.78 ± 0.14^{dB}	2.47 ± 0.48^{dA}
	CP3	22.66 ± 0.38^{aA}	21.92 ± 1.72^{aA}	23.94 ± 0.71^{aA}
b*	**C**	19.88 ± 0.71^{cA}	18.22 ± 0.55^{bA}	19.16 ± 0.07^{bA}
	CP1	31.44 ± 1.06^{bA}	30.02 ± 1.83^{aA}	29.81 ± 1.07^{aA}
	CP2	21.58 ± 0.07^{cA}	21.70 ± 1.08^{bA}	20.47 ± 0.62^{bA}
	CP3	36.21 ± 1.64^{aA}	29.43 ± 2.94^{aA}	33.42 ± 2.63^{aA}
	C	0.30 ± 0.01^{abC}	0.62 ± 0.07^{aB}	0.98 ± 0.02^{aA}
[1]TBARS number	**CP1**	0.30 ± 0.01^{abB}	0.49 ± 0.06^{abA}	0.62 ± 0.01^{bA}
	CP2	0.34 ± 0.04^{aB}	0.27 ± 0.02^{cB}	0.53 ± 0.01^{cA}
	CP3	0.22 ± 0.04^{bA}	0.35 ± 0.06^{bcA}	0.26 ± 0.01^{dA}

Mean ± standard error. Within the same row values with different uppercase superscript letters indicate significant differences (P < 0.05). Within the same column, values with different lowercase superscript letters indicate significant differences (P < 0.05). C: Control; CP1: Bird's eye chili powder added chicken patty; CP2; Jalapeño powder added chicken patty; CP3; Mexican chili powder added chicken patty. [1]: mg MA/kg sample.

3.3. TBARS Number

Table 3 presents the TBARS numbers of the chicken patty samples during 6 days at 4^0C. TBARS values on day 1 varied from 0.22 to 0.34 mg MA/kg sample, with the CP2 group exhibiting the highest value and the CP3 group the lowest (P < 0.05). On day 2, an increase in TBARS numbers was observed in the control and CP1 groups, likely due to oxidation (P < 0.05), while no statistically significant changes were detected in the samples containing Jalapeño and Mexican chili (P > 0.05).

On day 6, TBARS numbers further increased in the control and CP2 groups (P < 0.05), whereas no significant changes were recorded in the CP1 and CP3 groups compared to the previous analysis day (P > 0.05). The significant decrease in TBARS values observed in the chili powder–supplemented samples can be largely attributed to the presence of antioxidant phytochemicals such as phenolic acids and flavonoids. In the present study, the antioxidant activity of each chili variety was assessed through the DPPH radical scavenging assay, and both total phenolic and total flavonoid contents were determined. Among the tested varieties Jalapeno powder exhibited the highest antioxidant capacity (69.14% DPPH inhibition), as well as the highest levels of flavonoids (32.95 mg CE/100 ml). These compounds have been reported to prevent lipid oxidation by scavenging free radicals, donating hydrogen atoms, and inhibiting pro-oxidant enzymes. Therefore, the inhibitory effect on lipid oxidation in the chili powders is likely due to these active constituents. Differences among the chili types in terms of their phytochemical composition may also explain the variability in lipid oxidation inhibition.

Overall, the TBARS numbers of the control group increased from 0.30 mg MA/kg sample on day 1 to 0.98 mg MA/kg sample by the end of the storage period ($P < 0.05$). However, the incorporation of different chili varieties in the formulation demonstrated a general protective effect against lipid oxidation. Among them, the use of Mexican chili (CP3) was found to be the most effective ($P < 0.05$), as it maintained stable TBARS numbers throughout the storage period without statistically significant changes. Similarly, Olorunsanya et al., (2009) investigated the effects of different *Capsicum species* (red hot pepper, bell pepper, tabasco, and habanero) on the oxidative stability of raw and cooked patties prepared from frozen pork. The authors reported that the addition of these pepper species significantly reduced lipid oxidation compared to both the control group and the group supplemented with α-tocopheryl acetate. Notably, red hot pepper exhibited the highest antioxidant activity, resulting in the lowest TBARS values among the treatments.

Our results were also found to be compatible with those of Menegali et al., (2020). In chicken burgers containing pink pepper, the addition of pink pepper extract significantly reduced lipid oxidation compared to both the control and BHT-added samples. It was reported that only the control group showed an increase in TBARS values during the storage period. Lipid free radicals can stay stable at low temperatures and may spread over greater distances, which aids in the advancement of oxidation, according to Kanner (1994). The necessity of using antioxidants is thus highlighted by the fact that keeping samples at refrigeration temperature (4^0C) is insufficient to considerably slow down the oxidative process. Kim (2020) indicates that the TBARS values, used to assess lipid oxidation, increased over time in control and formulated with pepper seed (*Capsicum annuum* L.). However, sausages containing pepper seed exhibited significantly lower TBARS values compared to the control group, indicating that pepper seed addition effectively retarded lipid oxidation. After 14 days, TBARS values were 0.38 μg MDA/mL for treatment group and 0.47 μg MDA/mL for control group. In conclusion, the results demonstrate that the incorporation of pepper seed contributes to the inhibition of lipid oxidation in chicken sausages.

In an another study evaluating the impact of *Capsicum annuum* (sweet red and hot cayenne) and *Piper nigrum* (black and white) pepper powders on the quality characteristics of chicken breast meat, polyphenolic and alkylamide compounds were extracted from the peppers. Treatment with the polyphenol fraction (PF, 6 mg/mL) led to a marked decrease in lipid oxidation, as evidenced by significantly lower TBARS values compared to both the control and other treatment groups (Ivane and Romeo, 2025).

3.4. Color Properties

The effects of incorporating various chili powders into the chicken patty formulation on the color parameters such as *L** (lightness), *a** (redness), and *b** (yellowness) of the samples are presented in Table 3. On days 1 and 2, all chili powder types resulted in darker-colored patties compared to the control group. The *L** values were highest in the control samples (54.71 and 55.67, respectively) and lowest in the CP3 samples (44.83 and 43.61, respectively) on days 1 and 2 ($P < 0.05$).

On day 6, the inclusion of Bird's eye chili in the formulation yielded patties with a color similar to that of the control group ($P > 0.05$) and brighter than those in the CP2 and CP3 groups ($P < 0.05$). While the *L** values of the control, CP2, and CP3 groups remained stable throughout the storage period, an increase was observed in the CP1 group on day 6 compared to earlier measurements ($P < 0.05$).

According to the Table 3, the CP3 group consistently exhibited the highest *a** values, while the CP2 group had the lowest *a** values across all analysis days ($P < 0.05$). This is likely attributed to the inherent redness of the chili varieties used in the formulations. While no significant changes in *a** values were observed in the control and CP3 groups during storage ($P > 0.05$), noticeable fluctuations occurred in the other treatment groups. The incorporation of Mexican chili contributed to the production of patties with a redder and more color-stable appearance throughout the storage period.

The lack of significant differences in color parameters (*L**, *a**, *b**) among the samples may be attributed to several factors. First, the concentration of chili powder (2.5%) used in the formulation may not have been sufficient to induce noticeable changes in color, especially considering it was incorporated by replacing an equivalent amount of breadcrumb. Moreover, the pigments in the chili powders—such as carotenoids or capsanthin—may not have been present in high enough quantities or may have had limited solubility and interaction within the meat matrix. The binding of pigments to muscle proteins and the relatively short diffusion distance in finely ground meat products could also limit their visual impact. Additionally, the natural color of chicken meat might have masked minor pigment contributions, leading to non-significant differences in instrumental color measurements.

The inclusion of Jalapeño powder in the formulation did not significantly affect the *b** values of the patties compared to the control group ($P > 0.05$) (Table 3). In contrast, higher *b** values were recorded in samples containing Bird's eye chili and Mexican chili ($P < 0.05$). No significant changes in *b** values were observed in any of the groups throughout the storage period ($P > 0.05$).

Martínez et al. (2006) packaged pork sausage samples containing red sweet pepper or cayenne pepper (*Capsicum annuum*) (0.1%, 0.5%, or 2%) or black or white pepper (*Piper nigrum*) (0.1%, 0.5%, and 1%) in an environment with 20% CO_2 and 80% O_2 and stored them at 2 °C in the dark for 16 days. The study reported that the incorporation of different pepper types into the sausage formulation did not significantly affect *L** and *b** values. However, red sweet pepper and hot cayenne pepper increased the *a** values of the sausages. Despite this, the addition of peppers was not effective in preventing discoloration during storage.

4. Conclusion

The present study demonstrated that the incorporation of chili powders—specifically Bird's eye chili, Jalapeño, and Mexican chili—into chicken patty formulations significantly influenced lipid oxidation, pH stability, and color characteristics during refrigerated storage. Among the tested varieties, Mexican chili was the most effective in limiting lipid oxidation, as evidenced by stable TBARS values throughout the 6-day storage period. Additionally, chili inclusion reduced pH values compared to the control, with Jalapeño maintaining pH stability over time. Color analysis revealed enhanced redness (a*) in patties containing Mexican chili, supporting its role in improving both oxidative stability and visual quality. These findings highlight the potential of chili powders, particularly Mexican chili, as natural functional ingredients to improve the shelf life and quality attributes of poultry-based meat products. There is no data in the literature regarding the use of Bird's chili, jalapeno, or Mexican chili in chicken patties, and it is believed that the current study is significant in providing data in this area.

Conflicts of Interest

The authors declare no potential conflicts of interest.

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Author Contributions

The authors declare that they have contributed equally to the article.

Compliance with ethics requirements

This manuscript does not contain any studies with human participants or animals performed by the author.

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