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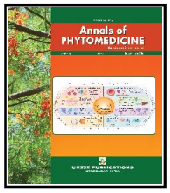

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Studies on preservation of chicken by using natural preservatives to extend the shelf-life

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Abstract

Poultry meat is widely preferred by consumers because of its high nutritional value, low fat content, desirable flavour and economical production cost. Country chicken meat has recently gained considerable attention as a functional food due to the presence of several bioactive compounds that provide health promoting benefits beyond basic nutrition. The present study was undertaken to evaluate the influence of natural preservatives, packaging materials and storage conditions on the physicochemical, microbiological and sensory preserved country chicken meat. Fresh chicken samples were treated with dry ginger powder (T_1), salt with turmeric (T_2) and salt with pepper (T_3), while untreated samples served as control (T_0). The samples were packaged in aluminium foil, polypropylene containers and banana leaves and stored under freezer and refrigeration conditions for 15 days. Country chicken meat have some important bioactive compounds such as carnosine, anserine, creatine, carnitine, betaine, inosine monophosphate (IMP) and bioactive peptides, which contribute to antioxidant, anti-inflammatory, antiaging, anti-glycation, antimicrobial, antihypertensive, neuroprotective and immunomodulatory activities. These compounds also support muscle energy metabolism, fatty acid oxidation, cellular protection and enhanced meat flavour and palatability. The initial moisture, protein and fat contents of fresh chicken were recorded as 62.0%, 32.0 g/100 g, and 8.6 g/100 g, respectively. During storage, moisture and fat contents gradually decreased, whereas peroxide value and free fatty acid content increased, indicating progressive lipid oxidation and hydrolytic rancidity. However, preservative treated samples exhibited significantly lower oxidative deterioration and microbial proliferation compared with untreated samples. Among the treatments, T_2 and T_3 demonstrated superior antioxidant and antimicrobial activities due to the presence of curcumin and piperine. Sensory evaluation revealed that freezer stored T_3 samples retained better colour, flavour, texture, taste and overall acceptability than refrigerated samples. Aluminium foil packaging exhibited superior preservation efficiency by minimizing oxidative deterioration and microbial spoilage. The findings indicate that natural spice based preservatives combined with suitable packaging materials and freezer storage effectively enhance shelf-life, microbial safety, oxidative stability and sensory quality of country chicken meat, offering a sustainable and eco-friendly alternative to synthetic preservatives.

1. Introduction

India possesses one of the largest livestock populations in the world and approximately 5.3 million metric tons of meat are consumed annually. India is the largest producer of buffalo meat and the second largest producer of goat meat. At present, the meat processing level in the poultry industry is around 6%, while the overall meat industry accounts for nearly 21% processing levels (Khalid *et al.,* 2021). The poultry meat industry in India is a highly organized and vertically integrated sector that has achieved efficiency levels comparable to those of many Western countries. The Government of India has also initiated modernization programs for municipal abattoirs to ensure the production of safe and hygienic meat for consumers.

The poultry sector has significantly benefited the Indian economy by improving rural livelihoods and generating foreign exchange through exports. Among Indian states, Tamil Nadu ranks second in egg production with approximately 10.8 billion eggs annually and contributes about 17.71% of the country's poultry population. More than 90% of poultry and poultry products exported from India originate from Tamil Nadu. In recent years, the state has produced over 455 thousand metric tons of poultry meat (Shelepov *et al.,* 2019). However, poultry meat is highly susceptible to contamination by pathogenic microorganisms such as Campylobacter, Salmonella and Escherichia coli, which may naturally inhabit the intestinal tract of chickens and pose serious food safety concerns.

Meat is defined as the edible flesh of animals used for human consumption. Fresh meat includes meat obtained from recently slaughtered animals as well as vacuum packed or modified atmosphere packed meat that has not undergone any preservation treatment

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other than chilling. Due to its rich nutrient composition, meat provides an ideal medium for the growth and multiplication of spoilage microorganisms and food borne pathogens. Therefore, effective preservation technologies are essential to maintain meat safety and quality (Banaszak *et al.,* 2022). Preservation techniques are primarily aimed at controlling microbial spoilage while minimizing undesirable changes such as discoloration, lipid oxidation and textural deterioration.

Traditionally, meat preservation methods can be classified into three major categories based on the control of temperature, moisture reduction and inhibitory processes such as bactericidal or bacteriostatic treatments, including packaging and irradiation techniques. In many cases, preservation methods involve the combined application of several antimicrobial principles. Each preservation factor acts as a "hurdle" against microbial growth and the combined use of these factors, known as hurdle technology, helps achieve improved microbial safety and desirable sensory quality of meat products (Almanea *et al.,* 2019).

Recent studies have highlighted the nutritional and functional significance of indigenous poultry varieties such as Kadaknath chicken. Sehrawat *et al.* (2021) reported that Kadaknath chicken meat contains comparatively higher protein levels and exhibits superior antioxidant properties than commercial broiler meat. Enhanced antioxidant activity was demonstrated through greater free radical scavenging ability, metal chelation capacity, and higher ABTS, DPPH, CUPRAC and FRAP assay values in both breast and thigh meat samples. The application of multiple *in vitro* antioxidant assays strengthened the scientific reliability of the findings. The study emphasized the nutraceutical and functional food potential of indigenous black chicken meat due to its rich bioactive and antioxidative components, which may provide additional health benefits to consumers. Furthermore, the findings provide baseline information for future research on indigenous poultry genetic resources and support the commercial utilization of Kadaknath meat in functional food and nutraceutical industries. Nevertheless, further studies on bioactive compounds, fatty acid profiles and sensory properties are necessary for a more comprehensive understanding of its nutritional significance.

In recent years, several novel preservation technologies have been investigated for improving the shelf life and safety of fresh meat. Among these, non-thermal processing methods such as high hydrostatic pressure (HHP), modified atmosphere packaging (MAP), active packaging (AP), natural antimicrobial compounds and bio-preservation techniques have gained considerable attention (Hansen *et al.,* 2014). These advanced preservation technologies are designed to be mild, energy efficient, environmentally friendly and capable of maintaining the natural appearance and quality of meat while effectively controlling spoilage microorganisms and pathogens.

Therefore, the present study was undertaken to evaluate the preservation of country chicken meat using natural preservatives for shelf-life extension. The objectives of the study were:(i) To standardize and develop preserved chicken (Country hen) products using natural preservatives; (ii) To analyze the physicochemical and microbial characteristics of the preserved chicken products and (iii) To evaluate storage stability under different packaging materials and storage conditions.

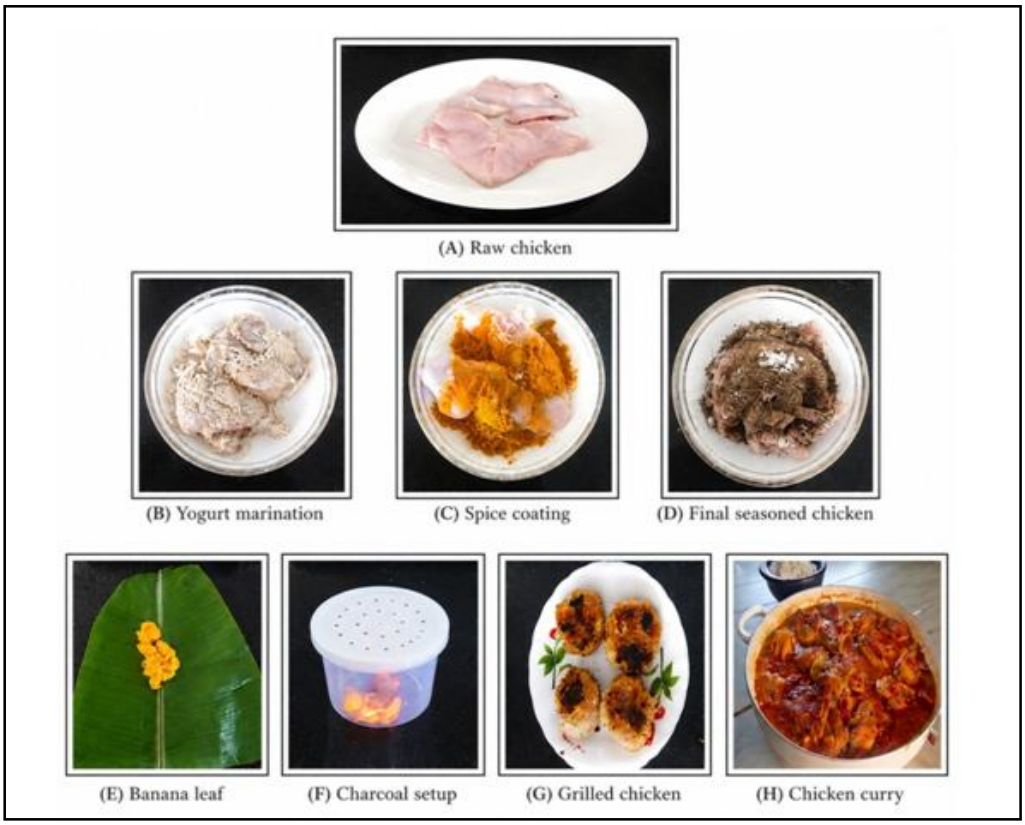

Figure 1: Treatments of chicken.

2. Materials and Methods

Chicken (Country hen) was used in this research. Raw materials such as ginger, dry ginger, turmeric, salt and pepper were purchased from the local shops of Madurai. The design of the study is preserving the chicken by using natural preservatives and assesses the nutritional properties in untreated and processed chicken. Packaging material, *viz.,* polypropylene bags, banana leaves and aluminium foil were used for packaging the treated chicken. Packaging materials selected for the study were purchased in bulk from ramani packaging, Madurai.

2.1 Preparation of chicken and other preservatives

Chicken was thoroughly cleaned to remove blood stains and hair particles. The clean meat were cut into pieces. Ginger was peeled and grounded in the mixie to extract the juice. Dry ginger is grounded in the mixie to make fine powder.

2.2 Treatments of chicken

Chicken was mixed with ginger extract, dry ginger powder, salt and pepper and salt and turmeric. This process lasted for about 3 to 4 min per treatment. The treated chicken was placed in different packaging materials like polypropylene box, banana leaves and aluminium foil. The packed chicken was stored in both refrigerator and freezer condition for about more than 15 days.

Treatments: T_0 - 250 g raw chicken; T_1 - 250 g of chicken + 2.5 g of dry ginger powder; T_2 - 250 g of chicken + 1% salt and 1% turmeric; T_3 - 250 g of chicken + 1% salt and 1% pepper.

2.3 Chemical analysis

The moisture, protein, fat, free fatty acid and peroxide value of the sample was estimated by Ranganna (1995). The microbiological load of the stored sample was enumerated at regular intervals by the methods described by Istawankiss (1984).

2.4 Organoleptic evaluation

The developed chicken products s was evaluated for organoleptic characteristics namely colour, appearance, flavour, texture, taste and overall acceptability by using score card with nine point Hedonic rating scale (9-1).

2.5 Developed value added products

Chicken curry and cutlets was prepared by using preserved meat and evaluated the quality of the product during storage at regular intervals.

2.6 Statistical analysis

The data obtained from the various experiments were subjected to statistical analysis to find out the impact of storage condition used and storage period. Completely randomized design (CRD) was applied for the analysis of the study as described by Rangaswamy (1995).

3. Results

Chicken and poultry are protein-rich. Chicken gives you 7 g protein per 28 g. Like other animal proteins and soy, chicken is a complete protein, so it provides all nine essential amino acids your body needs. Protein does a lot for your body, it helps build tissues and muscles. Chicken has no carbohydrates. Nutrition data says skinless chicken breast is the lowest-calorie option: around 143 calories with 3 g total fat and 1 g saturated fat.

Table 1: Proximate composition of raw chicken as well as treated chicken

S.No.	Particulars	Value
1.	Moisture (%)	62.0 ± 0.12
2.	Protein (g/100 g)	32.0 ± 0.10
3.	Fat (g/100 g)	8.6 ± 0.05
4.	Peroxide value (meq O, /kg fat)	3.02 ± 0.03
5.	Free fatty acid (% as oleic acid)	3.52 ± 0.04

3.1 Proximate composition of raw chicken

The proximate composition of raw chicken as well as treated chicken samples is presented in Table 1. The moisture content was recorded as 62.0 ± 0.12%, indicating good water-holding capacity and desirable freshness of the meat samples. The protein content was found to be 32.0 ± 0.10 g/100 g, revealing that the chicken samples were rich in high-quality protein. The fat content was observed as 8.6 ± 0.05 g/ 100 g, contributing to the sensory quality and palatability of the meat. The peroxide value was recorded as 3.02 ± 0.03 meq O, /kg fat, suggesting lower lipid oxidation and better oxidative stability of the samples. The results indicated that both raw and treated chicken samples possessed satisfactory nutritional quality and acceptable storage stability.

Table 2: Changes in moisture content in both freezer and refrigeration condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	62.0 ± 0.12	61.0 ± 0.15	60.5 ± 0.18	60.2 ± 0.16
	P_2	62.0 ± 0.14	60.8 ± 0.17	60.2 ± 0.14	60.0 ± 0.18
	P_3	62.0 ± 0.11	60.8 ± 0.16	60.2 ± 0.15	59.8 ± 0.19
	S_1	62.0 ± 0.10	62.0 ± 0.12	61.5 ± 0.16	61.0 ± 0.14
	S_2	62.0 ± 0.13	62.0 ± 0.11	61.8 ± 0.17	61.2 ± 0.15
	S_3	62.0 ± 0.12	61.9 ± 0.13	61.5 ± 0.14	61.3 ± 0.16
T_1	P_1	60.0 ± 0.16	59.8 ± 0.14	59.1 ± 0.19	58.6 ± 0.17
	P_2	60.0 ± 0.13	59.6 ± 0.16	59.2 ± 0.15	59.4 ± 0.18
	P_3	60.0 ± 0.14	59.6 ± 0.15	59.2 ± 0.16	59.2 ± 0.19

	S_1	61.0 ± 0.11	61.0 ± 0.12	60.8 ± 0.13	60.5 ± 0.15	
	S_2	61.0 ± 0.12	60.8 ± 0.14	60.4 ± 0.16	60.2 ± 0.17	
	S_3	61.0 ± 0.10	60.6 ± 0.13	60.1 ± 0.15	59.9 ± 0.16	
T_2	P_1	59.0 ± 0.15	58.4 ± 0.17	57.9 ± 0.16	57.6 ± 0.18	
	P_2	59.0 ± 0.14	58.3 ± 0.16	58.1 ± 0.15	57.5 ± 0.17	
	P_3	59.0 ± 0.13	58.1 ± 0.15	57.3 ± 0.18	57.0 ± 0.19	
	S_1	60.0 ± 0.12	59.6 ± 0.13	59.5 ± 0.14	59.3 ± 0.16	
	S_2	60.0 ± 0.11	59.5 ± 0.15	59.4 ± 0.16	59.1 ± 0.17	
	S_3	60.0 ± 0.13	60.0 ± 0.12	59.3 ± 0.15	59.1 ± 0.16	
T_3	P_1	59.0 ± 0.16	57.8 ± 0.18	57.5 ± 0.17	57.2 ± 0.19	
	P_2	59.0 ± 0.14	57.6 ± 0.16	57.3 ± 0.15	57.1 ± 0.18	
	P_3	59.0 ± 0.15	57.3 ± 0.17	57.1 ± 0.18	56.8 ± 0.20	
	S_1	60.0 ± 0.11	59.4 ± 0.14	59.1 ± 0.15	58.9 ± 0.16	
	S_2	60.0 ± 0.12	59.4 ± 0.13	58.8 ± 0.16	58.5 ± 0.17	
	S_3	60.0 ± 0.10	60.0 ± 0.12	59.3 ± 0.14	59.1 ± 0.15	
Statistical value	S-0.06524*	T-0.05945*	P-0.03762*	ST-0.20662*	SP-0.20662*	STP-0.20662*

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

3.1.1 Changes in moisture content in both freezer and refrigeration condition

The changes in moisture content of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 2. Moisture content showed a gradual decreasing trend in all treatments and packaging materials throughout the storage period from the initial day to the 15th day. In raw chicken samples (T_0) stored under freezer conditions, the moisture content decreased from 62.0 ± 0.12% on the initial day to 60.2 ± 0.16%, 60.0 ± 0.18%, and 59.8 ± 0.19% in aluminium foil (P_1), polypropylene box (P_2), and banana leaf packaging (P_3), respectively, at the end of storage. Similar reductions were observed in treated chicken samples, indicating progressive moisture loss during storage. In T_1 samples treated with dry ginger powder, moisture values decreased from 60.0 ± 0.16% to 58.6 ± 0.17%, 59.4 ± 0.18% and 59.2 ± 0.19% under freezer storage in P_1, P_2 and P_3 packaging, respectively. The T_2 treatment also exhibited a gradual decline in moisture content, where the final moisture values reached 57.6 ± 0.18%, 57.5 ± 0.17% and 57.0 ± 0.19% in P_1, P_2 and P_3 packaging materials, respectively. Among all treatments, T_3 samples recorded the lowest moisture content at the end of storage, with values of 57.2 ± 0.19%, 57.1 ± 0.18% and 56.8 ± 0.20% in freezer stored samples packed in aluminium foil, polypropylene box and banana leaves, respectively.

Under refrigeration conditions, the decrease in moisture content was comparatively lower than freezer storage, indicating improved moisture retention in refrigerated samples. In raw chicken samples stored under refrigeration, the moisture content decreased only slightly from 62.0 ± 0.10% to 61.0 ± 0.14%, 61.2 ± 0.15% and 61.3 ± 0.16% in S_1, S_2 and S_3 packaging materials, respectively, by the 15th day. Similar trends were observed in treated samples, where refrigerated storage maintained comparatively higher moisture levels than freezer storage throughout the experimental period. Among the refrigeration packaging materials, aluminium foil and polypropylene box showed better moisture retention compared to banana leaf packaging. The reduction in moisture content during storage could be attributed to moisture evaporation, dehydration, protein denaturation and drip loss occurring during prolonged storage. Freezer-stored samples exhibited greater moisture loss due to ice crystal formation and subsequent cellular damage, which can increase drip loss during storage. The results further indicated that treated samples showed varying moisture retention capacities depending on the treatment and packaging material used.

3.1.2 Changes in protein content in both freezer and refrigeration condition

The changes in protein content of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 3. The protein content of raw chicken samples (T_0) showed a gradual decline throughout the storage period under both freezer and refrigeration conditions. Under freezer storage, the protein content decreased from 32.10 ± 0.05 g/100 g to 31.20 ± 0.05 g/100 g in aluminium foil packaging (P_1), 31.10 ± 0.03 g/100 g in polypropylene box packaging (P_2) and 31.30 ± 0.04 g/100 g in banana leaf packaging (P_3) by the 15th day. Similarly, refrigerated samples also exhibited a reduction in protein content, reaching 30.90 ± 0.04 g/100 g, 30.80 ± 0.05 g/100 g and 30.90 ± 0.04 g/100 g in S_1, S_2 and S_3 packaging materials, respectively. The decrease in protein content during storage may be due to protein denaturation, enzymatic degradation and microbial activity during prolonged storage. Among the storage conditions, refrigeration showed slightly greater reduction in protein content compared to freezer storage.

Table 3: Changes in protein content in both freezer and refrigeration condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	32.10 ± 0.05	31.80 ± 0.04	31.50 ± 0.03	31.20 ± 0.05
	P_2	32.05 ± 0.04	31.70 ± 0.05	31.40 ± 0.04	31.10 ± 0.03
	P_3	32.15 ± 0.03	31.80 ± 0.05	31.50 ± 0.05	31.30 ± 0.04
	S_1	32.08 ± 0.05	31.60 ± 0.04	31.20 ± 0.05	30.90 ± 0.04
	S_2	32.12 ± 0.04	31.50 ± 0.03	31.10 ± 0.04	30.80 ± 0.05
	S_3	32.06 ± 0.05	31.60 ± 0.05	31.20 ± 0.03	30.90 ± 0.04
T_1	P_1	32.18 ± 0.04	33.00 ± 0.05	34.00 ± 0.04	34.70 ± 0.05
	P_2	32.14 ± 0.05	32.90 ± 0.04	33.80 ± 0.05	34.50 ± 0.04
	P_3	32.20 ± 0.03	32.80 ± 0.05	33.70 ± 0.04	34.40 ± 0.05
	S_1	32.11 ± 0.04	32.60 ± 0.03	33.20 ± 0.05	33.80 ± 0.04
	S_2	32.09 ± 0.05	32.50 ± 0.04	33.00 ± 0.03	33.60 ± 0.05
	S_3	32.13 ± 0.04	32.50 ± 0.05	33.10 ± 0.04	33.70 ± 0.03
T_2	P_1	32.16 ± 0.05	32.70 ± 0.04	33.30 ± 0.05	34.00 ± 0.04
	P_2	32.07 ± 0.03	32.60 ± 0.05	33.20 ± 0.04	33.80 ± 0.05
	P_3	32.10 ± 0.04	32.50 ± 0.03	33.00 ± 0.05	33.70 ± 0.04
	S_1	32.04 ± 0.05	32.30 ± 0.04	32.80 ± 0.03	33.30 ± 0.05
	S_2	32.02 ± 0.04	32.20 ± 0.05	32.70 ± 0.04	33.10 ± 0.03
	S_3	32.08 ± 0.03	32.30 ± 0.04	32.80 ± 0.05	33.20 ± 0.04
T_3	P_1	32.12 ± 0.04	32.50 ± 0.05	33.00 ± 0.04	33.70 ± 0.05
	P_2	32.06 ± 0.05	32.40 ± 0.03	32.90 ± 0.05	33.50 ± 0.04
	P_3	32.14 ± 0.04	32.40 ± 0.04	32.80 ± 0.03	33.40 ± 0.05
	S_1	32.03 ± 0.03	32.20 ± 0.05	32.60 ± 0.04	33.00 ± 0.03
	S_2	32.01 ± 0.05	32.10 ± 0.04	32.50 ± 0.05	32.90 ± 0.04
	S_3	32.05 ± 0.04	32.20 ± 0.03	32.60 ± 0.05	33.00 ± 0.05
Statistical value	S-0.06524* T-0.05945*	P-0.03762*	ST-0.20662*	SP-0.20662*	STP-0.20662*

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

In contrast, treated chicken samples (T_1, T_2 and T_3) exhibited a gradual increase in protein content throughout the storage period under both freezer and refrigeration conditions. Among all treatments, T_1 samples treated with dry ginger powder recorded the highest protein values, increasing from 32.18 ± 0.04 g/100 g to 34.70 ± 0.05 g/100 g in P_1 packaging under freezer conditions by the 15th day. Similarly, T_2 and T_3 samples also showed progressive increases in protein content during storage. The increase in protein content may be attributed to moisture reduction during storage, resulting in concentration of nutrients, along with the protective effect of the treatments against protein degradation. Freezer stored samples showed comparatively higher protein content than refrigerated samples, while aluminium foil packaging demonstrated better retention of protein compared to polypropylene box and banana leaf packaging. Overall, the results indicated that treatment type, packaging material, and storage conditions significantly influenced the protein stability and nutritional quality of chicken samples during storage.

Concentration of salt raises from 0 to 2 may increase the water holding capacity from 60 to 100%, which stays an indication of increase in the extraction of salt soluble proteins (Norma *et al.,* 2017). The impaired protein component of myofibril may also improve the meat tenderness (Rokade *et al.,* 2016).

3.1.3 Changes in fat content in both freezer and refrigeration condition

Due to addition of salt there is a gradual decrease in fat content reported by Saranya *et al.,* (2016). Turmeric chemical content in chicken body tends to play greater role in lowering fat, therefore it did not affect the tenderness which in fact is influenced by meat pH (Ziauddin *et al.,* 2015).

Table 4: Changes in fat content in both freezer and refrigerator condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	8.60 ± 0.12	8.40 ± 0.11	8.20 ± 0.13	7.80 ± 0.15
	P_2	8.60 ± 0.10	8.30 ± 0.12	8.01 ± 0.14	7.90 ± 0.13
	P_3	8.60 ± 0.11	8.20 ± 0.13	8.23 ± 0.12	8.18 ± 0.11
	S_1	8.00 ± 0.09	7.95 ± 0.10	7.89 ± 0.12	7.82 ± 0.13
	S_2	8.00 ± 0.08	7.96 ± 0.11	7.92 ± 0.10	7.87 ± 0.12
	S_3	8.00 ± 0.10	7.97 ± 0.09	7.93 ± 0.11	7.88 ± 0.10
T_1	P_1	8.00 ± 0.12	7.75 ± 0.13	7.57 ± 0.14	7.45 ± 0.16
	P_2	8.00 ± 0.10	7.91 ± 0.12	7.83 ± 0.13	7.76 ± 0.14
	P_3	8.00 ± 0.11	7.82 ± 0.10	7.78 ± 0.12	7.64 ± 0.13
	S_1	8.17 ± 0.09	8.07 ± 0.11	8.00 ± 0.10	7.91 ± 0.12
	S_2	8.17 ± 0.10	8.09 ± 0.09	8.01 ± 0.11	7.96 ± 0.10
	S_3	8.17 ± 0.08	8.09 ± 0.10	8.01 ± 0.12	7.96 ± 0.11
T_2	P_1	7.86 ± 0.11	7.73 ± 0.12	7.51 ± 0.14	7.30 ± 0.15
	P_2	7.86 ± 0.10	7.80 ± 0.11	7.77 ± 0.12	7.70 ± 0.13
	P_3	7.86 ± 0.09	7.82 ± 0.10	7.79 ± 0.11	7.62 ± 0.12
	S_1	8.28 ± 0.10	7.96 ± 0.12	7.94 ± 0.11	7.91 ± 0.13
	S_2	8.28 ± 0.11	8.17 ± 0.10	7.95 ± 0.12	7.91 ± 0.14
	S_3	8.28 ± 0.09	8.03 ± 0.11	8.01 ± 0.10	7.96 ± 0.12
T_3	P_1	7.85 ± 0.10	7.79 ± 0.11	7.70 ± 0.13	7.65 ± 0.14
	P_2	7.85 ± 0.09	7.80 ± 0.10	7.77 ± 0.11	7.71 ± 0.12
	P_3	7.85 ± 0.11	7.88 ± 0.12	7.80 ± 0.10	7.75 ± 0.13
	S_1	8.49 ± 0.12	8.11 ± 0.13	7.94 ± 0.12	7.88 ± 0.14
	S_2	8.49 ± 0.10	7.98 ± 0.11	7.94 ± 0.10	7.63 ± 0.15
	S_3	8.49 ± 0.11	8.30 ± 0.12	7.96 ± 0.11	7.73 ± 0.13
Statistical value	S-0.06524* T-0.05945*	P-0.03762*	ST-0.20662*	SP-0.20662*	STP-0.20662*

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

The changes in fat content of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 4. A gradual reduction in fat content was observed in all treatments and packaging materials throughout the storage period from the initial day to the 15th day. In raw chicken samples (T_0) stored under freezer conditions, the fat content decreased from 8.60 ± 0.12 g/100 g to 7.80 ± 0.15 g/100 g in aluminium foil packaging (P_1), 7.90 ± 0.13 g/100 g in polypropylene box packaging (P_2), and 8.18 ± 0.11 g/100 g in banana leaf packaging (P_3). Similarly, under refrigeration conditions, the fat content decreased slightly from 8.00 ± 0.09 g/100 g to 7.82 ± 0.13 g/100 g, 7.87 ± 0.12 g/100 g and 7.88 ± 0.10 g/100 g in S_1, S_2 and S_3 packaging materials, respectively. The reduction in fat content during storage may be attributed to lipid oxidation, hydrolytic rancidity, enzymatic activity and degradation of fatty acids during prolonged storage. Freezer stored samples exhibited comparatively higher reduction in fat content than refrigerated samples, possibly due to oxidative changes associated with extended frozen storage.

Among the treated samples, T_1, T_2 and T_3 also showed a decreasing trend in fat content throughout the storage period under both freezer and refrigeration conditions. In T_1 samples treated with dry ginger powder, the fat content decreased from 8.00 ± 0.12 g/100 g to 7.45 ± 0.16 g/100 g in P_1 packaging under freezer conditions, while refrigerated samples retained comparatively higher fat values during storage. Similarly, T_2 samples treated with salt and turmeric showed a decline in fat content, reaching 7.30 ± 0.15 g/100 g in P_1 packaging by the 15th day, which was the lowest among all treatments. T_3

samples treated with salt and pepper also exhibited a gradual reduction in fat content during storage under both freezer and refrigeration conditions. Among the packaging materials, banana leaf packaging demonstrated comparatively better retention of fat content in several treatments, whereas aluminium foil packaging showed greater reduction under freezer storage.

Table 5: Changes in free fatty acid content in both freezer and refrigeration condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	3.50 ± 0.05	3.59 ± 0.06	3.62 ± 0.07	3.63 ± 0.08
	P_2	3.50 ± 0.04	3.58 ± 0.05	3.67 ± 0.06	3.68 ± 0.07
	P_3	3.50 ± 0.05	3.56 ± 0.06	3.65 ± 0.07	3.70 ± 0.08
	S_1	3.50 ± 0.04	3.66 ± 0.05	3.68 ± 0.06	3.72 ± 0.07
	S_2	3.50 ± 0.05	3.56 ± 0.06	3.58 ± 0.07	3.59 ± 0.08
	S_3	3.50 ± 0.04	3.44 ± 0.05	3.39 ± 0.06	3.58 ± 0.07
T_1	P_1	3.32 ± 0.05	3.46 ± 0.06	3.56 ± 0.07	3.75 ± 0.08
	P_2	3.32 ± 0.04	3.49 ± 0.05	3.52 ± 0.06	3.56 ± 0.07
	P_3	3.32 ± 0.05	3.43 ± 0.06	3.52 ± 0.07	3.65 ± 0.08
	S_1	3.17 ± 0.04	3.27 ± 0.05	3.36 ± 0.06	3.59 ± 0.07
	S_2	3.17 ± 0.05	3.25 ± 0.06	3.44 ± 0.07	3.66 ± 0.08
	S_3	3.17 ± 0.04	3.24 ± 0.05	3.32 ± 0.06	3.50 ± 0.07
T_2	P_1	3.14 ± 0.05	3.38 ± 0.06	3.51 ± 0.07	3.75 ± 0.08
	P_2	3.14 ± 0.04	3.36 ± 0.05	3.46 ± 0.06	3.53 ± 0.07
	P_3	3.14 ± 0.05	3.22 ± 0.06	3.41 ± 0.07	3.50 ± 0.08
	S_1	3.28 ± 0.04	3.29 ± 0.05	3.34 ± 0.06	3.58 ± 0.07
	S_2	3.28 ± 0.05	3.37 ± 0.06	3.46 ± 0.07	3.54 ± 0.08
	S_3	3.28 ± 0.04	3.36 ± 0.05	3.45 ± 0.06	3.51 ± 0.07
T_3	P_1	3.25 ± 0.05	3.20 ± 0.06	3.49 ± 0.07	3.70 ± 0.08
	P_2	3.25 ± 0.04	3.35 ± 0.05	3.39 ± 0.06	3.55 ± 0.07
	P_3	3.25 ± 0.05	3.37 ± 0.06	3.42 ± 0.07	3.45 ± 0.08
	S_1	3.45 ± 0.04	3.53 ± 0.05	3.57 ± 0.06	3.61 ± 0.07
	S_2	3.45 ± 0.05	3.48 ± 0.06	3.53 ± 0.07	3.55 ± 0.08
	S_3	3.45 ± 0.04	3.49 ± 0.05	3.53 ± 0.06	3.57 ± 0.07
Statistical value	S-0.06534* T-0.05965*	P-0.03772*	ST-0.20662^{NS}	SP-0.20662^{NS}	STP-0.20662^{NS}

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

3.1.4 Changes in free fatty acid content in both freezer and refrigeration condition

The changes in free fatty acid (FFA) content of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 5. An increasing trend in free fatty acid content was observed in all treatments and packaging materials throughout the storage period from the initial day to the 15th day. In raw chicken samples (T_0) stored under freezer conditions, the FFA content increased from 3.50 ± 0.05% to 3.63 ± 0.08%, 3.68 ± 0.07% and 3.70 ± 0.08% in aluminium foil (P_1), polypropylene box (P_2) and banana leaf packaging (P_3), respectively. Similarly, under refrigeration conditions, the FFA content increased gradually and reached 3.72 ± 0.07%, 3.59 ± 0.08% and 3.58 ± 0.07% in S_1, S_2 and S_3 packaging materials, respectively, by the 15th day of storage. The increase in free fatty acid content during storage may be attributed to lipid hydrolysis and oxidative deterioration of fats caused by enzymatic activity and prolonged storage duration. Higher FFA values indicate progressive breakdown of lipids and deterioration in fat quality during storage.

Among the treated samples, T_1, T_2 and T_3 also showed gradual increases in FFA content under both freezer and refrigeration conditions. In T_1 samples treated with dry ginger powder, the FFA content increased from 3.32 ± 0.05% to 3.75 ± 0.08% in P_1 packaging under freezer conditions, whereas refrigerated samples showed

comparatively lower increases during storage. Similarly, T_2 samples treated with salt and turmeric exhibited an increase in FFA values, reaching 3.75 ± 0.08% in P_1 packaging by the 15th day, while T_3 samples treated with salt and pepper showed comparatively moderate increases in FFA content throughout storage. Among the packaging materials, polypropylene box and banana leaf packaging exhibited slightly higher FFA values in several treatments compared to aluminium foil packaging, indicating comparatively greater lipid degradation. Overall, refrigeration storage showed relatively controlled increases in FFA content when compared with freezer storage in some treatments.

Lipid autolysis or enzymatic hydrolysis increases in the formation of free fatty acid (Gaedon *et al.,* 2012). Increased level of free fatty acid had never had any toxicological effects (Shweta *et al*., 2018). Increase in free fatty acid is due to oxidative degradation of polyenoic fatty acids (Hansen *et al*., 2014).

Table 6: Changes in total plate count in both freezer and refrigeration condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	0	3	3	3
	P_2	0	3	3	3
	P_3	0	3	3	3
	S_1	0	3	3	3
	S_2	0	3	3	3
	S_3	0	3	3	3
T_1	P_1	0	2	2	2
	P_2	0	2	2	2
	P_3	0	2	2	2
	S_1	0	2	2	2
	S_2	0	2	2	2
	S_3	0	2	2	2
T_2	P_1	0	2	2	2
	P_2	0	2	2	2
	P_3	0	2	2	2
	S_1	0	2	2	2
	S_2	0	2	2	2
	S_3	0	2	2	2
T_3	P_1	0	1	2	2
	P_2	0	1	2	2
	P_3	0	2	2	2
	S_1	0	2	2	2
	S_2	0	2	2	2
	S_3	0	2	2	3

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

3.2 Microbial content of both raw and treated sample

3.2.1 Changes in total plate count in both freezer and refrigeration condition

The changes in total plate count (TPC) of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 6. No microbial growth was observed on the initial day in any of the treatments and packaging materials, indicating good initial microbiological quality of the samples. During storage, a significant increase in microbial count was observed in all samples under both freezer and refrigeration conditions. In untreated raw chicken samples (T_0), the total plate count increased significantly from 0 to 3 log CFU/g by the 5th day and remained at the same level up to the 15th day in all packaging materials, indicating rapid microbial proliferation in the absence of treatment. In contrast, treated samples showed significantly lower microbial counts throughout the storage period. T_1 samples treated with dry ginger powder and T_2 samples treated with salt and turmeric maintained lower counts of 2 log CFU/g up to

the 15th day under both freezer and refrigeration conditions, demonstrating the antimicrobial effectiveness of the treatments. Similarly, T_3 samples treated with salt and pepper exhibited microbial counts ranging from 1 to 2 log CFU/g in most packaging materials, except S_3 packaging, which reached 3 log CFU/g on the 15th day. Overall, treated samples showed significantly better microbiological stability and shelf-life extension compared to untreated samples, while freezer storage conditions significantly reduced microbial growth when compared with refrigeration storage.

There is a reduction in values in treated chicken compared to fresh chicken. In T_3 there is higher decrease in microbial load. Allicin, isolated from garlic oil, inhibits the growth of both Gram-negative and Gram-positive bacteria (Zakariene *et al.,* 2015). Gingerols was having effective antimicrobial activity against *Bacillius subtilis* and *E. coli* (Sharif *et al.,* 2017) and mycobacterium. The spices can be effectively used as biopreservative due to their antimicrobial activity (Rouger *et al.,* 2017; Reema *et al.,* 2005).

3.2.2 Changes in yeast and mould count in both freezer and refrigeration condition

Garlic kept on killing bacteria when Salmonella and E. coli contaminated chicken legs were stored at 4°C up to 15 days. While the number of bacteria in the non-treated meat continued to increase upon storage, in the garlic treated meat bacterial growth was significantly reduced (Olatidoye *et al.,* 2015).

Table 7: Changes in yeast and mould count in both freezer and refrigeration condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	0	1	2	3
	P_2	0	1	2	3
	P_3	0	1	2	3
	S_1	0	1	3	4
	S_2	0	2	3	4
	S_3	0	2	3	5
T_1	P_1	0	1	1	2
	P_2	0	1	2	2
	P_3	0	1	2	2
	S_1	0	1	2	3
	S_2	0	1	2	3
	S_3	0	2	3	3
T_2	P_1	0	1	1	2
	P_2	0	1	1	2
	P_3	0	1	2	2
	S_1	0	1	2	2
	S_2	0	1	2	3
	S_3	0	1	2	3
T_3	P_1	0	1	1	1
	P_2	0	1	1	2
	P_3	0	1	1	2
	S_1	0	1	2	2
	S_2	0	1	2	2
	S_3	0	1	2	3

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

The changes in yeast and mould count of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 7. No yeast and mould growth was observed on the initial day in any of the treatments and packaging materials, indicating good microbiological quality of the fresh samples. During storage, a significant increase in yeast and mould count was observed in all samples under both freezer and refrigeration conditions. In untreated raw chicken samples (T_0), the yeast and mould count increased progressively from 0 to 3 log CFU/g under freezer storage conditions in P_1, P_2 and P_3 packaging materials by the 15th day. Under refrigeration

conditions, higher microbial growth was observed, where S_1 and S_2 packaging materials reached 4 log CFU/g, while S_3 packaging recorded the highest count of 5 log CFU/g on the 15th day. The higher microbial load observed in untreated samples may be due to the absence of antimicrobial treatment and favourable conditions for fungal growth during storage.

Among the treated samples, T_1, T_2 and T_3 exhibited significantly lower yeast and mould counts compared to untreated samples throughout the storage period. T_1 samples treated with dry ginger powder maintained lower counts ranging from 1 to 2 log CFU/g under freezer conditions and 2 to 3 log CFU/g under refrigeration conditions up to the 15th day. Similarly, T_2 samples treated with salt and turmeric showed controlled yeast and mould growth, with counts remaining at 1 to 2 log CFU/g in freezer storage and 2 to 3 log CFU/g in refrigeration storage. T_3 samples treated with salt and pepper demonstrated the lowest yeast and mould counts among all treatments, where P_1 packaging maintained only 1 log CFU/g even on the 15th day under freezer conditions. Overall, treated samples exhibited significantly better microbiological stability and shelf-life extension compared to untreated samples. Freezer storage conditions significantly reduced yeast and mould growth when compared with refrigeration storage, while aluminium foil packaging showed comparatively better microbial control than polypropylene box and banana leaf packaging.

Table 8: Changes in bacterial count in both freezer and refrigeration condition

Treatments	Packaging materials	Initial day	5th day	10th day	15th day
T_0	P_1	0	1	2	3
	P_2	0	1	2	3
	P_3	0	1	2	3
	S_1	0	2	2	3
	S_2	0	2	3	3
	S_3	0	2	3	3
T_1	P_1	0	1	2	2
	P_2	0	1	2	2
	P_3	0	1	2	2
	S_1	0	1	2	3
	S_2	0	2	2	3
	S_3	0	2	3	3
T_2	P_1	0	1	1	2
	P_2	0	1	1	2
	P_3	0	1	2	2
	S_1	0	1	2	2
	S_2	0	1	2	3
	S_3	0	2	2	3
T_3	P_1	0	1	1	1
	P_2	0	1	1	2
	P_3	0	1	1	2
	S_1	0	1	2	2
	S_2	0	1	2	2
	S_3	0	1	2	3

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper; P_1-Stored in aluminium foil in freezer condition; P_2- Stored in polypropylene box in freezer condition; P_3- Stored in banana leaves in freezer condition; S_1- Stored in aluminium foil in refrigeration condition; S_2- Stored in polypropylene box in refrigeration condition; S_3- Stored in banana leaves in refrigeration condition.

3.2.3 Changes in bacterial count in both freezer and refrigeration condition

The changes in bacterial count of raw and treated chicken samples stored under freezer and refrigeration conditions are presented in Table 7. No bacterial growth was observed on the initial day in any of the treatments and packaging materials, indicating good microbiological quality of the fresh samples. During storage, a significant increase in bacterial count was observed in all samples under both freezer and refrigeration conditions. In untreated raw chicken samples (T_0), the bacterial count increased progressively

from 0 to 3 log CFU/g by the 15th day in all freezer packaging materials (P_1, P_2 and P_3), while refrigeration stored samples S_1, S_2 and S_3 also reached 3 log CFU/g during storage. Among the treated samples, T_1 samples treated with dry ginger powder maintained comparatively lower bacterial counts ranging from 1 to 2 log CFU/g under freezer conditions and 2 to 3 log CFU/g under refrigeration conditions up to the 15th day. Similarly, T_2 samples treated with salt and turmeric showed controlled bacterial growth with counts remaining at 1 to 2 log CFU/g in freezer storage and 2 to 3 log CFU/g in refrigeration storage. T_3 samples treated with salt and pepper exhibited the lowest bacterial growth among all treatments, particularly in P_1 packaging under freezer conditions, where the bacterial count remained at only 1 log CFU/g even on the 15th day. Overall, treated samples showed significantly better microbiological stability and shelf-life extension compared to untreated samples, while freezer storage and aluminium foil packaging demonstrated comparatively better bacterial control than refrigeration storage and other packaging materials.

3.2.4 Organoleptic evaluation of preserved chicken products

The preserved chicken products (chicken curry and cutlet) were organoleptically evaluated by using a panel of 15 to 20 untrained judges with 9 to 1 Hedonic scale (Table 9). The sensory attributes *viz.,* colour and appearance, flavour, taste, texture and overall acceptability of the preserved chicken product showed slight variation.

Table 9: Sensory evaluation of preserved chicken product

Sensory evaluation	Freezer condition				Refrigerator condition			
	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3
Color and appearance	8.0 ± 0.10	7.0 ± 0.08	7.5 ± 0.09	8.0 ± 0.11	6.0 ± 0.07	7.5 ± 0.09	6.0 ± 0.08	7.5 ± 0.10
Flavour	7.0 ± 0.09	7.5 ± 0.10	7.5 ± 0.08	7.0 ± 0.09	6.0 ± 0.07	7.5 ± 0.11	7.0 ± 0.09	7.5 ± 0.10
Texture	8.0 ± 0.12	7.0 ± 0.09	7.5 ± 0.10	8.0 ± 0.11	6.0 ± 0.08	7.0 ± 0.09	7.0 ± 0.08	7.5 ± 0.10
Taste	7.0 ± 0.08	7.5 ± 0.09	7.5 ± 0.10	8.0 ± 0.12	6.0 ± 0.07	6.5 ± 0.08	6.5 ± 0.09	7.5 ± 0.10
Overall acceptability	7.4 ± 0.09	7.2 ± 0.08	7.5 ± 0.10	7.6 ± 0.11	6.0 ± 0.07	6.9 ± 0.08	6.7 ± 0.09	7.2 ± 0.10

Note: T_0- Raw chicken; T_1- Treated with dry ginger powder; T_2- Treated with salt and turmeric; T_3- Treated with salt and pepper

The sensory evaluation scores of preserved chicken products stored under freezer and refrigeration conditions are presented in Table 8. Sensory attributes such as color and appearance, flavour, texture, taste and overall acceptability showed noticeable variations among treatments and storage conditions. Under freezer conditions, T_0 and T_3 samples recorded the highest scores for color and appearance (8.0 ± 0.10 and 8.0 ± 0.11, respectively) and texture (8.0 ± 0.12 and 8.0 ± 0.11, respectively), indicating better visual quality and firmness of the products. In terms of flavour and taste, T_1 and T_2 samples showed comparatively higher scores ranging from 7.5 ± 0.08 to 7.5 ± 0.10, suggesting that dry ginger powder, salt, turmeric and pepper treatments positively influenced sensory characteristics. The highest overall acceptability score under freezer conditions was observed in T_3 samples (7.6 ± 0.11), followed by T_2 samples (7.5 ± 0.10), indicating greater consumer preference for these treatments.

Under refrigeration conditions, comparatively lower sensory scores were observed than freezer stored samples, indicating quality deterioration during refrigerated storage. T_0 samples recorded the lowest scores for all sensory attributes, with values of 6.0 ± 0.07 for color and appearance, flavour, taste and overall acceptability, reflecting reduced sensory quality during storage. In contrast, T_3 samples maintained comparatively higher sensory scores under refrigeration conditions, recording 7.5 ± 0.10 for color and appearance, flavour, texture and taste, along with an overall acceptability score of 7.2 ± 0.10. T_1 and T_2 samples also exhibited acceptable sensory qualities, with moderate scores for flavour, texture and overall acceptability. Overall, freezer stored samples demonstrated significantly better sensory quality and consumer acceptability compared to refrigerated samples. Among all treatments, T_3 samples treated with salt and pepper showed the highest sensory acceptability, suggesting that the treatment effectively improved the organoleptic quality and shelf stability of preserved chicken products.

4. Discussion

Country chicken meat has gained increasing attention as a functional food due to the presence of several biologically active compounds that provide health promoting benefits beyond basic nutrition. Indigenous chicken breeds are reported to contain higher concentrations of endogenous bioactive compounds than commercial broilers, thereby enhancing their nutraceutical value. Among these compounds, carnosine and anserine are the major histidyl dipeptides abundantly present in skeletal muscles. These compounds exhibit strong antioxidant, antiageing, antiglycation, anti-inflammatory and neuroprotective activities (Charoensin *et al.,* 2021). Carnosine plays an important role in scavenging reactive oxygen species and delaying lipid oxidation, thereby improving meat quality and storage stability. Similarly, anserine contributes to antioxidant defense, anti-fatigue activity and pH buffering capacity in muscle tissues. Other naturally occurring bioactive compounds such as creatine and carnitine are involved in muscle energy metabolism and fatty acid oxidation, while betaine functions as an osmoprotectant and methyl donor supporting liver health and cellular metabolism. Inosine monophosphate (IMP), found in relatively higher quantities in indigenous chicken meat, contributes significantly to the characteristic umami flavor and palatability of meat products (Jayasena *et al.,* 2015). In addition, bioactive peptides generated during protein hydrolysis possess antioxidant, antimicrobial, antihypertensive and immunomodulatory properties. The favorable amino acid composition and fatty acid profile of native chicken meat further enhance its functional and therapeutic significance. The elevated levels of these bioactive compounds may be attributed to the genetic background, slower growth rate, free-range rearing system and natural feeding behavior of indigenous birds. Therefore, country chicken meat can be considered a valuable source of functional nutrients with promising applications in health oriented and value added poultry products.

In the present study, natural preservatives such as dry ginger powder, salt with turmeric and salt with pepper effectively enhanced the storage stability, microbial safety and sensory quality of preserved chicken under both freezer and refrigeration conditions. The results demonstrated that storage conditions, packaging materials and preservative treatments significantly influenced the physicochemical, microbiological and sensory characteristics of chicken during storage. Among the treatments evaluated, salt with pepper (T_3) and salt with turmeric (T_2) exhibited comparatively superior preservation efficiency, particularly under freezer storage conditions.

A gradual reduction in moisture content was observed in all samples throughout the storage period. Moisture loss was more pronounced under freezer storage than refrigeration storage, which could be attributed to ice crystal formation, cellular disruption, dehydration and drip loss during frozen storage. Hansen *et al.* (2014) similarly reported that frozen storage accelerates moisture migration and tissue damage in meat products. Treated samples showed comparatively better moisture retention than untreated samples, suggesting that natural preservatives may stabilize muscle proteins and reduce water loss during storage. Banana leaf packaging under freezer conditions exhibited slightly higher moisture reduction, possibly due to its porous structure and lower barrier properties compared with aluminium foil and polypropylene packaging materials.

Protein content showed varying trends between untreated and treated samples. Untreated samples exhibited a gradual decline in protein content during storage due to protein denaturation, enzymatic degradation and microbial activity. In contrast, treated samples demonstrated an apparent increase in protein concentration, especially in T_1 samples treated with dry ginger powder. This increase may be associated with moisture reduction, resulting in concentration of protein components within the meat matrix. Ogbodo *et al.* (2022) similarly reported that natural antioxidant treatments help preserve protein integrity and reduce oxidative degradation in meat systems. Freezer storage and aluminium foil packaging were more effective in retaining protein content than refrigeration and banana leaf packaging, likely due to reduced oxidative and microbial deterioration.

The fat content of chicken samples gradually decreased during storage under both freezer and refrigeration conditions. Lipid degradation during storage is primarily associated with hydrolytic rancidity, lipid oxidation, and enzymatic lipolysis. The lowest fat values were recorded in T_2 samples treated with salt and turmeric, indicating the antioxidant potential of turmeric constituents such as curcumin. Rajput *et al.* (2013) also reported that curcumin supplementation improves lipid stability and reduces oxidative deterioration in poultry products. Banana leaf packaging showed comparatively better fat retention, possibly due to reduced oxygen exposure and the presence of natural antioxidant compounds within the leaves.

Free fatty acid (FFA) values progressively increased throughout storage in all treatments, indicating lipid hydrolysis and oxidative degradation of fats. However, treated samples exhibited comparatively controlled increases in FFA values, particularly under refrigeration storage. Gaedon and Hansen *et al.* (2012) similarly explained that prolonged storage promotes lipid breakdown and oxidative rancidity in meat products. The antioxidant properties of ginger, turmeric and pepper likely delayed lipid oxidation and reduced the rate of FFA formation in treated samples. Aluminium foil packaging demonstrated superior oxidative stability due to its excellent barrier properties against oxygen and light.

Microbiological evaluation revealed that natural preservatives significantly inhibited microbial proliferation during storage. Total plate count, bacterial count and yeast and mould counts were substantially lower in treated samples than in untreated controls. Among all treatments, T_3 (salt with pepper) exhibited the strongest antimicrobial effect, particularly under freezer storage conditions. Pepper contains bioactive compounds such as piperine, while turmeric contains curcuminoids, both of which possess well-documented antimicrobial properties. Similar antimicrobial activities of spices and plant extracts in meat preservation were reported by Sharif *et al.* (2017) and Rouger *et al.* (2017). Reduced microbial growth under freezer conditions may be attributed to low storage temperatures that inhibit microbial metabolism and multiplication. Aluminium foil packaging also demonstrated superior microbial control because of its lower permeability to oxygen and moisture.

The antifungal effects observed in treated samples may be associated with the phenolic compounds and essential oils present in ginger, turmeric and pepper. T_3 samples maintained the lowest yeast and mould counts even after 15 days of storage, indicating strong preservative potential. Olatidoye Olawale Paul *et al.* (2015) similarly reported that ginger extract effectively inhibited microbial growth in refrigerated meat products. Freezer storage significantly reduced fungal growth compared with refrigeration storage because low temperatures suppress fungal enzyme activity and spore germination.

Sensory evaluation indicated that preserved chicken products maintained acceptable sensory qualities throughout the storage period. Freezer stored samples received higher sensory scores for colour, flavour, texture, taste and overall acceptability than refrigerated samples. Among the treatments, T_3 samples treated with salt and pepper achieved the highest overall acceptability scores. The enhanced flavour and taste may be attributed to the aromatic compounds present in pepper and the flavor enhancing properties of salt. Saranya *et al.* (2016) similarly reported that natural spices improve flavour stability and sensory acceptance in preserved meat products. The superior sensory quality observed under freezer storage conditions may be related to reduced microbial spoilage and slower physicochemical deterioration.

The findings of the present study confirm that country chicken meat possesses significant functional and nutraceutical potential due to its rich bioactive composition. Furthermore, the incorporation of natural preservatives combined with appropriate packaging materials and freezer storage conditions effectively extended shelf life while maintaining the nutritional, microbial and sensory quality of chicken meat. Among the treatments evaluated, salt with pepper and salt with turmeric demonstrated the highest preservation efficiency and consumer acceptability. These findings support the application of natural preservation strategies as safe, eco-friendly and sustainable

alternatives to synthetic preservatives in poultry meat preservation systems.

5. Conclusion

The present study concluded that country chicken meat possesses considerable nutritional, functional and nutraceutical significance due to the presence of several bioactive compounds such as carnosine, anserine, creatine, carnitine, betaine, inosine monophosphate (IMP) and bioactive peptides. These compounds contribute to various health promoting properties including antioxidant, anti-inflammatory, antiageing, antiglycation, antimicrobial, antihypertensive, neuroprotective and immunomodulatory activities, thereby enhancing the therapeutic and functional value of indigenous chicken meat. The study further demonstrated that natural preservatives effectively improved the physicochemical quality, oxidative stability, microbial safety and sensory acceptability of preserved chicken products under both freezer and refrigeration storage conditions. Moisture content gradually decreased from 62.0% to approximately 58 to 60% during storage, while protein content in treated samples remained relatively stable between 31.0 and 32.5 g/100 g, indicating reduced protein deterioration. Fat content decreased slightly from 8.6 to around 7.2 to 7.8 g/100 g due to lipid oxidation, whereas free fatty acid values increased from 3.52 ± 0.05% to nearly 5.0 ± 0.08% during extended storage. Peroxide values also increased moderately from 3.02 ± 0.04 to approximately 5.5 ± 0.07 meq O, /kg fat, confirming progressive oxidative changes during storage. However, preservative treated samples, particularly T_2 (salt with turmeric) and T_3 (salt with pepper), exhibited comparatively lower lipid oxidation, reduced microbial proliferation, and better oxidative stability than untreated samples. The antioxidant and antimicrobial properties of turmeric, pepper and ginger effectively inhibited bacterial, yeast and mould growth throughout the storage period. Among the different storage conditions and packaging materials evaluated, freezer storage combined with aluminium foil packaging demonstrated superior preservation efficiency by minimizing moisture loss, oxidative deterioration and microbial growth while maintaining better nutritional quality and sensory characteristics. Sensory evaluation further confirmed that T_3 samples retained higher scores for colour, flavour, texture, taste and overall acceptability (7.5 to 8.0) compared with refrigerated samples (6.0 to 7.0). The findings indicate that country chicken meat can be considered an excellent source of functional nutrients and health promoting bioactive compounds, while the incorporation of natural spice based preservatives together with suitable packaging materials and low temperature storage offers a safe, sustainable, eco-friendly and consumer acceptable alternative to synthetic preservatives for poultry meat preservation and value added meat product development.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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