International Journal of Bio-resource and Stress Management

https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM June 2026, 17(6): 01-11

Article AR7102

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.7102

Impact of Frozen Storage Period (-18±1°C) and Formulation on Keeping Quality of Vacuum Packaged Functional Chicken Sausages

Janagam Indumathi

Dept. of Livestock Products Technology, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh (517 502), India

Open Access

Corresponding indumathijanagam@gmail.com

0000-0003-1507-4355

ABSTRACT

The present research was carried out during 2024 (June to December, 2024) in the Department of Livestock Products Technology, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh, India to determine the shelf-life of vacuum packaged functional chicken sausages and its organoleptic qualities was carried out with the objectives to assess the storage stability and sensory qualities of spent chicken sausages stored at frozen (-18°C) temperature. Functional chicken sausages were developed with 10% level of replacement of chicken fat with grounded poppy, sesame, groundnut seeds and were analysed for their keeping quality along with high fat control kept at frozen (-18±1°C) temperatures for 180 days. Results revealed that, there was significant ($p<0.05$) effect on functional chicken sausages with replacement of fat with 10% level of ground vegetable oil seeds under frozen storage. FFA, TBARS, tyrosine, pH and all microbiological parameters of chicken sausages were significantly ($p<0.05$) influenced by formulation in frozen storage and functional chicken sausages were found to have significantly lower values than control. Regardless of formulation, the mean values of pH, FFA, TBARS, tyrosine, standard plate, psychrophilic, yeast and moulds, lactobacillus and anaerobic counts were significantly ($p<0.05$) increased throughout the storage period in all chicken sausages under frozen conditions. Scores for all sensory attributes decreased significantly ($p<0.05$) in all chicken sausages irrespective of formulation. Combination of vacuum packing and fat replacement with ground vegetable oilseeds reduced lipid oxidation and microbial growth in chicken sausages and maintained the sensory quality characteristics during frozen storage for 180 days.

KEYWORDS: Functional chicken sausage, vacuum packaging, freezing

***Citation* (VANCOUVER):** Indumathi, Impact of Frozen Storage Period (-18±1°C) and Formulation on Keeping Quality of Vacuum Packaged Functional Chicken Sausages. *International Journal of Bio-resource and Stress Management*, 2026; 17(6), 01-11. HTTPS://DOI.ORG/10.23910/1.2026.7102.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 31st March 2026 RECEIVED in revised form on 05th June 2026 ACCEPTED in final form on 19th June 2026 PUBLISHED on 23rd June 2026

1. INTRODUCTION

Spent hen meat is primarily used in comminuted meat products because of inherent toughness of spent hen meat, which can be removed through mincing and chopping process (Sharada et al., 2025). Among various comminuted meat products, sausages are one which could find prominent position in food industry, particularly at fast food outlets (Barbut, 2001). Chicken sausages are liked for its unique taste and is a rich source of nutrients, providing good quality animal proteins, essential amino acids and fatty acids, minerals, trace elements and vitamins particularly B-complex (Singh et al., 2014, Pereira and Vicente, 2013 and Almeida et al., 2015). Fat plays a crucial role in enhancing flavor, tenderness, juiciness, appearance, texture, and shelf life of meat products. Consequently, the meat industry faces the challenge of creating low-fat options without sacrificing sensory qualities (Hasan et al., 2024). Therefore, reduction of animal fat in meat products and substitution of animal fat with vegetable oils and dietary fiber could result in healthier meat products (Lima et al., 2022). Chicken sausages, despite their nutritional advantages, are more susceptible to lipid oxidation due to their high polyunsaturated fatty acid content, as well as to microbial spoilage. Lipid oxidation causes deterioration of meat by adversely affecting its color, flavor, sensorial quality, nutritional value and generation of toxic products such as malonaldehyde and cholesterol oxidation products (Garcia-Lomillo et al., 2017). Various synthetic chemicals are being used as antioxidant and antimicrobial agents to combat the above mentioned problems. However, the use of synthetic compounds is quite debatable because of their ill effects on human health (Zhang et al., 2016; Anisa et al., 2024). This has revived the search for natural preservatives having both antioxidant and antimicrobial activities for maintaining chicken meat quality, extending shelf-life and preventing economic loss (Khare et al., 2014; Dinda et al., 2025). Vegetable oil seeds differ considerably in physical properties such as color, flavor, free fatty acids, and fatty acid composition and they could have different effects on the quality characteristics and nutritional value of meat products (Mohamed and Joerg-Thomas, 2006; Paneras and Bloukas, 1994). Thus, the use of certain vegetable oil seeds in sausages could improve their nutritional quality without adversely affecting the palatability of the product. Poppy (*Papaver somniferum*) possesses significant antioxidant and antimicrobial properties, largely due to its rich composition of bioactive compounds such as alkaloids, flavonoids, phenolic compounds, and polyunsaturated fatty acids (Sharopov et al., 2018). Sesame seeds (*Sesamum indicum*) possess significant antioxidant and antimicrobial properties, largely driven by lignans like sesamin, sesamolin, and sesamol, as well as high vitamin E (alpha-tocopherol) content (Dravie et al., 2020; Park et al., 2010). Peanuts (*Arachis hypogaea*) are rich source of protein and possess strong antioxidant and antimicrobial properties due to high concentrations of phenolic compounds, such as resveratrol, proanthocyanidins, and flavonoids which provides numerous health benefits (Sebei et al., 2013. Shasidhar et al., 2017 and Indumathi et al., 2022). Low-temperature with aerobic packaging preservation is widely used to minimize spoilage and biochemical degradation in poultry meat. However, Refrigerated storage (4±1°C) slows deterioration but is limited to short-term use and unsuitable for long-term storage. Frozen storage in combination with vacuum packaging enables long-term preservation. The present study was to determine the shelf-life of vacuum packaged functional chicken sausages and its organoleptic qualities was carried out with the objectives to assess the storage stability and sensory qualities of spent chicken sausage stored at freezing (−18°C) temperature.

2. MATERIALS AND METHODS

The present research was carried out during 2024 (June, 2024–December, 2024) in the Department of Livestock Products Technology, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati.

2.1. Procurement of raw materials

Spent broiler breeder hens were slaughtered, deboned and meat was harvested. All subcutaneous fat and inter muscular fat was removed from the meat and used as the fat source. The spice ingredients were purchased from local super market were cleaned thoroughly and dried in a hot air oven at 50°C per 60 min. The ingredients were ground separately in a Blender and sieved through a fine mesh. The powders were mixed in suitable proportions to obtain the spice mix and were stored at room temperature in air tight container for further use. Other Non-meat ingredients like sugar, salt, garlic, onions, binder were purchased from local super market. Onions and garlic were peeled off and made a fine paste in the ratio of 3:1 with help of mixer grinder.

2.2. Standardization of functional chicken sausages with vegetable oil seeds

Preliminary trails were conducted to select three vegetable oilseeds as partial fat replacers in the standardization of functional chicken sausages. Three types of vegetable oil seeds were selected for partial replacement of animal fat in the formulation of functional chicken sausages. Selected oilseeds like poppy, sesame and groundnut seeds were purchased from local super market. Three oilseeds were separately cleaned thoroughly, dry roasted in a pan and made in to paste and were used to incorporate as partial replacer of animal fat in formulation of functional chicken sausages. The pastes were prepared freshly on the day of incorporation.

2.3. Assessment of comparative effect of three vegetable oil seeds on keeping quality of functional chicken sausages under vacuum packaging

Functional chicken sausages were prepared as per the selected combination (As per Table 1) in 4 batches that was, Control (15% chicken fat), T_1 (5% chicken fat+10% PSE), T_2 (5% chicken fat+10% SSP) and T_3 (5% chicken fat+10% GSP) and were packed in HDPE by vacuum packaging. Vacuum packed functional chicken sausages were analyzed during storage period at frozen temperatures (-18±1°C) at every 30 days interval over a period of six months to determine quality of the product by physico chemical, microbiological and organoleptic parameters.

Table 1: Formulations of low fat chicken sausages fortified with optimum level of vegetable oil seed as fat replacer

Ingredient	Control	Low fat sausages incorporated with vegetable oil seed as fat replacer		
		T_1	T_2	T_3
Chicken meat (%)	85	85	85	85
Chicken fat (%)	15	5	5	5
Poppy seed paste (%)	0	10	-	-
Sesame seed paste (%)	-	-	10	
Ground nut seed paste (%)	-	-	-	10
Salt (%)	1.8	1.8	1.8	1.8
Sugar %	1	1	1	1
Polyphosphate (STPP) %	0.3	0.3	0.3	0.3
Ice %	10	10	10	10
Dry spice mix %	2	2	2	2
Wet condiment mix*	3	3	3	3
Binder (Maida)	3	3	3	3

*Onion: Garlic paste (3:1)

2.3.1. Analysis

The PH of the samples was determined by following the procedure of Jay (1964). Free fatty acids (FFA) vaue was calucated by described by Koniecko (1979). 2-Thio barbituric acid reactive substance value (2-TBARS) was determined based on the procedure of Witte et al. (1970). Tyrosine value of samples was determined based on the procedure of Strange et al. (1977). Microbiological parameters of samples were determined as per the methods described by Anonymous (2001). Sensory evaluation done on a 9 point hedonic scale by a semi-trained six member taste panel. Cost of production of functional chicken sausages (per kg) was calculated by taking into account the cost of spent broiler breeder chicken meat, fat, vegetable oil seeds and other ingredients i.e. spice mix, condiments, binders and other processing charges. The data obtained in the present study was analyzed statistically as per the methods outlined by Snedecor and Cochran (1980).

3. RESULTS AND DISCUSSION

3.1. Physico chemical parameters

Mean pH values of all vacuum packaged functional chicken sausages were not significantly (p<0.05) affected by the formulation (Table 2). However, Control chicken sausages reported higher pH values than functional chicken sausages. This might be due to increase in oxidation of fatty acids (Emiroglu et al., 2010). Similar trend was observed by Kumar et al., 2014 in dressed chicken and Mir and Masoodi, (2017) in mutton meat balls. Storage period affected the pH values significantly (p<0.05) with the highest pH observed on day 180. The pH values increased significantly (p<0.05) as storage period progressed all vacuum packaged chicken sausages. This significant increase in mean pH values might be due to the concomitant increase in the bacterial load which release metabolites during their metabolism and cause deamination of proteins (Jay, 1996). The increase in pH was also attributed to higher degree of oxidation and loss of free acidic groups of meat protein upon cooking (Lawrie, 1998). Similar trend was reported by Malav et al. (2015) in mutton patties and Kristam et al. (2016) in chicken nuggets.

Functional chicken sausages incorporated with Sesame seed paste recorded lower FFA, TBARS and tyrosine mean values than other functional chicken sausages and high fat control sausages throughout the storage period. This might be due to superior antioxidant activity (phenolic compounds, tocopherols, sesamin and sesamolin, sesamin) of sesame seeds over poppy and groundnut seeds. And higher fat in control which was responsible for more oxidation (Cyprian et al. (2017) and Similar trend was reported by Mir and Masoodi (2017). The overall mean free fatty acid, TBARS and tyrosine values of all vacuum packed functional chicken sausages increased gradually with increasing storage period and no off flavours was detected in all the treatments throughout the storage period which probably could be due to anti-oxidant property (poly phenols) of vegetable oilseeds. This might be due to progressive oxidation of lipids during storage. The major cause for increase in the tyrosine values might be due to proteolysis brought either by microbial growth or chemical reaction (Leistner, 1994). These findings were correlated Soumia et al. (2012) in chicken burger, Naveena et al. (2014) in vacuum packed chicken products, Akesowan (2016) in chicken nuggets, Nath et al. (2016) in chicken nuggets, Naveen et al. (2016) in vacuum packed chicken sausages, Kristam et al. (2016) in chicken nuggets, Khursheed et al. (2017) in chicken meat

Table 2: Impact of frozen storage period (-18±1°C) and formulation on physico-chemical quality of vacuum packaged functional chicken sausages (Mean±SE)

Sl. No.	Treatments	Frozen storage days (-18±1°C)						
		Day 0	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180
1. pH								
	Control	6.31± 0.004^{a1}	6.31± 0.003^{a1}	6.32± 0.003^{a12}	6.33± 0.004^{a23}	6.33± 0.007^{a23}	6.34± 0.004^{a3}	6.38± 0.004^{bc4}
	T_1	6.32± 0.004^{a1}	6.32± 0.005^{a12}	6.33± 0.003^{a123}	6.34± 0.003^{ab34}	6.34± 0.005^{a23}	6.35± 0.004^{ab4}	6.38± 0.006^{b5}
	T_2	6.32± 0.007^{a1}	6.32± 0.004^{a1}	6.33± 0.004^{a12}	6.33± 0.003^{a12}	6.34± 0.004^{a23}	6.35± 0.007^{a3}	6.36± 0.004^{ab4}
	T_3	6.32± 0.005^{a1}	6.32± 0.007^{a1}	6.33± 0.004^{a1}	6.35± 0.006^{b2}	6.35± 0.004^{a2}	6.36± 0.005^{ab2}	6.37± 0.006^{b3}
2. FFA (% oleic acid)								
	Control	0.146± 0.002^{c1}	0.152± 0.002^{c1}	0.170± 0.004^{de2}	0.212± 0.005^{a3}	0.282± 0.004^{b4}	0.368± 0.01^{b5}	0.434± 0.003^{cd6}
	T_1	0.130± 0.001^{b1}	0.144± 0.004^{bc2}	0.153± 0.002^{ab2}	0.210± 0.001^{a3}	0.267± 0.005^{b4}	0.317± 0.003^{a5}	0.417± 0.002^{bc6}
	T_2	0.124± 0.001^{a1}	0.135± 0.001^{a2}	0.144± 0.002^{a2}	0.207± 0.002^{a3}	0.246± 0.005^{a4}	0.301± 0.004^{a5}	0.399± 0.003^{a6}
	T_3	0.129± 0.001^{ab1}	0.143± 0.001^{ab2}	0.152± 0.002^{ab2}	0.210± 0.002^{a3}	0.246± 0.005^{a4}	0.312± 0.007^{a5}	0.414± 0.004^{ab6}
3. TBARS (mg of malonaldehyde)								
	Control	0.219± 0.001^{b1}	0.264± 0.007^{b2}	0.379± 0.01^{c3}	0.462± 0.003^{b4}	0.611± 0.003^{c5}	0.764± 0.006^{c6}	0.828± 0.005^{c7}
	T_1	0.215± 0.001^{b1}	0.240± 0.004^{a2}	0.327± 0.004^{ab3}	0.473± 0.006^{b4}	0.560± 0.005^{b5}	0.634± 0.005^{a6}	0.811± 0.002^{b7}
	T_2	0.210± 0.001^{a1}	0.231± 0.001^{a2}	0.305± 0.003^{a3}	0.431± 0.002^{a4}	0.519± 0.007^{a5}	0.628± 0.004^{a6}	0.793± 0.001^{a7}
	T_3	0.216± 0.002^{b1}	0.238± 0.002^{a2}	0.325± 0.004^{ab3}	0.426± 0.003^{b4}	0.574± 0.004^{b5}	0.630± 0.001^{a6}	0.809± 0.002^{b7}
4. Tyrosine (mg)								
	Control	0.498± 0.00 5^{b1}	0.698± 0.011^{bcd2}	0.758± 0.00 6^{b3}	0.860± 0.007^{a4}	0.944± 0.003^{a5}	1.261± 0.011^{a6}	1.865± 0.030^{b7}
	T_1	0.467± 0.007^{a1}	0.685± 0.009^{bc2}	0.746± 0.005^{ab3}	0.839± 0.005^{a4}	0.933± 0.004^{a5}	1.21± 0.017^{a6}	1.805± 0.03^{ab7}
	T_2	0.450± 0.007^{a}	0.632± 0.006^{a2}	0.733± 0.006^{a3}	0.830± 0.008^{a4}	0.914± 0.001^{a5}	1.19± 0.027^{a6}	1.743± 0.024^{a7}
	T_3	0.466± 0.006^{a1}	0.671± 0.007^{b2}	0.742± 0.004^{ab3}	0.833± 0.003^{a4}	0.921± 0.003^{a5}	1.2± 0.010^{a6}	1.786± 0.015^{ab7}

Means bearing same numerical superscripts in each column and same alphabetical superscripts in each row do not differ significantly (p<0.05)

and Mir and Masoodi (2017) in meat balls.

3.2. Microbial parameters

Mean standard plate counts of all the functional chicken sausages were differed significantly (p<0.05) from each other and also from control (Table 3). Among functional chicken sausages, sesame seed paste incorporated sausages recorded significantly (p<0.05) lower counts followed by sausages with groundnut seed paste and sausages with poppy seed paste. Similar trend was reported by Soher et al. (2013) chicken burger. The means of standard plate counts were influenced by storage period and were increased significantly as storage period advances irrespective of the formulation. However, lower counts were noticed in functional chicken sausages than control. Similar trend was reported by Nath et al. (2016) in chicken nuggets, Naveena et al. (2017) in chicken sausages, Khursheed et al. (2017) in chicken meat balls, Naveen et al. (2016) in vacuum packed chicken sausages and Biswas et al. (2017) in chicken products.

Table 3: Effect of frozen storage (-18±1°C) and formulation on microbial quality of vacuum packaged functional chicken sausages (Mean±SE)

Sl. No.	Treatments	Frozen storage days						
		Day 0	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180
1. Standard plate count (cfu g^{-1})								
	Control	2.97±0.009^{c1}	3.00±0.004^{c1}	3.25±0.065^{ab2}	3.80±0.05^{c3}	4.30±0.04^{bc4}	5.38±0.01^{a5}	5.79±0.018^{b6}
	T_1	2.84±0.016^{b1}	2.98±0.007^{bc2}	3.17±0.034^{ab3}	3.75±0.04^{bc4}	4.17±0.043^{ab5}	5.29±0.051^{a6}	5.72±0.004^{ab7}
	T_2	2.74±0.014^{a1}	2.93±0.020^{a2}	3.12±0.020^{a3}	3.12±0.020^{a3}	4.09±0.024^{a5}	5.26±0.043^{a6}	5.62±0.057^{a7}
	T_3	2.81±0.015^{b1}	2.97±0.018^{abc2}	3.15±0.007^{ab3}	3.62±0.039^{a4}	4.16±0.051^{ab5}	5.28±0.049^{a6}	5.77±0.019^{b7}
2. Psychrophilic count (cfu g^{-1})								
	Control	ND	ND	ND	1.10±0.022^{ab1}	1.19±0.019^{a1}	1.55±0.076^{b2}	1.83±0.056^{ab3}
	T_1	ND	ND	ND	1.09±0.028^{ab1}	1.19±0.016^{a1}	1.475±0.062^{b2}	1.77±0.044^{ab3}
	T_2	ND	ND	ND	1.02±0.016^{a1}	1.18±0.018^{a2}	1.41±0.047^{b3}	1.62±0.041^{a4}
	T_3	ND	ND	ND	1.07±0.029^{ab1}	1.22±0.018^{a2}	1.54±0.060^{b3}	1.79±0.050^{b4}
3. Yeast and mould count (cfu g^{-1})								
	Control	ND	ND	ND	0.673±0.213^{ab1}	1.013±0.008^{ab2}	1.05±0.022^{b2}	1.12±0.014^{a2}
	T_1	ND	ND	ND	0.545±0.244^{a1}	0.881±0.177^{a1}	1.06±0.023^{b2}	1.15±0.022^{a2}
	T_2	ND	ND	ND	0.506±0.226^{a1}	0.84±0.168^{a12}	1.04±0.016^{b2}	1.12±0.018^{a2}
	T_3	ND	ND	ND	0.66±0.210^{ab1}	1.01±0.012^{ab2}	1.07±0.007^{b2}	1.14±0.018^{a2}
4. Lactobacillus count (cfu g^{-1})								
	Control	1.69±0.079^{a1}	1.66±0.061^{a1}	1.58±0.088^{a1}	1.32±0.071^{b2}	1.34±0.053^{a2}	1.23±0.029^{a23}	1.09±0.029^{a3}
	T_1	1.66±0.054^{a1}	1.63±0.042^{a1}	1.55±0.034^{a12}	1.45±0.058^{ab23}	1.47±0.038^{a23}	1.38±0.048^{a3}	1.13±0.028^{ab4}
	T_2	1.67±0.053^{a1}	1.65±0.047^{a1}	1.58±0.041^{a12}	1.55±0.052^{a12}	1.46±0.041^{a23}	1.37±0.044^{a3}	1.21±0.023^{b4}
	T_3	1.65±0.057^{a1}	1.65±0.050^{a1}	1.57±0.030^{a1}	1.40±0.045^{ab2}	1.38±0.036^{a2}	1.23±0.022^{a3}	1.15±0.036^{ab3}

Table 3: Continue...

Sl. No.	Treatments	Frozen storage days						
		Day 0	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180
5. Anaerobic count (cfu g^{-1})								
	Control	ND	1.10± 0.032^{a1}	1.25± 0.020^{b2}	1.36± 0.033^{b3}	1.46± 0.027^{c4}	1.60± 0.050^{b5}	1.85± 0.035^{b6}
	T_1	ND	1.11± 0.035^{a1}	1.14± 0.032^{a12}	1.27± 0.048^{ab23}	1.31± 0.040^{ab3}	1.53± 0.055^{a4}	1.76± 0.060^{b5}
	T_2	ND	1.06± 0.023^{a1}	1.12± 0.030^{a12}	1.19± 0.035^{a23}	1.26± 0.048^{a34}	1.34± 0.046^{b4}	1.61± 0.043^{a5}
	T_3	ND	1.08± 0.025^{a1}	1.18± 0.020^{ab12}	1.25± 0.024^{ab2}	1.39± 0.037^{bc3}	1.52± 0.044^{b4}	1.73± 0.050^{ab5}

Means bearing same numerical superscripts in each column and same alphabetical superscripts in each row do not differ significantly ($p<0.05$)

Regardless of formulation, psychrophilic counts could not detected in any of the sausages up to 60 days of frozen storage. The mean psychrophilic counts of sausages increased significantly ($p<0.05$) as frozen storage progressed from 90 to 180 days. Similar increase in psychrophilic counts were in agreement with Ilayabharathi et al. (2012) in chicken sausages, Nath et al. (2016) in chicken nuggets and Naveen et al. (2016) in chicken sausages.

Mean yeast and mould counts were not significantly influenced by the formulation. Functional chicken sausages recorded lower counts than control. This might be due to antimicrobial properties of vegetable oil seeds. Functional chicken sausages with sesame seed paste recorded lower counts than others. This is in conformity with Soher et al. (2013) in chicken burger. Regardless of formulation, the yeast and mould counts were not recorded in any of the sausages up to 60 days of frozen storage. The mean yeast and mould counts of sausages increased significantly ($p<0.05$) as frozen storage progressed from 90 to 180 days. Similar findings were reported by Ilayabharathi et al. (2012) in chicken sausages. Regardless of formulation, coliforms could not be detected in any of the vacuum packaged sausages throughout the frozen storage period. These results are in agreement with Khursheed et al. (2017) in frozen stored chicken meat balls, Soher et al. (2013) in low fat chicken burger and Waliullah and Ahsan (2011) in low fat chicken burger containing defatted pea nut flour,

The mean lacto bacillus and anaerobic counts were significantly ($p<0.05$) influenced by storage period but not by formulation. These findings were in accordance with Reddy et al. (2013) grape seed extract incorporated vacuum packaged restructured mutton slices and Naveena et al. (2014) in vacuum packed chicken products. Vacuum packed sausages with sesame seed paste recorded higher lacto bacillus counts than other functional chicken sausages and control. The mean lactobacillus counts for vacuum packed sausages gradually decreased as storage period advanced irrespective of the formulation. These results were correlated with Reddy et al. (2013) in vacuum packaged restructured mutton slices. Regardless of formulation, the mean anaerobic counts increased significantly with progress of storage period. These finding were in agreement with Karthikeyan et al. (2000) in caprine.

3.3. Organoleptic parameters

Formulation not influenced the mean appearance, juiciness, tenderness and overall acceptability scores of chicken sausages significantly but the mean flavour scores of sausages were significantly ($p<0.05$) effected. However, functional chicken sausages scored slightly higher than control (Table 4). The scores of all organoleptic parameters functional and control sausages were comparable throughout the storage period. Functional chicken sausages with sesame seed paste had higher scores for all the organoleptic parameters when compared other functional chicken sausages and control. These results were in agreement with

The mean scores of all organoleptic parameters were significantly ($p<0.05$) influenced by the storage period and have decreased as storage progressed irrespective of packaging and formulation. The decrease in scores of all the organoleptic parameters of sausages with advancement of storage period might be due to pigment and lipid oxidation, due to some loss of moisture from the product during storage, breakdown of fat and protein (Bhat et al., 2011). Similar pattern was reported by Akesowan (2016), Nath et al. (2016) in chicken nuggets, Kristam et al. (2016) in chicken nuggets and Mir and Masoodh (2017) in meat balls.

3.4. Cost formulation

Cost of the product was one of the major factor in deciding the product rating by the consumer. Cost evaluation of the product was also made with particular reference to certain

Table 4: Effect of frozen storage (-18±1°C) and formulation on sensory quality of vacuum packaged functional chicken sausages (Mean±SE)

Sl. No.	Treat-ments	Frozen storage days						
		Day 0	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180
1. Appearance								
	Control	7.62±0.14^{a1}	7.40±0.08^{a12}	7.15±0.09^{a2}	6.68±0.08^{a3}	6.48±0.09^{a3}	6.19±0.09^{a4}	5.68±0.09^{a5}
	T_1	7.91±0.13^{a1}	7.44±0.10^{a2}	7.11±0.10^{a3}	6.70±0.08^{a4}	6.59±0.08^{a4}	6.24±0.09^{a5}	5.70±0.09^{a6}
	T_2	7.87±0.11^{a1}	7.45±0.10^{a2}	7.15±0.10^{a3}	6.77±0.09^{a4}	6.51±0.09^{a45}	6.27±0.09^{a5}	5.70±0.08^{a6}
	T_3	7.75±0.09^{a1}	7.45±0.10^{a2}	7.09±0.10^{a3}	6.77±0.09^{a4}	6.50±0.08^{a5}	6.30±0.07^{a5}	5.69±0.09^{a6}
2. Flavour								
	Control	7.52±0.11^{a1}	7.40±0.09^{a1}	7.05±0.06^{a2}	6.79±0.08^{a23}	6.55±0.09^{a3}	6.23±0.10^{a4}	5.54±0.08^{ab5}
	T_1	7.68±0.11^{a1}	7.41±0.08^{a2}	7.08±0.08^{a3}	6.80±0.08^{a3}	6.58±0.09^{a4}	6.26±0.09^{a5}	5.58±0.08^{b6}
	T_2	7.70±0.12^{a1}	7.45±0.15^{a1}	7.09±0.08^{a2}	6.83±0.09^{a23}	6.61±0.12^{a3}	6.29±0.11^{a4}	5.61±0.09^{b5}
	T_3	7.66±0.109^{a1}	7.43±0.11^{a1}	7.05±0.09^{a2}	6.81±0.07^{a23}	6.59±0.13^{a3}	6.15±0.11^{a4}	5.59±0.09^{b5}
3. Juiciness								
	Control	7.54±0.11^{a1}	7.40±0.10^{a1}	7.08±0.11^{a2}	6.86±0.09^{a23}	6.66±0.09^{a3}	6.25±0.10^{a4}	5.61±0.10^{ab5}
	T_1	7.70±0.11^{a1}	7.40±0.08^{a2}	7.15±0.09^{a23}	6.94±0.10^{a3}	6.59±0.09^{a4}	6.26±0.09^{a5}	5.65±0.09^{ab6}
	T_2	7.77±0.12^{a1}	7.43±0.09^{a2}	7.15±0.08^{a23}	6.94±0.08^{a3}	6.59±0.12^{a4}	6.22±0.11^{a5}	5.73±0.10^{b6}
	T_3	7.72±0.09^{a1}	7.37±0.12^{a2}	7.08±0.10^{a23}	6.88±0.11^{a34}	6.62±0.12^{a4}	6.23±0.10^{a5}	5.66±0.08^{ab6}
4. Tenderness								
	Control	7.82±0.11^{a1}	7.22±0.12^{a2}	7.09±0.09^{a2}	6.73±0.09^{a3}	6.56±0.10^{c3}	6.09±0.11^{a4}	5.56±0.11^{a5}
	T_1	7.81±0.11^{a1}	7.18±0.12^{a2}	7.04±0.08^{a2}	6.70±0.10^{a3}	6.52±0.10^{c3}	6.08±0.09^{a4}	5.54±0.09^{a5}
	T_2	7.81±0.09^{a1}	7.27±0.06^{a2}	7.04±0.09^{a2}	6.7±0.10^{a3}	6.29±0.08^{abc4}	6.19±0.09^{a4}	5.47±0.09^{a5}
	T_3	7.80±0.09^{a1}	7.19±0.09^{a2}	7.04±0.11^{a2}	6.66±0.09^{a3}	6.50±0.08^{bc3}	6.05±0.08^{a4}	5.52±0.08^{a5}
5. Overall acceptability								
	Control	7.65±0.10^{a1}	7.41±0.08^{a12}	7.19±0.08^{a2}	6.76±0.08^{ab3}	6.47±0.08^{a4}	6.23±0.08^{a4}	5.68±0.11^{a5}
	T_1	7.66±0.13^{a1}	7.44±0.08^{a1}	7.26±0.09^{a2}	6.72±0.09^{ab3}	6.45±0.07^{a34}	6.22±0.11^{a4}	5.61±0.10^{a5}
	T_2	7.68±0.13^{a1}	7.45±0.08^{a12}	7.31±0.09^{a2}	6.87±0.09^{b3}	6.55±0.09^{a4}	6.26±0.07^{a5}	5.64±0.10^{a6}
	T_3	7.66±0.08^{a1}	7.41±0.09^{a12}	7.25±0.08^{a2}	6.77±0.09^{ab3}	6.48±0.09^{a4}	6.22±0.10^{a5}	5.61±0.09^{a6}

Means bearing same numerical superscripts in each column and same alphabetical superscripts in each row do not differ significantly ($p<0.05$)

non-meat ingredients like vegetable oilseeds, extenders, seasonings. Type and cost of the vegetable oil seed affected the cost of production of chicken sausages. Functional chicken sausages incorporated with 10% groundnut seed paste as fat replacer was found to have lower cost of production compared to those with 10% sesame seed paste, 10% poppy seed paste and high fat control sausages. Cost of production (kg^{-1}) of low fat sausages incorporated with poppy seed paste was higher compared to all other studied. This might be due to higher cost of poppy seeds when compared to the rest of low fat sausages and high fat control.

Cost of production of sesame seed paste incorporated low fat sausages was same as that of high fat control sausages (Table 5). Even though, low fat sausages incorporated with 10% groundnut seed paste was found to have low cost of production, the low fat sausages incorporated with 10% sesame seed paste registered superior quality characteristics compared to the rest of the formulations. Among all formulations, the cost of production kg^{-1} of chicken sausages incorporated with groundnut seed paste was found to be ₹ 187/- which was lowest followed by sesame seed paste ₹ 193.00/-, control ₹ 193.00/- and poppy seed paste ₹ 265.00/-. Sriphochanart and Skolpap 2018 estimated the preparation cost of Thai fermented sausages.

Table 5: Cost of production kg^{-1} of spent hen meat low fat sausages fortified with vegetable oil seed paste as far replacer

Ingredient	Cost in rupees			
	Control	T_1	T_2	T_3
Spent chicken meat	153.00	153.00	153.00	153.00
Chicken fat	27.00	9.00	9.00	9.00
Poppy seed paste	-	90.00	-	-
Sesame seed paste	-	-	9.00	-
Groundnut seed paste	-	-	-	12.00
Other ingredients	10.00	10.00	10.00	10.00
Processing charges	3.00	3.00	3.00	3.00
Total	193.00	265.00	193.00	187.00

Control: 15% Chicken fat (CF); T_1: 5% CF+10% PSP; T_2: 7.5% CF+10% SSP; T_3: 5% CF+10% GSP.

4. CONCLUSION

Combination of Vacuum packaging and fat replacement extended the shelf life of the sausages up to 180 days irrespective of formulation with minor changes in physico-chemical, microbiological and sensory quality. Ground sesame seed incorporated chicken sausages showed significantly lower microbial and fatty acid changes when compared to other and control. Cost of production kg^{-1} of functional chicken sausages incorporated with ground groundnut seed was found to be lowest followed by ground sesame seed and ground poppy seed incorporated sausages.

5. REFERENCES

Akesowan, A., 2016. Production and storage stability of formulated chicken nuggets using konjac flour and shiitake mushrooms. Journal of Food Science and Technology 53(10), 3661–3674. Available from: https://link.springer.com/article/10.1007/s13197-016-2332-7.

Almeida, P.L., Lima, S.N., Costa, L.L., Oliveira, C.C., Damasceno, K.A., Santos, B.A., Campagnol, P.C.B., 2015. Effect of jabuticaba peel extract on lipid oxidation, microbial stability and sensory properties of Bologna-type sausages during refrigerated storage. Meat Science 110, 9–14. DOI: https://doi.org/10.1016/j.meatsci.2015.06.012.

Anisa, C.D., Evanuarini, H.A., Mertaningtyas, D., 2024. The Quality of spent hen chicken sausage with tomato paste at different refrigerated storage time. Asian Food Science Journal 23, 26–32. DOI: https://doi.org/10.9734/afsj/2024/v23i2699.

Anonymous, 2001. Standard methods for the examination of water and wastewater. American Public Health Association (21st Edn.) APHAAWWA-WEF, Washington, DC, USA. Sri Venkateswara Veterinary University Library. Available from: https://www.umass.edu/mwwp/pdf/9222b.PDF#:~:text=Laboratory%20Apparatus,that%20may%20affect%20bacterial%20growth. Accessed on: 11.06.2024.

Barbut, S., 2001. Effect of illumination source on the appearance of fresh meat cuts. Meat Science 59(2), 187–191. DOI: 10.1016/s0309-1740(01)00069-9.

Bhat, Z.F., Pathak, V., Bukhari, S.A.A., Ahmad, S.R., Bhat, H., 2011. Quality changes in Chevon Harrisa (Meat based product) during refrigerated storage. International Journal of Meat Science 1(1), 52–61. DOI: 10.3923/ijmeat.2011.52.61.

Biswas, M.K., Debnath, C., Das, S.K., Pramanik, A.K., Biswas, S., Ganguly, S., Kumar, P., 2017. Studies on some comminuted meat products prepared from spent chicken during storage at refrigeration and frozen temperatures under aerobic packaging conditions. Indian Journal of Poultry Science 52(1), 104–113. Available from: https://indianjournals.com/article/ijps-52-1-018.

Cyprian, O.O., Sveinsdottir, K.M.V., Nguyen, T., Tomasson, G., Thorkelsson, S., 2017. Influence of lipid content and packaging methodson the quality of dried capelin (*Mallotusvillosus*) during storage (2017). Journal of Food Science Technology 54(2), 293–302. DOI 10.1007/s13197-016-2462-y.

Dinda, P.M., Agus, S., Evanuarini, H., 2025. Application of chicken sausage using psyllium husk flour as a natural antioxidant. In: 8th International Conference on Green Agro-Industry and Bioeconomy (ICGAB 2024)05005 165:7 Section: Food Science and Biotechnology. https://doi.org/10.1051/bioconf/202516505005.

Dravie, E.E., Kortei, N.K., Essuman, E.K., Tettey, C.O., Boakye, A.A., Hunkpe, G., 2020. Antioxidant, phytochemical and physicochemical properties of sesame seed (*Sesamum indicum* L). Scientific African 8, e00349. DOI: https://doi.org/10.1016/j.sciaf.2020.e00349.

Emiroglu, Z.K., Yemis, G.P., Coskun, B.K., Ogan, K., 2010. Anti microbial activity of soy edible films incorporated with thyme and oregano essential oilson fresh ground beef patties. Meat Science 86(2), 283–288. DOI: 10.1016/j.meatsci.2010.04.016.

Garcia-Lomillo, J., Gonzalez-SanJose, M.L., 2017. Applications of wine pomace in the food industry: approaches and functions. Comprehesive Review in Food Science and Food Safety 16(1), 3–22. DOI: 10.1111/1541-4337.12238. Epub . PMID: 33371551.

Hasan, M., Shahiduzzaman, M., Hashem, M.D., Abul K., Mouhammed Rahman, M.D., 2024. Effects of edible oil on the quality of chicken meat in short-term preservation. Meat Research 4(4) 1–7. DOI: https://doi.org/10.55002/mr.4.4.99.

Ilayabharathi, D., Sheriff, F.R., Raj Manohar, G., 2012. Shelf-life of spent chicken sausage andIts organoleptic qualities. Tamilnadu Journal of Veterinary & Animal Science 8(2), 60–67. Available from: https://www.semanticscholar.org/paper/shelf-life-of-spent-chicken-sausage-and-its-Ilayabharathi-Sheriff/5d1ca9ae9ba4b43c76aefbd491b29f8fef471570.

Indumathi, J., Shashikumar, M., Bhaskarreddy, G.V., Jagadeesh Babu, A., Gnanprakash, M., 2022. Study on the keeping quality of functional spent broiler breeder hen chicken sausages at refrigeration temperature. International Journal of Bio-resource and Stress Management 13(8), 887–898. DOI: 10.23910/1.2022.3080.

Jay, J.M., 1996. Modern food microbiology (4th Edn.). New Delhi: CBS Publishers and Distributors. Available from: https://books.google.co.in/books/about/Modern_Food_Microbiology.html?id=DdDfvLdUC-EC&redir_esc=y.

Jay, J.M., 1964. Beef microbial quality determined by extract release volume (ERV). Food Technology 18, 1633. Available from: https://scholar.google.com/scholar_lookup?&title=Beef%20microbial%20quality%20determined%20by%20extract-release%20volume%20%28ERV%29&journal=Food%20Technol&volume=18&pages=1637-1641&publication_year=1964&author=Jay%2CJM.

Karthikeyan, J., Kumar, S.A., Anjaneyulu, A.S.R., Rao, K.H., 2000. Application of hurdle technology for the development of Caprinekeema and its stability at ambient temperature. Meat Science 54(1), 9–15. DOI: 10.1016/S0309-1740(99)00053-4.

Khare, A.K., Biswas, J., Sahoo, 2014. Comparison study of chitosan, EDTA, eugenol and peppermint oil for antioxidant and antimicrobial potentials in chicken noodles and their effect on colour and oxidative stability at ambient temperature storage. LWT-Food Science and Technology 55(1), 286–293. Avialable from: https://www.researchgate.net/publication/267035650_Comparison_study_of_chitosan_EDTA_eugenol_and_peppermint_oil_for_antioxidant_and_antimicrobial_potentials_in_chicken_noodles_and_their_effect_on_colour_and_oxidative_stability_at_ambient_temperature_s.

Khursheed, I., Bandral, J.D., Sood, M., Ahmed, N., 2017. Influence of knolkhol on quality characteristics of chicken meat balls. Journal of Applied and Natural Science 9(4), 2221–2227. Available from: https://journals.ansfoundation.org/index.php/jans/article/view/1515.

Koniecko, E.K., 1979. Handbook for meat chemists. Wayne, New Jersey, USA, Avery Publishing Group Inc (Ch. 6), pp. 68–69. Available from: https://www.sciepub.com/reference/38151.

Kristam, P., Naga Mallika, E., Eswara Rao, B., Srinivas Rao, T., 2016. Evaluation of edible polymer coatings enriched with green tea extracton quality of chicken nuggets. Veterinary World 9(7), 685–692. DOI: 10.14202/vetworld.2016.685-692.

Kumar, S.H.T., Pal, U.K., Mandal, P.K., Das, C., 2014. Changes in the quality of dressed chicken obtained from different sources during frozen storage. Exploratory Animal and Medical Research 4(1), 95–100. Available from: https://www.researchgate.net/profile/Prabhat-Mandal/publication/280548549_changes_in_the_quality_of_dressed_chicken_obtained_from_different_sources_during_frozen_storage/links/55b89adf08ae092e9658abaa/changes-in-the-quality-of-dressed-chicken-obtained-from-different-sources-during-frozen-storage.pdf.

Lawrie, R.A., 1998 Lawrie's meat science (6th Edn.). Woodhead Publishing Limited, Oxford, 79–80. Available from: https://books.google.co.in/books/about/Lawrie_s_Meat_Science_Sixth_Edition.html?id=Txu80syytroC&redir_esc=y.

Leistner, L., 1994. Further developments in the utilization of hurdle technology for food preservation. Journal of Food Engineering 22(1–4), 421–432. DOI: https://doi.org/10.1016/0260-8774(94)90044-2.

Lima, T.L., Costa, G.F., Cruz, G.R.B., Araújo, I.B., Ribeiro, N.L., Ferreira, V.C.S., Silva, F.A.P., Beltrao Filho, E.M., 2022. Effect of storage time on colorimetric, physiochemical, and lipid oxidation parameters in sheep meat sausages with pre-emulsified linseed oil. Food Science and Technology, 42. DOI: https://doi.org/10.1590/fst.24721.

Malav, O.P., Sharma, B.D., Kumar, R.R., Talukder, S., Ahmed, S.R., Irshad, A., 2015. Antioxidant potential and qualitycharacteristics of functionalmutton patties incorporated with cabbage powder. Nutrition & Food Science 45(4), 542–563. DOI: https://doi.org/10.1108/NFS-03-2015-0019.

Mir, S.A., Masoodi, F.A., 2017. Effect of packaging on lipid oxidation, sensory and color attributes of the value added mutton meat balls during refrigeration. Journal of Nutritional Health & Food Engineering 7(3), 301–309. Available from: https://www.researchgate.net/publication/322964147_effect_of_packaging_on_lipid_oxidation_sensory_and_color_attributes_of_the_value_added_mutton_meat_balls_during_refrigeration.

Mohamed, F.R., Joerg-Thomas, M., 2006. Screening of the antiradical action of vegetable oils. Journal of Food Composition and Analysis 19(8), 838–842. ISSN 0889-1575. DOI: https://doi.org/10.1016/j.jfca.2006.02.013.

Nath, P.M., Kumar, V.P.K., Ganguly, S., 2016. Effect of chicken skin, soy protein and olive oil onquality characteristics of chicken nuggets. International Journal of Science Environment and Technology 5(3), 1574–1585. Available from: https://www.researchgate.net/publication/303698365_effect_of_chicken_skin_soy_protein_and_olive_oil_on_quality_characteristics_of_chicken_nuggets.

Naveen, Z., Naik, B.R., Subramanyam, B.V., Reddy, P.M., 2016. Studies on the quality of duck meatsausages during refrigeration. Springer Plus 5, 2061. Available from: https://link.springer.com/article/10.1186/s40064-016-3743-7.

Naveena, B.M., Muthukumar, M., Muthulakshmi, L., Anjaneyulu, A.S.R., Kondaiah, N., 2014. Effect of different cooking methods on lipid oxidation and microbial quality of vacuum-packaged emulsion products from chicken. Journal of Food Processing and Preservation 38, 39–47. Available from: https://www.researchgate.net/publication/262957432_effect_of_different_cooking_methods_on_lipid_oxidation_and_microbial_quality_of_vacuum-packaged_emulsion_products_from_chicken.

Naveena, B.M., Khansole, P.S., Kumar, S.M., Krishnaiah, N., Vinayak, V., Kulkarni, Deepak, S.J., 2017. Effect of sous vide processing on physicochemical, ultrastructural, microbial and sensory changes in vacuum packaged chicken sausages. Food Science and Technology International 23(1), 75–85. PMID: 27386881. DOI: 10.1177/1082013216658580.

Paneras, E.D., Bloukas, J.G., 1994. Vegetable oils replace pork backfat for low-fat frankfurters. Journal of Food Science 59, 725–728. Available from: https://ift.onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2621.1994.tb08113.x.

Park, S.H., Ryu, S.N., Bu, Y., Kim, H., Simon, J.E., Kim, K.S., 2010. Antioxidant components as potential neuroprotective agents in sesame (*Sesamum indicum* L.). Food Reviews International 26(2), 103–121. https://doi.org/10.1080/87559120903564464.

Pereira, P.M.D.C.C., Vicente, A.F.D.R.B., 2013. Meat nutritional composition and nutritive role in the human diet. Meat Science 93(3), 586–592. doi: 10.1016/j.meatsci.2012.09.018.

Reddy, G.V., Sen Pramod, A.R., Nair, N., Reddy, S.K., Reddy, K.K., Kondaiah, N., 2013. Effects of grape seed extract on the oxidative and microbial stability of restructured mutton slices. Meat Science 95, 288–294. DOI: 10.1016/j.meatsci.2013.04.016.

Sebei, K., Gnouma, A., Herchi, W., Sakouhi, F., Boukhchina, S., 2013. Lipids, proteins, phenolic composition, antioxidant and antibacterial activities of seeds of peanuts (*Arachis hypogaea* L.) cultivated in Tunisia. Biological Research 46(3), 257–263. DOI: 10.4067/S0716-97602013000300006.

Sharada, S.M.V., Indumathi, J., Bhaskar Reddy, G.V., Shakila, S., Chandra Mouli, A., 2025. Effect of incorporation of potato dried powder on the quality characteristics of spent broiler breeder hen chicken koftas. International Journal of Bio-resource and Stress Management 16(7), 01–08. DOI: https://doi.org/10.23910/1.2025.6207.

Sharopov, F., Valiev, A., Gulmurodov, I., 2018. Alkaloid content, antioxidant and cytotoxic activities of various parts of *Papaver somniferum*. Pharmaceuticals Chemistry Journal 52, 459–463. DOI: https://doi.org/10.1007/s11094-018-1839-9.

Shasidhar, Y., Vishwakarma, M.K., Pandey, M.K., 2017. Molecular mapping of oil content and fatty acids using dense genetic maps in groundnut (*Arachis hypogaea* L.). Frontier in Plant Science 8, 794. DOI: https://doi.org/10.3389/fpls.2017.00794.

Singh, P., Sahoo, J., Chatli, M.K., Ashim, K., Biswas, A.K., 2014. Shelf life evaluation of raw chicken meat emulsion incorporated with clove powder, ginger and garlic paste as natural preservatives at refrigerated storage (4±1°C). International Food Research Journal 21(4), 1363–1373. Available from: http://www.ifrj.upm.edu.my/21%20(04)%202014/14%20IFRJ%2021%20(04)%202014%20Singh%20377.pdf.

Snedecor, G.W., Cochran, W.H., 1980. Statistical methods (13th Edn.) Oxford and IBH publishing Co. Calcutta. Available from: https://www.scirp.org/reference/ReferencesPapers?ReferenceID=1896667.

Soher, E.A., El-Faham, S., Ibrahim, M.A., Hathout, A.S., Sabry, B.A., 2013. Characterization and microbiological quality of low-fat chicken burger containing defatted peanut flour. Journal of Applied Sciences Research 9(11), 5599–5608. Available from: https://www.researchgate.net/publication/262070222_Characterization_and_microbiological_quality_of_low-fat_chicken_burger_containing_defatted_peanut_flour.

Soumia, D., El-Geddawy, M.A.H., Khalifa, R.M.B., Mohamed, R.A.A., 2012. Antioxidant activities of some spices and herbs added to frozen chicken burger. Frontiers in Science 2(6), 144–152. DOI: 10.5923/j.fs.20120206.03.

Sriphochanart, W., Skolpap, W., 2018. Modeling of starter cultures growth for improved Thai sausage fermentation and cost estimating for sausage preparation and transportation. Food Science and Nutrition 6(6), 1479–1491. DOI: 10.1002/fsn3.708.

PMID: 30258590; PMCID: PMC6145271.

Strange, E.D., Benedict, R.C., Smith, J.L., Swift, G.E., 1977. Evaluation of rapid tests for monitoring alteration in meat quality during storage. Journal of Food Protection 40, 843–847. DOI: 10.4315/0362-028X-40.12.843.

Virginia, P., 2015. Utilization of poppy seeds (*Papaver somniferum*) and sesame seeds (*Sesamum indicum*) for development of nutria-enriched snacks. Indian Journal of Community Health 27. Available from: https://www.iapsmupuk.org/journal/index.php/IJCH/article/view/617.

Waliullah, S., Ahsan, C.R., 2011. Assessment of microbiological quality of some meat-based fast foods collected from street vendors. Journal of Innovation & Development Strategy 5(3), 44–46. Available from: https://www.researchgate.net/profile/Sumyya-Waliullah/publication/282673723_assessment_of_microbiological_quality_of_some_meat-based_fast_foods_collected_from_street_vendors/links/5731647a08aed286ca0dce02/assessment-of-microbiological-quality-of-some-meat-based-fast-foods-collected-from-street-vendors.pdf.

Witte, V.C., Krause, G.F., Bailey, M.E., 1970. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. Journal of Food Science 35(5), 582–585. Available from: https://ift.onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2621.1970.tb04815.x.

Zhang, H., Jingjuan, W.U., Xinyu, G., 2016. Effects of antimicrobial and antioxidant activities of spice extracts on raw chicken meat quality. Food Science and Human Wellness 5(1), 39–48. DOI: https://doi.org/10.1016/j.fshw.2015.11.003.