

Impact of adding Liquid Smoke and Thyme Essential Oil on the quality of Chicken and Turkey Meatballs products during frozen storage

Abstract:

This study was carried out to evaluate the effect of liquid smoke (LS) produced from beech sawdust and thyme essential oil (TEO) as natural antioxidants in chicken and turkey meatballs during frozen storage. The LS and TEO were added to chicken and turkey meatballs at levels of 1% and 0.1%, respectively, and storage at $-18 \pm 1^{\circ}\text{C}$ for 6 months. pH value, water holding capacity (WHC), total volatile nitrogen (TVN), thiobarbituric acid (TBA) value, peroxide values (PV), total phenolic compounds (TPC) and antioxidant activity (DPPH %) were determined. The results demonstrated that the addition of LS or ETO had a positive effect on storage stability and a little change in the physical properties as well as quality attributes of chicken and turkey meatballs during frozen storage compared to the control sample. The results indicated that total phenolic content and antioxidant activity of treated chicken and turkey meatballs decreased during frozen storage. Furthermore, the lowest change was noticed in samples treated with LS and then TEO during the six-month of frozen storage period. The data revealed that the use of liquid smoke in meatballs increased the rate of maintaining the physical properties and quality attributes and was better accepted compared to TEO and control.

Key words: Meatballs, liquid smoke, thyme essential oil, natural antioxidant, physical and quality.

1. Introduction:

Chicken meat consumption continues to rise, owing to its reduced cost, ease of preparation, and desired nutritional value, which includes a high content of easily absorbed protein, low fat content, and a comparatively high content of polyunsaturated fatty acids when compared to beef [1, 2]. The poultry industry has evolved and adapted to satisfy customer needs for meat products; today, further processed meats have the largest market share, followed by chicken parts and whole carcasses, with 47.6%, 41.8%, and 13%, respectively [3, 4]. Meatballs are one of the most popular meat products in the world, and there are many different sorts (including chicken meatballs, beef meatballs and fish meatballs). The chicken meatballs are the most popular and widely consumed. They are frequently served with noodles or vermicelli, veggies, and gravy [5].

Meat spoiling can be caused by a variety of internal and exogenous reasons, such as physical damage or chemical changes [6]. The main causes of meat quality deterioration and meat product shelf life limitations are lipid and protein oxidation. Oxidation processes are the principal cause of meat quality degradation and meat product shelf life reduction, resulting in negative changes in nutritional value, sensory, and physicochemical qualities of meat [7]. Physical and chemical variables such as color, pH, and water holding capacity, lipid oxidation, and microbial contamination affect the nutritional and sensory characteristics of foods, particularly meat and meat products [8]. The pH value is regarded important since it influences several properties of meat and meat products, including shelf life, color, water holding capacity, and texture [9]. The breakdown of glycogen may cause a reduction in pH in meat, whereas partial proteolysis may cause a rise in pH value [10]. Followed by an increase in total volatile nitrogen [11]. Meat degradation can be delayed by using synthetic or natural antioxidants. Synthetic antioxidants, on the other hand, haven't been

used as much because they could be harmful to people and be toxic [12]. Consumers are becoming more interested in using natural products that are rich in bioactive compounds to keep meat products stable during freezing [13].

Smoke flavorings are produced on a large scale and used in a variety of foods, including meat, fish, and cheese [14, 15]. Smoking as a food processing method contributes to guaranteeing food safety due to various advantages, such as being rich in bioactive compounds, low cost, and control of polycyclic aromatic hydrocarbon (PAH) content [16, 17]. Liquid smoking has recently gained popularity in the food industry [15]. The presence of antibacterial and antioxidant chemicals such as aldehyde, carboxylic acids, and phenols in food smoking provides a preservative effect [18, 19].

Essential oils are complex natural combinations of hydrocarbons (mostly terpenoids) and oxygenated molecules (alcohols, esters, ethers, aldehydes, ketones, lactones, phenols and phenol ethers) [20, 21]. Thyme (*Thymus vulgaris*) essential oil (TEO) is a rich source of aromatic bioactive components such as thymol and carvacrol, both of which have antioxidant and antibacterial properties [22, 23]. The small concentration of TEO is not enough to significantly extend the meat products' shelf life [24]. The objective of this study was to evaluate the effect of adding liquid smoke or TEO as natural antioxidants on the physical properties and quality attributes of chicken and turkey meatballs during frozen storage and the effect of the storage on total phenolic content and antioxidant content.

2. Materials and Methods:

2.1. Materials:

36 kg of fresh breast chicken and turkey meat were purchased from the local market in Assiut city, Assiut, Egypt during September 2020. Meat of chicken and turkey were washed carefully then deboned. The breast chicken and turkey meat were minced using a meat mincer. Some samples were used directly for physiochemical analysis at zero time, while others were prepared for processing product.

2.1.2. Beech sawdust waste:

Beech sawdust waste was used in liquid smoke preparation and was obtained from a local furniture manufacturer in Assiut, Egypt.

2.1.3. Essential oil:

Thyme (*Thymus vulgaris*) was purchased from Natural oil extraction unit, National Research Centre, Cairo, Egypt. (2020).

2.1.4. Spices:

The spice mixture was prepared using equal weights (black pepper, sweet paprika, chili paprika, and cumin). Also, salt, rusk flour, and onions were obtained from the local market during September 2020 in Assiut city, Egypt.

2.1.5. Chemicals and reagents:

All chemicals and reagents used in the analytical methods (analytical grade) were produced by Sigma chemical co. (St. Louis, M., USA) and purchased from EL. gamhouria trading chemicals and drugs co.

2.2. Methods:

2.2.1. Preparation of liquid smoke:

The beech sawdust waste was moistened to a moisture content of about 20%. A small laboratory smoke generator was used to generate smoke, and the destructive distillation was condensed using a small condenser. The **concomitant** substances were removed from the obtained smoke condensates by settling about 7 days at 4°C, followed by centrifugation at 2500 rpm for 10 min., filtration by Watman No.1 papers, and titration by carbonate solution to pH 4-5.5. **Finally it** diluted with distilled water in a ratio 1:4 (condensate: distilled water) to obtain liquid smoke [25]. **A some** modification in this method was carried out by lengthening the condenser tube until a large amount of compounds of large molecular weight is deposited on the wall of the condenser to reduce harmful compounds, also passing of filtered liquid smoke through active charcoal filtration to obtain liquid smoke completely free from harmful substances such as benzo[a]pyrene.

2.2.2. Preparation of chicken and turkey meatballs samples:

The ingredients for the meatballs include (minced meat of chicken and turkey 71 gm, rusk flour 10 gm, salt 2.00 gm, onion 7gm, black pepper 0.40 gm, sweet paprika 0.25 gm, chilli paprika 0.25 gm, cumin 0.10 gm, and iced water 9.00 ml) [26].

2.2.3. Preparation of meatballs treated with LS or TEO oil:

The samples were divided into three groups; the first group was treated with 1% **liquid smoke** or 0.1% thyme essential oil for chicken meatballs; the second group was treated with either 1% **LS** or 0.1% TEO for turkey meatballs; and the third group was kept as a control group. Each sample was packed in

polyethylene bags and stored under the refrigerator stored at $-18 \pm 1^{\circ}\text{C}$ for 6 months [27].

2.2.4. pH value:

The pH of meatballs sample were measured by homogenizing 10 gm of the sample with 100 ml distilled water for 30 sec. The pH of the prepared sample was measured using a pH meter (OAKTON, pH/ mV/ $^{\circ}\text{C}$ meter, USA) with a glass electrode at 20P o PC according to the method described by [28].

2.2.5. Determination of water holding capacity (WHC):

Water holding capacity (WHC) was measured according to the methods mentioned by [29, 30].

2.2.6. Determination of total volatile nitrogen (TVN):

The total volatile nitrogen determined according to method described by [31]. The results were given in milligrams of TVN per 100g sample.

2.2.7. Determination of thiobarbituric acid (TBA):

The value of thiobarbituric acid (TBA mg MDA/kg) was determined by a distillation method, according to [32].

2.2.8. Determination of peroxide value (PV):

The peroxide concentrations were measured in meq O_2/Kg of sample according to method described by [33]. The PV was calculated using the following formula:

$$\text{Peroxide value meq } \text{O}_2/\text{ Kg muscle} = (V - B) \times Nf/W) * 1000$$

where V is the volume of sodium thiosulfate consumed, B is the volume of normal sodium thiosulfate consumed during a blank titration, W is the weight of the sample (g) and Nf is the normality of sodium thiosulfate multiplied by a factor.

2.2.9. Determination of total phenolic compounds in meatballs:

The Folin–Ciocalteu method [34] was used to determine the total phenol content. Gallic acid was used as a standard to produce the calibration curve. The total phenol content was measured in mg of Gallic acid equivalents (GAE) per 100 g of a fresh weight sample.

2.2.10. Determination of antioxidant activity in meatballs:

The DPPH method was used according to [35] with certain adjustments. In a 99 % ethanol solution, a 60- μ mol/L DPPH solution was prepared. Extract from chicken and turkey meatballs (100 μ L) was reacted with 3.9 ml of the DPPH solution. The solution was incubated for 60 min in a dark environment. The absorbance (A) at 515 nm was measured using a spectrophotometer against a blank of 95% ethanol. Antioxidant activity was calculated as follows: DPPH radical-scavenging activity (%) = $(A_{\text{control}} - A_{\text{sample}}) / A_{\text{control}} * 100$

Where, A is the absorbance at 515 nm. All DPPH tests were carried out in triplicate.

2.2.11. Statistical analysis:

Data were analyzed by analysis of variance (ANOVA) using a completely randomised factorial design. Basic statistics and ANOVA were performed to test the significance within replications and between treatments [36]. (L.S.D) tests were used to determine the differences among means at the level of 0.05%.

3. Results and Discussion:

3.1. Effect of LS or TEO on pH value of chicken and turkey meatballs:

The pH values of chicken and turkey meatballs for control and treated with 1% LS or 0.1% TEO at zero time and during frozen storage at $-18^{\circ}\text{C}\pm 1$ up to 180 days are shown in Table (1). From these results, it could be observed that the sample treated with 1% liquid smoke or 0.1% TEO had a lower pH value than the control. With a significant difference ($P<0.05$) between treatments. The maximum thyme essential oil concentration was more successful in decreasing pH values than lower concentrations compared to untreated samples those reported by[37]. The pH of the meat treated with the higher concentration of liquid smoke will be lower. This is caused by the presence of phenol and organic acid in liquid smoke, which cause the pH to decrease[38].

The pH values of all chicken and turkey meatball samples gradually increased as the frozen storage period was extended, with a significant difference ($P<0.05$) observed between the samples and frozen storage periods. The highest increased was observed in the control samples and the lowest in liquid smoke then TEO. During freezing storage, the pH value increases and this may be due to microorganisms and endogenous enzymes breaking down meat proteins, releasing ammonia, organic sulphides, and amines, all of which raise pH values [39]. During different intervals of analysis, samples treated with thyme essential oil had lower pH values than control samples. This might be owing to the activation action of thyme oil as an antibacterial agent producing protein breakdown and the development of alkyl groups those found by[40].

Table (1): Changes in pH values of chicken and turkey meatballs treated with LS or TEO during frozen storage at $-18^{\circ}\text{C}\pm 1$ up to 180 days.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	5.87	5.92	5.97	6.09	6.14	6.21	6.23	6.06
	LS	5.63	5.74	5.75	5.77	5.77	5.85	5.83	5.76
	TEO	5.73	5.86	5.85	5.83	5.84	5.92	5.96	5.85
Mean		5.75	5.84	5.86	5.90	5.92	6.00	5.90	5.88
Turkey	C	5.72	5.83	5.81	5.91	5.98	6.13	6.10	5.92
	LS	5.54	5.59	5.59	5.61	5.63	5.67	5.72	5.62
	TEO	5.67	5.70	5.73	5.78	5.81	5.90	5.90	5.78
Mean		5.65	5.87	5.71	5.77	5.81	5.90	5.95	5.80
Main effects	C	5.80	5.67	5.89	6.00	6.06	6.17	6.17	5.96
	LS	5.58	5.78	5.67	5.69	5.70	5.76	5.77	5.71
	TEO	5.70	5.77	5.79	5.80	5.82	5.91	5.93	5.82
Mean		5.69	5.92	5.78	5.83	5.86	5.95	5.95	
F-test A(Var.)=**		L.S.D0.05	B= 0.016	AB=0.022	C =0.024	AC=n.s	BC=0.041	ABC=0.059	

* C: control sample LS: liquid smoke TEO: thyme essential oil

F-test	A= Types meat	**
L.S.D0.05	B= Treatments	0.016
	C= Storage periods	0.024
	AB= interaction between types meat x treatments	0.022
	AC= interaction between types meat x storage periods	n.s
	BC= interaction between treatments x storage periods	0.041
	ABC= interaction between types meat x treatments x storage periods	0.059

3.2. Effect of LS or TEO on water holding capacity of chicken and turkey meatballs:

The ability of meat to bind and retain moisture (Water-holding capacity, WHC) is the most important quality of meat products, particularly frozen meat, because it influences consumer acceptance and final product weight [41].

Data given in Table (2) displayed the effect of addition 1% LS, and 0.1% TEO for chicken and turkey meatballs compared to control sample on **water holding capacity** (WHC) during frozen storage at **-18°C±1 180days**. The obtained results showed that the chicken and turkey meatballs with the addition of 1% LS or 0.1% TEO, the WHC increased.

During frozen storage, the **water holding capacity** slow decreased. With a significant effect ($p<0.05$) between treatments and frozen storage periods. The effects of freezing storage on the physical properties of turkey breast meat, such as **WHC** and cooking loss percentages, **were** significantly decreased while the pH was significantly increased those obtained by [42]. When the pH of a muscle drops from 7 to 5.5, there is always some loss of WHC and the water is expelled into the intracellular space those suggest by[43].

Table (2): Changes in water holding capacity (WHC%) of chicken and turkey meatballs treated with LS or TEO during frozen storage at -18°C±1.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	83.87	79.16	78.11	75.44	74.38	72.48	68.36	75.97
	LS	84.62	84.00	84.34	82.13	81.06	80.96	79.28	82.34
	TEO	81.64	81.30	81.30	80.74	79.67	80.05	79.00	80.53
Mean		83.37	81.49	81.25	79.44	78.37	77.83	78.56	80.04
Turkey	C	79.55	75.32	76.64	74.95	73.63	72.81	69.81	74.67
	LS	82.96	81.89	82.19	81.13	80.09	81.42	77.90	81.08
	TEO	84.25	83.53	83.08	80.28	80.59	81.46	78.36	81.65
Mean		82.25	77.24	80.64	78.79	78.10	78.56	75.90	78.78
Main effects	C	81.71	82.95	77.38	75.20	74.01	72.65	69.08	76.14
	LS	83.79	82.42	83.26	81.63	80.58	81.19	78.59	81.64
	TEO	82.94	80.87	82.19	80.51	80.13	80.75	78.68	80.87
Mean		82.81	79.16	80.94	79.11	78.24	78.20	75.45	
F-test A(Var.)=**		L.S.D0.05	B= 0.37	AB= 0.53	C (P)=0.57	AC=0.80	BC=0.98	ABC=1.39	

* C: control sample LS: liquid smoke TEO: thyme essential oil

3.3. Effect of LS or TEO on total volatile nitrogen of chicken and turkey meatballs:

The total volatile nitrogen (TVN) is a positive predictor of meat and meat products quality during storage [44].

TVN content might be utilized as a measure of the data presented in the Table (3) from the results the TVN for chicken and turkey meatballs was affected by using LS and 0.1% TEO oil compared with the control during frozen storage periods.

At the end of frozen storage period, the control sample was recorded 12.54 and 11.98 mg / 100g. While, for samples containing 1% liquid smoke or TEO 0.1% the TVN was 9.71, 10.07 and 9.62, 10.08 mg/100g, respectively; for chicken and turkey meatballs. Some active perishable bacteria activate a working enzyme and aid in protein breakdown, resulting in a reduction in meat quality[45]. Degradation of protein compounds producing base-basevolatile. According to the Egyptian Organization for Standardization [46], all of the samples for poultry meatballs were within the acceptable limit, with TVN levels of less than 20 mg/100. The freezing process resulted in the production of ice crystals, which stopped the bacteria from emerging. This proportion rises with the length of freezing storage, halting microbe development and reducing their numbers while creating adverse circumstances for the rest of them to growth those reported by[47].

From the obtained results, it was also observed that samples treated with liquid smoke or thyme essential oil caused a decrease in total volatile nitrogen when compared to control samples during frozen storage periods with significantly deferens ($P < 0.05$) between types meat x treatments x storage periods. This may be attributed to phenol compounds being able to inhibit microbial activities. Phenols from liquid smoke are antimicrobial agents able to

inhibit microbial activities, which is very effective in preserving [48]. During storage, the greatest rate of TVN values was recorded in control samples, and thyme oil was more effective in lowering TVN values those found by [40].

Table (3): Changes in total volatile nitrogen (per100 g sample) of chicken and turkey meatballs treated with LS or TEO during frozen storage at $-18^{\circ}\text{C}\pm 1$.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	8.48	8.95	9.53	10.40	10.89	11.83	12.54	10.38
	LS	6.68	6.91	7.15	7.46	7.84	8.87	9.71	7.80
	TEO	7.08	7.20	7.51	7.92	8.55	9.43	10.07	8.25
Mean		7.41	7.69	8.07	8.60	9.10	10.05	9.89	8.68
Turkey	C	7.78	7.98	8.34	8.75	9.80	11.14	11.98	9.39
	LS	5.49	5.74	6.14	6.91	7.61	8.86	9.62	7.19
	TEO	5.69	5.93	6.69	7.82	8.21	9.66	10.08	7.72
Mean		6.32	8.46	7.06	7.83	8.54	9.89	10.56	8.38
Main effects	C	8.13	6.32	8.94	9.58	10.35	11.48	12.26	9.58
	LS	6.08	6.57	6.64	7.18	7.73	8.87	9.67	7.53
	TEO	6.38	7.12	7.10	7.87	8.38	9.54	10.08	8.07
Mean		6.87	8.95	7.56	8.21	8.82	9.96	10.67	
F-test A(Var.)=**		L.S.D0.05	B =0.13	AB=0.19	C =0.20	AC=0.29	BC=n.s	ABC=0.50	

* C: control sample LS: liquid smoke TEO: thyme essential oil

3.4. Effect of LS or TEO on thiobarbituric acid (TBA) of chicken and turkey meatballs:

The change in TBA values for chicken and turkey meatballs samples were evaluated for 180 days during frozen storage, and the data are summarized in Table (4). At zero time of frozen storage, there were no significant differences between chicken and turkey meatballs samples treated with liquid smoke or TEO compared with control samples.

Moreover, throughout frozen storage periods at $-18\pm 1^{\circ}\text{C}$, TBA values of the control sample increased significantly over time, reaching their highest values (0.87 and 0.91 mg malonaldehyde/kg sample) for chicken and turkey meatballs,

at the end of frozen storage period. Although, during frozen storage the other treatments displayed a slight increase in TBA values. These increases were significantly smaller than that in the control group. The highest significant difference ($P < 0.05$) was observed in the interaction between treatments and frozen storage periods. This might explain these observations due to the frozen storage and high antioxidant effect of liquid smoke and TEO, which is connected to the scavenger nature of their phenolic content. Freezing of foods does not stop the change in physicochemical, but it does slow down the activities that cause food to deteriorate [49, 50]. TBA values of minced beef in the control sample increased rapidly with storage time, although TBA values of thyme treatment samples on day 0 were substantially lower than those of the control sample those found by [51]. The phenols, which contain fewer carboxylic acids, are known to be strong antioxidants, so that liquid smoked products are more resistant to rancidity those suggest by [52]. Liquid smoke had a remarkable result in reduction of oxidation by affecting 2-thiobarbituric acid (TBARs) [53].

Table (4): Changes in TBA values (mg malonaldehyde per kg. sample) of chicken and turkey meatballs treated with LS and TEO during storage at $-18\pm 1^{\circ}\text{C}$ up to 180days.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	0.56	0.60	0.68	0.75	0.78	0.85	0.87	0.73
	LS	0.49	0.50	0.55	0.60	0.64	0.66	0.69	0.59
	TEO	0.49	0.53	0.56	0.58	0.65	0.6	0.72	0.60
Mean		0.52	0.55	0.60	0.65	0.69	0.73	0.76	0.64
Turkey	C	0.66	0.69	0.74	0.78	0.82	0.87	0.91	0.78
	LS	0.63	0.61	0.64	0.64	0.66	0.67	0.69	0.65
	TEO	0.61	0.63	0.65	0.68	0.69	0.71	0.73	0.67
Mean		0.64	0.64	0.68	0.70	0.73	0.76	0.77	0.70
Main effects	C	0.61	0.56	0.71	0.77	0.80	0.86	0.89	0.74
	LS	0.56	0.58	0.59	0.62	0.65	0.67	0.69	0.62
	TEO	0.55	0.59	0.61	0.63	0.67	0.69	0.73	0.64
Mean		0.57	0.60	0.64	0.67	0.71	0.74	0.77	
F-test A(Var.)=**		L.S.D0.05	B =0.010	AB=n.s	C =0.016	AC=0.022	BC=0.027	ABC=n.s	

* C: control sample LS: liquid smoke TEO: thyme essential oil

3.5. Effect of LS or TEO on peroxide values of chicken and turkey meatballs:

The changes of peroxide value for chicken and turkey meatballs mixed with 1% LS or 0.1 % TEO and control sample during frozen storage at $-18\pm 1^{\circ}\text{C}$ up to 180 days are shown in Table (5). At the end of frozen storage periods, peroxide values reached (14.15, 9.47, 10.10, and 13.27, 9.88, and 10.23 m.equiv./Kg) for chicken and turkey meatballs control, LS, and TEO, respectively. These agreement with [54], who study the changes in peroxide value (PV) in chicken during frozen storage and who reported that the increase in PV was probably due to the faster rate of formation of peroxides during months 1, 2 and 3 of storage than degradation of peroxides into secondary oxidation products.

Moreover, the lowest PV during the frozen storage period with significant differences ($P<0.5$) were noticed in samples treated with liquid smoke, followed

by samples treated with thyme essential oil during frozen storage periods. Such findings may be attributed to the high antioxidant effect. The slow rate of oxidation during storage might be related to the smoke antioxidants' efficacy [55]. Smoking process can impact on lipid oxidation as the activity of phenolic compounds [56]. Liquid smoke possesses antioxidant and antimicrobial capabilities due to the presence of phenol, carbonyl, organic acids, and a low pH **value**. Liquid smoke contains bioactive chemicals that can inhibit microbiological development [57]. Adding thyme extracts was the most successful in reducing the PV during storage those found by [58].

Table (5): Changes in peroxide values (m. equiv. per Kg. of sample) of chicken and turkey meatballs treated with LS or TEO during frozen storage at $-18\pm 1^{\circ}\text{C}$ up to 180 days.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	7.71	8.42	9.22	10.47	11.22	13.69	14.15	10.69
	LS	6.42	6.45	6.96	7.29	8.13	8.83	9.47	7.65
	TEO	5.59	6.03	6.78	7.37	8.94	9.78	10.10	7.80
Mean		6.57	6.97	7.66	8.38	9.440	10.76	11.24	8.71
Turkey	C	6.83	7.59	8.50	9.30	12.19	12.15	13.27	9.97
	LS	6.33	6.50	7.15	7.46	8.32	9.42	9.88	7.87
	TEO	5.98	6.29	6.98	7.56	8.49	9.13	10.23	7.81
Mean		6.38	6.79	7.54	8.11	9.67	10.23	11.12	8.55
Main effects	C	7.27	8.00	8.86	9.88	11.70	12.92	13.71	10.33
	LS	6.37	6.47	7.05	7.37	8.23	9.12	9.67	7.75
	TEO	5.69	6.45	6.83	7.41	8.83	9.62	10.13	7.85
Mean		6.44	6.97	7.58	8.22	9.58	10.55	11.17	
F-test A(Var.)=n.s		L.S.D0.05	B =0.35	AB=*	C =0.54	AC=n.s	BC=***	ABC=n.s	

* C: control sample LS: liquid smoke TEO: thyme essential oil

3.6. Effect of LS or TEO on phenolic compounds of chicken and turkey meatballs:

Phenolic chemicals are antioxidants that have a wide range of biological effects, including antibacterial, antiviral, ant carcinogenic, vasodilatory, and anti-inflammatory properties [59, 60]. The results in Table (6) Showed the amounts of total phenolic compounds (TPC) in the control and treated samples of chicken and turkey meatballs at zero time and during frozen storage. The levels of TPC after the addition of 1% LS and 0.1% TEO caused a significant increase in TPC content in chicken and turkey meatballs at zero time, and it showed that the control contained 82.30 and 78.80 mg/100 g TPC, while samples treated with LS or TEO had higher levels of TPC, reaching 312.3, 291.2, and 319.5, 275.1 mg/100g for chicken and turkey meatballs, respectively. This duo to the high level of phenolic compounds. The present results are agreement with [61]. The more phenols contained in liquid smoke are added to the meat, the higher the overall phenol content penetrates into the meat [62]. The ratio of the optimal concentration of liquid smoke during the process may be determined by the greatest total phenol value and the lowest pH value [63].

From the same Table, it could be observed that total phenol content was decreased in all samples during frozen storage, with significant differences ($P<0.5$) between treatments and storage periods. The reduction in TPC may be attributed to the decomposition of TPC during the storage periods this is consistent with [64]. Storage period affects the total phenolic content and antioxidant activities. The reason for decrease in antioxidant activity during storage may be attributed to possible oxidation of antioxidant components under favorable conditions during storage [65]. The phenol compounds are volatile, the amount of phenol in meat decreases with time as a result of evaporation those reported by [66].

Table (6): Changes in phenolic compounds (mg/100 g) of chicken and turkey meatballs treated with LS or TEO during frozen storage at $-18\pm 1^{\circ}\text{C}$ up to 80days.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	82.30	70.8	59.4	50.9	55.8	49.9	40.8	58.6
	LS	312.3	190.8	188.5	205.9	221.2	168.1	160.1	206.7
	TEO	291.2	187.2	177.9	158.3	221.8	171.0	159.0	195.2
Mean		228.6	149.6	141.9	138.4	166.3	129.7	119.2	153.4
Turkey	C	78.80	67.8	60.8	58.3	58.6	44.6	38.8	58.2
	LS	319.5	178.4	210.9	213.6	214.5	156.7	140.8	204.9
	TEO	275.1	176.5	201.4	210.7	203.4	147.3	136.6	193.0
Mean		224.5	140.9	157.7	160.9	158.8	116.2	105.4	152.0
Main effects	C	80.55	69.3	60.1	54.6	57.2	47.2	39.8	58.4
	LS	315.9	184.6	199.7	209.7	217.8	162.4	150.4	205.8
	TEO	283.1	181.3	189.6	184.5	212.6	159.1	147.8	194.1
Mean		226.5	70.8	149.8	149.6	162.6	122.9	112.7	
F-test A(Var.)=n.s		L.S.D0.05	B =2.67	AB=n.s	C (P)=4.07	AC=5.76	BC=7.06	ABC=9.98	

* C: control sample LS: liquid smoke TEO: thyme essential oil

3.7. Effect of LS or TEO on antioxidant activity of chicken and turkey meatballs:

The change in total antioxidant activity of chicken and turkey meatballs during frozen storage at $-18\pm 1^{\circ}\text{C}$ up to 180 days are shown in Table (7). A significant increase ($p\leq 0.05$) in total antioxidant activity (DPPH) was observed in treatments when compared to control sample at zero time. Also, the treatments caused a proportional increase in the antioxidant activity. Thus, the highest levels were observed in LS then TEO at zero time (78.87, 76.40 and 80.19, 74.15%, respectively) for chicken and turkey meatballs. These increases were attributed to the content of LS and TEO from polyphenols and other compounds as a source of antioxidant activity. The antioxidant properties of phenolic compounds have been extensively studied, and there is a direct

correlation between phenolic content and antioxidant activity. As a result, the high level of antioxidant activity in treated chicken and turkey meatballs with by LS or TEO was attributed to the high level of phenolic compounds. polyphenolic compounds and other biochemical compounds that mainly contribute to the antioxidant activity[67].

During frozen storage, antioxidant activity gradually decreased in all treatments. On the other hand, the treatments still had high levels of antioxidant activity at 180 days of frozen storage, such as samples treated by LS or TEO (45.12, 43.76, and 45.78, 43.43%, respectively) for chicken and turkey meatballs. The decrease in antioxidant activity may be attributed to the retard the oxidative process. This result agrees with [65], who reported that during storage antioxidant activity decreased. During frozen storage, the antioxidant activity was significantly reduced those found by[68]. The reduction in antioxidant activity might be attributable to effectively slowing down the oxidative process in beef products. The relationship between total phenolic content and total antioxidant activity may be seen. The principal microconstituents contributing to antioxidant action are phenolic chemicals thoes reported by [69].

Table (7): Changes in total antioxidant activity (DPPH %) of chicken and turkey meatballs treated with LS or TEO during frozen storage at $-18\pm1^{\circ}\text{C}$ up to 180days.

Var.	Tre.	Storage periods (days)							Mean
		0	30	60	90	120	150	180	
Chicken	C	27.47	26.81	23.20	18.61	18.56	12.42	8.16	19.32
	LS	78.87	69.05	61.31	56.69	56.59	51.43	45.12	59.87
	TEO	76.40	65.91	60.81	54.82	56.39	49.29	43.76	58.20
Mean		60.91	53.93	48.44	43.37	43.85	37.71	32.34	45.79
Turkey	C	30.48	31.62	22.45	17.38	17.89	9.69	7.79	19.61
	LS	80.19	73.53	62.17	56.35	61.30	49.25	45.78	61.22
	TEO	74.15	69.97	60.28	56.09	56.05	46.95	43.43	58.13
Mean		61.61	58.37	48.30	43.27	45.08	35.30	32.33	46.23
Main effects	C	28.97	29.21	22.82	17.99	18.22	11.05	7.97	19.46
	LS	79.53	71.29	61.74	56.52	58.94	50.34	45.45	60.54
	TEO	75.27	67.94	60.54	55.45	56.22	48.12	43.59	58.16
Mean		61.26	56.14	48.37	43.32	44.46	36.50	32.34	
F-test A(Var.)=*		L.S.D0.05	B = 0.51	AB=0.74	C (P)=0.79	AC=1.13	BC=1.38	ABC=**	

* C: control sample LS: liquid smoke TEO: thyme essential oil

Conclusion:

The rate of change in the physical and quality characteristics was reduced in chicken and turkey meatballs that were treated with 1% liquid smoke or 0.1% thyme essential oil during frozen storage. The most significant effect was observed on samples treated with liquid smoke, followed by thyme essential oil, compared to the control samples. During frozen storage, the total phenolic compounds and total antioxidant activity were significantly reduced. The reason for the decrease in phenolic compounds and total antioxidant activity may be attributed to possible oxidation of antioxidant components under favorable conditions during storage. As a result, liquid smoke can be used as an alternative to preservatives and can be used as a method of non-thermal processing in the food industry.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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