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The Efficacy of Ginger and Thyme Nanoemulsions on Enhancing Minced Beef Preservation, Microbial Inhibition and Quality Retention

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Abstract

ORGANIC oil nanoemulsions (NEs) have emerged as a promising approach to improve the preservation of meat products by utilizing their antimicrobial and antioxidant properties, and to overcome the health hazards of synthetic chemical food additives. Therefore, the current study was planned to evaluate the impact of ginger (GNE) and thyme (TNE) nano-emulsions (NEs) addition, by the concentrations of 10.0 and 20.0% for each and/or in combination, on minced beef shelf life and keeping quality during refrigeration storage (4±1°C). Examinations were repeated every three days until appearance of spoilage. Results revealed that different treatments showed potent enhancement in the keeping quality and acceptability of the treated samples. Organoleptic, microbiological, and chemical evaluations showed superiority of GNE (10.0%), especially in combination with TNE (10.0%). It is worth to be mentioned that all of the treated groups kept their sensory acceptability up to the 12th day of refrigerated storage. In contrast, control group showed spoilage signs after the 6th day of storage. In addition, a significant reduction in the microbial counts was recorded, based on the concentration of the used material, type of microorganism, and time of storage. Regarding the examined chemical criteria, the treated groups kept their values within the acceptable limits until the 15th day of storage, indicating chemical stability and longer shelf-life. After all, the used NEs showed a potent preservative effect on the treated minced beef samples represented by elongation of the keeping quality; so, it permits recommendation for its use safely in minced beef preservation.

Keywords: Ginger, Thyme, Meat Quality, Nanotechnology, Shelf-life.

Introduction

Beef is an important nutritional resource and is a key component of many diets globally. Its rich nutrient profile and high-quality protein content make it a valuable option for diverse populations [1].

The application of herbal oil-based nano-emulsions in meat products has garnered attention due to their potential to enhance freshness and extend shelf life [2]. Nano-emulsions can encapsulate bioactive compounds from essential oils, allowing for improved delivery and efficacy [3].

The incorporation of herbal essential oil-based nano-emulsions have been shown to positively affect the sensory attributes of meat. Specifically, flavor improvement, color maintenance and overall visual appeal of meat; besides that, nano-emulsions can improve the water-holding capacity (WHC) of meat, thereby preserving its juiciness and texture during storage [4]. Besides that, the antimicrobial effects of essential oil-based nano-emulsions are significant in extending the shelf life of meat products through microbial inhibition and shelf life extension [5].

Ginger and thyme nano-emulsions are increasingly recognized for their potential in meat preservation, particularly due to their antimicrobial and antioxidant properties. These natural preservatives can enhance sensory quality

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and microbial safety of meat products [6]. Moreover, the impact of herbal oil-based nano-emulsions on the pH and color stability of meat is also noteworthy.

Ginger and thyme nano-emulsions were reported to help lipid oxidation and protein decomposition inhibition, which have been evidenced by lower levels of thio-barbituric acid (TBA) and total volatile nitrogen (TVN) values in treated meats compared to controls revealing higher potential of oxidative stability [5]. The reduction in TBA and TVN levels have been strongly correlated with improved freshness and quality of meat and meat products [7].

The use of nano-emulsions in meat preservation aligns with Sustainable Development Goals (SDGs) in relation to zero hunger, good health, and responsible consumption by addressing food security, health, and sustainability challenges. By extending the shelf life of meat products through antimicrobial and antioxidant properties, nano-emulsions reduce food waste, as nearly one-third of global food production is lost annually. This preservation enhances food availability, supporting SDGs by ensuring safer, longer-lasting protein sources for populations facing hunger. In addition, nano-emulsions derived from natural essential oils (e.g., thyme, ginger) minimize reliance on synthetic preservatives, reducing exposure to harmful chemicals while inhibiting different foodborne pathogens, thereby improving food safety and public health outcomes [8].

Therefore, the present study was conducted to evaluate the application of ginger and/or thyme oil-nano-emulsion on the overall sensory, microbial, and chemical quality of minced beef during refrigeration storage.

Material and Methods

Statement and Ethical approval

The research was performed after approval of the ethical committee of the Faculty of Veterinary Medicine, Benha University (BUFVTM 20-08-24).

Collection and preparation of samples

Two kilograms and three hundred and ten grams of fresh minced beef were purchased from a high-quality butcher in Benha city. Minced beef samples were divided into seven equal groups, followed by addition of nano-emulsions by direct addition and assembled as meat balls, and left for 30 minutes, after which the experiment zero time was recorded.

Preparation and characterization of essential oil based nanoemulsion

Ginger and thyme nano-emulsions were prepared in the unit of nanomaterials, Animal Health Research Institute (AHRI), with a concentration of 20%, which was prepared according to Pouton and Porter [9] by using tween-80 as surfactant. The prepared nano-emulsions were kept in dark bottle in refrigerator (4^{o}c) until the usage. Nano-droplet size was determined in animal health research institute.

Experimental grouping according to El-Shaikh et al. [7]

2310 grams of minced beef were equally divided into seven groups as follow:

G1: Control untreated minced beef

G2: 330 g minced beef + 10% ginger nano-emulsion (GNE).

G3: 330 g minced beef + 10% thyme nano-emulsion (TNE).

G4: 330 g minced beef + 10% combined ginger-thyme nano-emulsions.

G5: 330 g minced beef + 20% ginger nano-emulsion.

G6: 330 g minced beef + 20% thyme nano-emulsion.

G7: 330 g minced beef + 20% combined ginger-thyme nano-emulsions.

Each group was sub-grouped into two subgroups for microbiological (150 g) and chemical examinations (180 g).

Sensory examinations of minced beef samples

The sensory quality (color, odor, texture, and taste) of the samples was graded on a scale of 1 to 5, with 5 denoting excellent and 1 denoting the worst sensory characteristics, following Mörlein [10]. Evaluation was performed by ten well-trained panels (Food Hygiene Specialists) working at Animal Health Research Institute – Benha Lab; where, the scoring variations was recorded based on the panel's preferences and consumability.

Microbiological examinations

After preparation of serial dilutions according to ISO 6887-2 [11], Control and treated beef mince were examined for their total aerobic plate counts (APC), Enterobacteriaceae count, Staphylococcus count, and total fungal count according to ISO 4833-

1 [12], ISO 21528-2 [13], ISO 6888-1 [14], and ISO 21527-1 [15], respectively.

Chemical analyses

Minced beef were examined for their pH estimation, total volatile nitrogen (TVN), and thiobarbituric acid (TBA) values according to the Egyptian standard methodology; EOS 63-11 [16] using a calibrated pH meter (Adwa, AD1200) dipped in 10g of mixed minced beef, EOS: 63-9 [17] was used for TVN, in which ten grams of minced beef were mixed with MgO and dist. water followed by boiling and shaking, where evaporation was condensed; after which, TVN was calculated and recorded; in addition, EOS 63-10 [18] was used for TBA determination through mixing of ten grams of well-mixed samples with dist. water + hydroaluric acid 4N, followed by heating the mixture to obtain about 50 ml of the distillate; from which, 5 ml was mixed with thiobarbituric acid reagent and was kept in a boiling water bath for 35 minutes. Optical density of the overall end products was measured at wavelength 538.

Examinations were repeated every three days of refrigeration in triplicate manner.

Statistical Analysis

The obtained data, of three trials in the same conditions, was statistically treated by two-way ANOVA using SPSS software for Windows (Version 16) for more than three comparable groups in relation to the time of storage and the type of treatment as two factors of the experiment. Duncan's post hoc analysis was used to analyze the data, with a *P* value of 0.05 being regarded statistically significant.

Results

Regarding to the sensory profile of the examined groups, different treatments showed longer visual acceptability in relation to control untreated group. Table (1) revealed significant elongation in the sensory acceptability scores of the different treated groups in relation to the control untreated group, which was apparently spoiled after the 6^{th} day of storage; where G2 showed the highest acceptability score (2.7 at the 12^{th} day of storage); while G7 showed the lowest acceptability score (2.0) at the same time; which was attributed to the strong flavor of higher concentrations of the used NEs.

Tables (2-5) revealed potent antimicrobial effects of the applied treatments appeared as significant ($P \leq 0.05$) reductions in the microbial counts. It is worth noted that the microbial count reductions were directly correlated to the concentration of the used NEs; where higher concentration revealed higher reduction %; therefore, G7 showed the highest reduction % in relation to the other treated groups.

Regarding the chemical indices of keeping quality, Tables (6-8) revealed significant enhancement in the chemical stability with general enhancement in the keeping quality of the treated minced meat in comparison with the control group. All of the treated groups had kept their pH, TVN and TBA values within the permissible limits up to the 15^{th} day of storage indicating longer keeping quality and shelf-life in relation to the control group that exceeded the permissible limits after the 6^{th} day of storage.

Discussion

For generations, meat products have been an essential component of diets all throughout the world and are vital to human nutrition. In addition, the use of herbal oils as meat preservatives has become increasingly popular in recent years because of their potential antioxidant and antimicrobial qualities [20]. These oils contain strong bioactive compounds that can increase the safety and shelf life of meat products by preventing the growth of spoilage microorganisms [20, 21]. However, some essential oils, like those from citrus fruits, have strong tastes and are volatile, which can limit their practical usage in food applications [22].

In order to overcome these challenges, scientists have resorted to nano-emulsion technology, which entails the nanoscale dispersion of essential oils in a carrier medium. This improves the oils' stability, bioavailability, and permits a more regulated release of the active ingredients, increasing their efficacy as preservatives while reducing any negative effects on the meat's sensory qualities [23].

It is also interesting that essential oil nanoemulsions can prolong the shelf life of meat products. These nanoemulsions have been demonstrated in studies to dramatically lower the microbial load and lipid oxidation in beef while it is being stored [3]. For instance, compared to untreated controls, ginger and thyme essential oil nanoemulsions have been shown to sustain reduced levels of malonaldehyde, a marker for lipid oxidation. By stopping the breakdown of vital fatty acids, this decrease in oxidative rancidity not only

maintains the meat's quality but also increases its nutritional wholesome [24].

According to the results of this study, the treated minced beef's shelf life was significantly ($P \leq 0.05$) extended, and its microbiological quality and chemical indices improved, particularly at higher concentrations. This could be because of possible antimicrobial and antioxidant effects that help maintain the acceptability criteria within a range for a longer period of time [25].

The current recorded results came in line with those of Noori *et al.* [5], El-Shaikh *et al.* [7], Bakheet *et al.* [24], and Bhat and Bhat [26] who recorded significant reductions in the treated foodborne bacterial counts post-treatment with ginger and/or thyme nano-emulsions with wide range of concentrations without adverse affecting the sensory characters of the treated meat samples.

The evaluated NEs have shown strong antioxidant and antibacterial properties. Its nanoscale size, which improves the stability and bioavailability of its active ingredients, may be the reason for its efficacy. Over time, this prolonged release increases the antibacterial activity by efficiently rupturing microbial cell membranes and causing cell lysis [27].

The mechanism of action entails the penetration of active ingredients such as thymol, carvacrol, and gingerol into the phospholipid bilayer of bacterial membranes, which increases permeability and causes cellular contents to leak out, finally leading to microbial death [28].

Additionally, the overall sensory acceptability of the treated samples was extended compared to the control samples, and the pH, TVN, and TBA increased over the course of storage. These findings were consistent with those of Bakheet *et al.* [24] and Höferl *et al.* [29], who attributed their findings to the observed antioxidant and antimicrobial properties of the used essential oils that were optimized in nanoemulsion form.

The ability of ginger and thyme essential oil nano-emulsions to gradually lower the pH of minced meat has been observed; this is advantageous because a lower pH can prevent the microbial multiplication. These oils have also been demonstrated to lower TVN levels, which are a sign of spoiling and protein deterioration. GNE aids in preserving the meat's freshness and quality while it is being stored by inhibiting the production of TVN. Additionally, its antioxidant qualities help to lower TBA levels, which show less rancidity and lipid oxidation in the meat [30].

Thyme and ginger essential oils proved to exert antioxidant and antimicrobial effects through distinct bioactive compounds and mechanisms. Thyme oil, rich in thymol, enhances cellular antioxidant defenses by increasing superoxide dismutase (SOD) and catalase (CAT) activity, scavenging free radicals like hydroxyl groups, and reducing lipid peroxidation [31]. Its antimicrobial action arises from disrupting bacterial cell membranes, inhibiting adhesion, and synergizing with antimicrobial agents to combat pathogens in meat products [32]. On the other hand, ginger oil, dominated by zingiberene and α-curcumene, targets bacterial energy metabolism and membrane integrity, causing protein degradation and nucleic acid leakage. Besides that, antioxidant activity of ginger oil is mediated via Nrf2 pathway activation, boosting SOD, CAT, and glutathione (GSH) levels, while compounds like 6-gingerol suppress pro-inflammatory cytokines (e.g., TNF-α, IL-6) and inhibit NF-κB signaling, reducing oxidative stress [33].

Referring to the recorded results, direct addition of GNE and TNE revealed significant enhancement in the sensory quality of the treated minced meat, with improved microbiological and chemical quality along the storage period that allows recommendation of its application in minced meat preservation during refrigeration storage. however, future studies on their safety on the consumer's health, residual potentiality, and evaluating its effect on major foodborne pathogens is strongly recommended.

Conclusion

All things considered, the use of essential oil nanoemulsions of ginger and/or thyme has demonstrated encouraging outcomes in enhancing the preservation of minced meat. Their capacity to decrease pH levels, lower TVN values, and inhibit lipid oxidation as indicated by TBA values, along with notable microbial reductions, highlights their potential as natural preservatives in the food industry. Further research into refining these formulations may result in wider uses in meat preservation, encouraging safer and more sustainable food practices.

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Declaration of Conflict of Interest

TABLE 1. Overall sensory profile of untreated and treated minced beef samples with different nanoemulsions.

Groups	G1	G2	G3	G4	G5	G6	G7
Zero day	4.7 ± 0.1^{Aa} (VG)	4.7 ± 0.1^{Aa} (VG)	4.7 ± 0.1^{Aa} (VG)	4.7 ± 0.1^{Aa} (VG)	4.6 ± 0.1^{Aa} (VG)	4.6 ± 0.1^{Aa} (VG)	4.6 ± 0.1^{Aa} (VG)
3rd day	3.4 ± 0.3^{Bb} (G)	4.3 ± 0.2^{Ba} (VG)	4.1 ± 0.1^{Ba} (VG)	4.2 ± 0.2^{Ba} (VG)	4.3 ± 0.2^{Ba} (VG)	4.3 ± 0.3^{Ba} (VG)	4.2 ± 0.2^{Ba} (VG)
6th day	1.6 ± 0.2^{Cb} (U)	3.8 ± 0.2^{Ca} (G)	3.8 ± 0.2^{Ca} (G)	3.8 ± 0.3^{Ca} (G)	3.7 ± 0.1^{Ca} (G)	3.7 ± 0.3^{Ca} (G)	3.8 ± 0.2^{Ca} (G)
9th day	<1 (S)	3.6 ± 0.2^{Da} (G)	3.3 ± 0.1^{Db} (G)	3.5 ± 0.2^{Da} (G)	3.3 ± 0.2^{Db} (G)	3.2 ± 0.2^{Db} (G)	2.9 ± 0.1^{Dc} (A)
12th day	<1 (S)	2.7 ± 0.2^{Ea} (A)	2.5 ± 0.1^{Eb} (A)	2.6 ± 0.3^{Ea} (A)	2.4 ± 0.1^{Eb} (A)	2.3 ± 0.1^{Ebc} (A)	2.0 ± 0.1^{Ec} (U)
15th day	<1 (S)	1.6 ± 0.1^{Fa} (U)	1.4 ± 0.2^{Fb} (U)	1.4 ± 0.1^{Fb} (U)	1.3 ± 0.1^{Fc} (U)	1.3 ± 0.1^{Fc} (U)	1.2 ± 0.1^{Fcd} (U)

Means within the same row (abcd) followed by different superscript letters are significantly different ($P \leq 0.05$).
Means within the same column (ABC) followed by different superscript letters are significantly different ($P \leq 0.05$).
4.0-5.0 very good (VG); 3.1-3.9 good (G); 2.1-3.0 Acceptable (A); 1.1-2.0 Unacceptable (U); 0.0-1.0 spoiled (S)
G1: Control untreated minced beef, G2: Treated minced beef with ginger NE (GNE 10%), G3: Treated minced beef with thyme NE (TNE 10%), G4: Treated minced beef with combined ginger + thyme NEs (10%), G5: Treated minced beef with ginger NE (20%), G6: Treated minced beef with thyme NE (20%), and G7: Treated minced beef with combined ginger + thyme NEs (20%).

TABLE 2. Average values and reduction % of Aerobic plate count (APC) (log_{10} CFU/g) in minced beef groups at cold storage ($4\pm1^{O}C$).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%	G6	R%	G7	R%
Zero day	5.1 ± 0.4^{Da}	5.1 ± 0.4^{Aa}	-	5.1 ± 0.4^{Aa}	-	5.1 ± 0.4^{Aa}	-	5.1 ± 0.4^{Aa}	-	5.1 ± 0.4^{Aa}	-	5.1 ± 0.4^{Aa}	-
3rd day	5.5 ± 0.3^{Ca}	4.8 ± 0.5^{Bb}	5.9	4.9 ± 0.4^{Bb}	3.9	4.5 ± 0.5^{Bd}	11.8	4.7 ± 0.3^{Bc}	7.8	4.8 ± 0.5^{Bc}	5.9	4.3 ± 0.5^{Be}	15.7
6th day	6.7 ± 0.6^{Ba}	4.5 ± 0.4^{Cb}	11.8	4.6 ± 0.4^{Cb}	9.8	4.3 ± 0.4^{Cc}	15.7	4.2 ± 0.4^{Cbc}	17.6	4.4 ± 0.6^{Cc}	13.7	4.0 ± 0.5^{Cd}	21.6
9th day	7.2 ± 0.6^{Aa}	4.2 ± 0.3^{Db}	17.6	4.3 ± 0.3^{Db}	15.7	4.0 ± 0.3^{Dc}	21.6	4.1 ± 0.4^{Dc}	19.6	4.0 ± 0.3^{Dc}	21.6	3.8 ± 0.3^{Dd}	25.5
12th day	S.	4.0 ± 0.3^{Eb}	21.6	4.4 ± 0.4^{Da}	13.7	3.9 ± 0.3^{Eb}	23.5	3.7 ± 0.5^{Ec}	27.5	3.8 ± 0.4^{Ec}	25.5	3.5 ± 0.3^{Ed}	31.4
15th day	S.	4.5 ± 0.5^{Cb}	11.8	4.7 ± 0.5^{Ca}	7.8	4.2 ± 0.2^{Cc}	17.6	4.0 ± 0.6^{Dd}	21.6	4.1 ± 0.3^{Dd}	19.6	3.9 ± 0.3^{De}	23.5

Means within the same row (abcd) followed by different superscript letters are significantly different ($P \leq 0.05$).
Means within the same column (ABC) followed by different superscript letters are significantly different ($P \leq 0.05$).

TABLE 3. Average values and reduction % of *Enterobacteriaceae* count (EC) (log_{10} CFU/g) in minced beef groups at cold storage ($4\pm1^{O}C$).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%	G6	R%	G7	R%
Zero day	2.6 ± 0.1^{Ca}	2.6 ± 0.1^{Aa}	--	2.6 ± 0.1^{Aa}	--	2.6 ± 0.1^{Aa}	--	2.6 ± 0.1^{Aa}	--	2.6 ± 0.1^{Aa}	--	2.6 ± 0.1^{Aa}	--
3nd day	3.1 ± 0.2^{Ba}	2.5 ± 0.3^{Ab}	3.8	2.4 ± 0.2^{Bb}	7.7	2.3 ± 0.1^{Bbc}	11.5	2.3 ± 0.1^{Bbc}	11.5	2.2 ± 0.1^{Bc}	15.4	2.1 ± 0.2^{Bc}	19.2
6th day	3.7 ± 0.3^{Aa}	2.2 ± 0.2^{Bb}	15.4	2.1 ± 0.1^{Cb}	19.2	2.0 ± 0.3^{Cbc}	23.1	2.1 ± 0.2^{Cbc}	19.2	2.0 ± 0.1^{Cc}	23.1	1.7 ± 0.1^{Cd}	34.6
9th day	S.	2.0 ± 0.2^{Ca}	23.1	1.8 ± 0.01^{Eb}	30.8	1.6 ± 0.2^{Dc}	38.5	1.7 ± 0.2^{Db}	34.6	1.6 ± 0.1^{Dc}	38.5	1.5 ± 0.3^{Dd}	42.3
12th day	S.	1.7 ± 0.1^{Eb}	34.6	2.0 ± 0.01^{Da}	23.1	1.5 ± 0.1^{Dc}	42.3	1.5 ± 0.1^{Dc}	42.3	1.4 ± 0.2^{Dc}	46.2	1.3 ± 0.2^{Ecd}	50.0
15th day	S.	1.9 ± 0.2^{Db}	26.9	2.1 ± 0.01^{Ca}	19.2	1.7 ± 0.1^{Dc}	34.6	1.6 ± 0.1^{Dc}	38.5	1.5 ± 0.2^{Dc}	42.3	1.2 ± 0.2^{Ed}	53.8

Means within the same row (abcd) followed by different superscript letters are significantly different ($P \leq 0.05$).
Means within the same column (ABC) followed by different superscript letters are significantly different ($P \leq 0.05$).

TABLE 4: Average values and reduction % of *Staphylococci* count (log_{10} CFU/g) in minced beef groups at cold storage ($4\pm1^{O}C$).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%	G6	R%	G7	R%
Zero day	3.1 ± 0.1^{Ca}	3.1 ± 0.1^{Aa}	--	3.1 ± 0.1^{Aa}	--	3.1 ± 0.1^{Aa}	--	3.1 ± 0.1^{Aa}	--	3.1 ± 0.1^{Aa}	--	3.1 ± 0.1^{Aa}	--
3nd day	3.5 ± 0.2^{Ba}	2.9 ± 0.2^{Bb}	6.4	2.8 ± 0.3^{Bb}	9.7	2.7 ± 0.1^{Bbc}	12.9	2.6 ± 0.1^{Bbc}	16.1	2.8 ± 0.1^{Bb}	9.7	2.4 ± 0.2^{Bc}	22.6
6th day	4.2 ± 0.3^{Aa}	2.8 ± 0.1^{Bb}	9.6	2.6 ± 0.2^{Cb}	16.1	2.4 ± 0.3^{Cc}	22.6	2.3 ± 0.2^{Cc}	25.8	2.7 ± 0.1^{Bb}	12.9	2.0 ± 0.1^{Cd}	35.5
9th day	S.	2.6 ± 0.01^{Cb}	16.1	2.3 ± 0.2^{Dc}	25.8	2.1 ± 0.2^{Dc}	32.3	2.0 ± 0.2^{Dc}	35.5	2.3 ± 0.1^{Cc}	25.8	1.7 ± 0.3^{Dd}	45.2
12th day	S.	2.5 ± 0.01^{Ca}	19.4	2.2 ± 0.1^{Db}	29.0	2.0 ± 0.1^{Dc}	35.5	1.8 ± 0.1^{Ed}	41.9	2.0 ± 0.2^{Dc}	35.5	1.3 ± 0.2^{Ee}	58.1
15th day	S.	2.3 ± 0.01^{Da}	25.8	2.0 ± 0.2^{Eb}	35.5	1.8 ± 0.1^{Ec}	41.9	1.7 ± 0.1^{Ec}	45.2	1.9 ± 0.2^{Dc}	38.7	1.5 ± 0.2^{Fd}	51.6

Means within the same row (abcd) followed by different superscript letters are significantly different ($P \leq 0.05$).
Means within the same column (ABC) followed by different superscript letters are significantly different ($P \leq 0.05$).

TABLE 5. Average values and reduction % of total fungal count (log_{10} CFU/g) in minced beef groups at cold storage (4±1^{O}C).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%	G6	R%	G7	R%
Zero day	1.3±0.1^{Ca}	1.3±0.1^{Ba}	--	1.3±0.1^{Ca}	--	1.3±0.1^{Aa}	--	1.3±0.1^{Aa}	--	1.3±0.1^{Ba}	--	1.3±0.1^{Aa}	--
3nd day	1.6±0.2^{Ba}	1.2±0.3^{Cb}	7.7	1.2±0.2^{Db}	7.7	1.1±0.1^{Bb}	15.4	1.0±0.1^{Bbc}	23.1	1.1±0.1^{Cb}	15.4	<1	>99.9
6th day	1.8±0.3^{Aa}	1.0±0.2^{Dc}	23.1	1.1±0.1^{Db}	15.4	1.0±0.3^{Cc}	23.1	<1	>99.9	1.0±0.1^{Dc}	23.1	<1	>99.9
9th day	S.	1.1±0.2^{Db}	15.4	1.3±0.01^{Ca}	--	<1	>99.9	1.0±0.2^{Bc}	23.1	<1	>99.9	<1	>99.9
12th day	S.	1.4±0.1^{Bb}	--	1.5±0.01^{Ba}	--	<1	>99.9	1.2±0.2^{Ac}	7.7	1.1±0.2^{Cd}	15.4	1.0±0.1^{Be}	23.1
15th day	S.	1.6±0.2^{Ab}	--	1.7±0.01^{Aa}	--	1.2±0.1^{Bd}	7.7	1.3±0.1^{Ac}	--	1.4±0.2^{Ac}	--	1.1±0.2^{Be}	15.4

Means within the same row (abcd) followed by different superscript letters are significantly different ($P \leq 0.05$).
Means within the same column (ABC) followed by different superscript letters are significantly different ($P \leq 0.05$).

TABLE 6. Average values of pH in the examined minced beef groups at cold storage (4±1^{O}C).

Groups	G1	G2	G3	G4	G5	G6	G7
Zero day	5.4±0.1^{Ca}	5.4±0.1^{Fa}	5.4±0.1^{Fa}	5.4±0.1^{Fa}	5.4±0.1^{Fa}	5.4±0.1^{a}	5.4±0.1^{a}
3nd day	5.7±0.2^{Ba}	5.6±0.3^{Ea}	5.7±0.2^{Ea}	5.3±0.1^{Eab}	5.4±0.3^{Eb}	5.6±0.1^{a}	5.5±0.3^{ab}
6th day	6.2±0.3^{Aa}	5.8±0.2^{Dbc}	5.9±0.1^{Db}	5.6±0.3^{Dbc}	5.6±0.3^{Dc}	5.7±0.1^{Dbc}	5.6±0.3^{c}
9th day	S.	6.0±0.2^{Cbc}	6.1±0.1^{Cb}	5.8±0.3^{Cc}	5.7±0.2^{Cc}	5.9±0.3^{Cc}	5.7±0.3^{c}
12th day	S.	6.2±0.1^{Ba}	6.3±0.1^{Ba}	5.9±0.1^{Bc}	6.0±0.2^{Bbc}	6.1±0.2^{Bb}	5.9±0.1^{c}
15th day	S.	6.5±0.2^{Aa}	6.6±0.1^{Aa}	6.4±0.1^{Ab}	6.6±0.1^{Aab}	6.5±0.2^{Aab}	6.1±0.2^{b}

Means within a row followed by different superscript letters are highly significantly different ($P \leq 0.05$).

TABLE 7. Average values of total volatile nitrogen (mg/100gm sample) in the minced beef groups during refrigerated storage (4±1°C)

Groups	G1	G2	G3	G4	G5	G6	G7
Zero day	14.2±0.1^{a}	14.2±0.1^{a}	14.2±0.1^{a}	14.2±0.1^{a}	14.2±0.1^{a}	14.2±0.1^{a}	14.2±0.1^{a}
3nd day	16.9±0.2^{a}	15.1±0.3^{b}	15.3±0.2^{b}	14.8±0.1^{c}	14.7±0.1^{c}	14.9±0.1^{c}	14.5±0.3^{d}
6th day	19.5±0.3^{a}	15.8±0.2^{c}	16.2±0.1^{b}	15.4±0.3^{d}	15.0±0.3^{f}	15.5±0.1^{d}	15.2±0.3^{e}
9th day	S.	16.4±0.2^{c}	17.0±0.1^{b}	16.0±0.3^{cd}	16.2±0.2^{c}	15.9±0.3^{d}	16.1±0.3^{cd}
12th day	S.	18.3±0.1^{b}	18.6±0.1^{a}	17.5±0.1^{cd}	17.1±0.2^{d}	17.7±0.2^{c}	16.9±0.1^{e}
15th day	S.	19.2±0.2^{ab}	19.5±0.1^{a}	18.9±0.1^{b}	18.5±0.1^{c}	19.1±0.2^{ab}	18.2±0.2^{d}

The values represent Mean ± SE of three trials.
Means within the same row (abcd) followed by different superscript letters are highly significantly different ($P \leq 0.05$).
Zero time: 30 min after inoculation.
MPL according to EOS No. 1694:2005**[19]** = ≤ 20 mg/100gm sample

TABLE 8. Average values of Thiobarbituric acid (mg malonaldehyde/kg) in the minced beef groups during refrigerated storage (4±1°C)

Groups	G1	G2	G3	G4	G5	G6	G7
Zero day	0.41±0.01^{a}	0.41±0.01^{a}	0.41±0.01^{a}	0.41±0.01^{a}	0.41±0.01^{a}	0.41±0.01^{a}	0.41±0.01^{a}
3nd day	0.66±0.01^{a}	0.50±0.01^{b}	0.52±0.01^{ab}	0.48±0.01^{b}	0.53±0.01^{ab}	0.55±0.01^{b}	0.49±0.01^{b}
6th day	0.87±0.01^{a}	0.57±0.01^{bc}	0.60±0.01^{b}	0.52±0.01^{c}	0.59±0.01^{bc}	0.61±0.01^{b}	0.53±0.01^{c}
9th day	S.	0.68±0.01^{c}	0.71±0.01^{bc}	0.61±0.01^{a}	0.67±0.01^{c}	0.74±0.01^{b}	0.63±0.01^{d}
12th day	S.	0.75±0.01^{b}	0.77±0.01^{ab}	0.70±0.01^{cd}	0.72±0.01^{c}	0.80±0.01^{a}	0.75±0.01^{b}
15th day	S.	0.82±0.01^{b}	0.84±0.01^{ab}	0.79±0.01^{b}	0.83±0.01^{ab}	0.86±0.01^{a}	0.81±0.01^{b}

The values represent Mean ± SE of three trials.
Means within the same row (abcd) followed by different superscript letters are highly significantly different ($P \leq 0.05$).
Zero time: 30 min after inoculation.
MPL according to EOS No. 1694:2005**[19]** = ≤ 0.9 mg malonaldehyde/kg sample.

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فعالية مستحلبات النانو من زيوت الزنجبيل والزعتر كمادة حافظة في تحسين جودة اللحم المفروم، وتثبيط الميكروبات

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ملخص

برزت مستحلبات النانو من الزيوت العضوية (NEs) كتقنية واعدة لتحسين جودة اللحوم وزيادة فترة صلاحيتها من خلال الاستفادة من خصائصها المضادة للميكروبات ومضادات الأكسدة. لذلك، هدفت الدراسة الحالية لتقييم تأثير إضافة مستحلبات النانو من الزنجبيل والزعتر، بتركيزات 10.0% و20.0% لكل منهما، على مدة صلاحية اللحم المفروم وجودة حفظه أثناء التخزين المبرد. أظهرت النتائج أن مختلف المعالجات أظهرت تحسنًا ملحوظًا في جودة الحفظ والقبول الحسي للعينات المعالجة. كما أظهرت التقييمات الحسية والميكروبيولوجية والكيميائية تفوقًا للمستحلبات المستخدمة، وخاصةً عند دمجها معاً بتركيز 10.0% لكل منها. تجدر الإشارة إلى أن جميع المجموعات المعالجة حافظت على قبولها الحسي حتى اليوم الثاني عشر من التخزين المبرد، بينما أظهرت المجموعة الضابطة علامات الفساد بعد اليوم السادس من التخزين. بالإضافة إلى ذلك، سُجِّل انخفاض ملحوظ في أعداد الميكروبات، بناءً على تركيز المادة المستخدمة ونوع الميكروب ومدة التخزين. وفيما يتعلق بالمعايير الكيميائية المدروسة، حافظت المجموعات المعالجة على قيم الاس الهيدروجيني والمركبات النيتروجينية الطيارة وحمض الثيوباربتيوريك ضمن الحدود المقبولة حتى اليوم الخامس عشر من التخزين، مما يدل على ثباتها الكيميائي وطول مدة صلاحيتها. وفي النهاية، أظهرت المواد النانوية المستخدمة تأثيرًا حافظًا قويًا على عينات اللحم المفروم المعالجة، متمثلًا في إطالة مدة صلاحيتها؛ مما يسمح بالتوصية باستخدامها بأمان في حفظ اللحم المفروم.

الكلمات الدالة: جودة اللحوم، تقنية النانو، مدة الصلاحية