



## The effect of volatile oil extracted from rosemary leaves on stored chicken meatballs

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## Abstract

The volatile oil in rosemary is extracted and their effect as natural antioxidants on stored chicken meatballs is investigated. The results showed that the fresh chicken breast meat contain of 69.63, 25.20, 0.58, 1.11, 3.48% for each of moisture, protein and crude fat, total ash and carbohydrates respectively. The results indicate that the meat used was in good condition and within the acceptable range. The feder number (2.42) indicated the quality of the meat. The protein-water coefficient (PWC) and protein-water-fat coefficient (PWFC) were 0.361 and 0.358, respectively. The results obtained indicated that there was a significant difference in the effect of the rosemary leaves extract on peroxide value and on free fatty acids. a decrease in peroxide values was observed with increasing rates of addition of volatile oil, and the addition of 0.2% had the advantage in affecting the peroxide number of fresh chicken meat. The results also showed an increase in the values of oxidative stability measures with increasing storage period.

**Key words:** volatile oils; chicken breast meat; rosemary.

## Introduction

The process of oxidation is one of the most important causes that cause economic losses in poultry meat and its products (Sohaib *et al.*, 2017). It is known that oxidation is a major cause of the formation of free radicals, and the occurrence of this damage has a direct impact on protein and genetic material (DNA), which is one of the most prominent major problems that cause damage (Chaudhary *et al.*, 2023). In types of meat, the changes caused are due to the development of undesirable flavors and the loss of the desired color of meat, and the oxidation of fats in meat leads to the emergence of unpleasant, unacceptable odors that make consumers repulsed by them (Huang & Ahn, 2019). The oxidation process occurs in fats when they interact directly with oxygen. Short-chain fatty acids, ketones, aldehydes, and alcohols, the products of the auto-oxidation process, are primarily responsible for the rancid flavor. Antioxidants prevent or inhibit the oxidation process, therefore the unwanted flavor can be controlled by inhibiting oxidation of fats in stored meat using antioxidants in order to maintain meat quality (Domínguez *et al.*, 2019). Given the tendency of the majority of consumers to focus on the health aspects of food products, the demand for the use and interest in natural additives has increased instead of chemical additives because they are natural and safe for health, and are considered one of the components of human food and are acceptable to consumers (Mesías *et al.*, 2021). Many



synthetic antioxidants, such as TBHQ and BHA, have been used in many food industries, but there are doubts about their safety. Recent studies have proven that synthetic antioxidants have a direct effect on contemporary diseases, the most important of which is cancer, which has led to them being banned from some countries such as Japan and Canada (Mika et al., 2023).

At the beginning of the seventies, a gradual return to the use of medicinal herbs began. Aromatic plants, including spices and their essential oils, were used in many food industries. Because it contains a distinctive flavor and taste, in addition to its antioxidant properties, it was found that adding some essential oils to minced and stored beef improved its physical, chemical and sensory properties (De Oliveira *et al.*, 2019). Aromatic plants, such as rosemary (*Rosmarinus officinalis* L.), are natural antioxidants because they contain many effective compounds with antioxidant properties. These plants contain effective phenolic compounds that contain multiple hydroxyl groups that increase their properties as antioxidants in foods, which increases their effectiveness in inhibiting fat oxidation and maintaining food stability, by delaying or hindering the occurrence of oxidative rancidity and prolonging its shelf life (Hcini *et al.*, 2013). Meat is exposed to many changes, whether physical, chemical, or microbial, which make it susceptible to oxidation and spoilage reactions, which affects the quality of the meat. Therefore, it is necessary to reduce spoilage in meat by preserving it by cooling or freezing (Addis, 2015). Processed meat products are defined as products in which the properties of fresh meat are transformed using one or more manufacturing methods, such as chopping or mashing, adding flavorings, changing color, or heat treatment, whether low or high (Pathiraje *et al.*, 2023). There has been recent interest in natural antioxidants that have been extracted from herbs such as rosemary and spices in general, including essential plant oils, whether in their raw form or extracts, or by isolating and purifying some of the active compounds (Lourenço *et al.*, 2019).

Studies have recently tended to benefit from plant wealth, especially wild ones, as there are many naturally growing aromatic plants in Libya, which are considered an important wealth, and which require attention to them by conducting many research and studies on them in various fields, especially in the field of food science. These plants have not received sufficient studies in Libya, especially in terms of their use in preserving and improving the sensory qualities of processed meat and extending their shelf life.

Therefore, this study aimed to estimate the phenolic compounds in rosemary and their effect as natural antioxidants extracted from rosemary leaves on stored chicken meatballs.

## Materials and Methods

### Materials

Chicken meat was obtained from the local market in Brack city. It is chicken that has been cleaned and unwanted parts removed. Only breast meat was used, as the bones were separated from it and kept in the freezer at a temperature of  $-18^{\circ}\text{C}$ . Until it is used. The fat was also obtained from the local market. It is sheep fat and was frozen, cut, and minced with an electric grinder immediately before the mixing process. The rosemary leaves sample was collected from the village of Qira in the Wadi Al-Shati area. It was fresh and washed with running water to remove dust, soil and unwanted materials. It was dried in the air, then the sample was ground until it became a powder, and it was passed through a sieve with a diameter of 50 mesh. It was stored in polyethylene bags at a temperature of  $4^{\circ}\text{C}$  for use in various treatments.

### Methods

#### Extraction of volatile oils

The volatile oils were prepared from the leaves using the water distillation method according to Nurbaş and Yeliz (2005), where 100 grams of dried and ground leaves were weighed and 1000 ml of distilled water were added to it in a distillation device. It was heated with a direct flame and heating continued until the water boiled. The steam carries the essential oil, then the steam and oil condense in the condenser, where the oil floats above the water in the oil trap, and the oil is separated from the surface. Then the obtained volatile oil was transferred to a small opaque flask, then it was weighed, its percentage was calculated, and it was kept in the refrigerator until use.

#### Preparing chicken meat

Chicken breasts were used after removing the skin from the meat and cutting it into small pieces. The meat was then chopped in an electric grinder according to the type of product to be manufactured, with an amount of fat added from time to time in the form of small pieces depending on the amount of fat required to be added to the product. The meat and fat were then minced together again with a meat grinder.

#### Preparing the chicken meatball product

The chicken meatballs product was prepared according to the traditional method, where the minced meat and fat were mixed by adding 15% fat, and the oil extract was added to it and mixed well to ensure that the ingredients were mixed in all parts of the mixture, then it was chopped using an electric grinder, and formed into balls weighing approximately 30 grams. It was packed in polyethylene bags. The manufactured products were then placed in the freezer at a temperature of  $(-18^{\circ}\text{C})$  for 90 days.



### **Chemical composition**

Moisture content, crude protein, crude oil, total ash and crude fibre were determined as stated in AOAC (2005).

Total carbohydrates were calculated by subtracting the total crude protein, crude fat, ash, and crude fiber from the dry weight of the sample

### **Estimation of mineral elements**

After burning of the samples, the resulting ash was dissolved in 10 ml of 6N hydrochloric acid (HCl), transferred quantitatively and the volume was completed to 25 ml in a standard flask after filtering on ash-free filter paper, and the resulting solution was used to estimate the various mineral elements after making dilutions. Iron, calcium, magnesium, manganese, zinc and copper were determined in the previously prepared ash solution using an atomic absorption spectrophotometer. Both sodium and potassium were determined by Flame Photometer, as for phosphorus, it was determined colorimetrically by the ammonium molybdate method, using a spectrophotometer at a wavelength of 650 nm in the presence of a standard curve, as stated in AOAC (2005).

### **Estimation of the total content of phenolic substances**

Total phenols were extracted according to the method described by Leouifoudi *et al* (2014). Using spectrophotometry and the Folin-Ciocalteu technique, the extract's total phenolic component content was determined.

### **Estimation of peroxide value**

The peroxide value (PV) was determined by the hydrometric method using potassium iodide and titration with sodium thiosulfate in the presence of starch evidence. The peroxide value was determined as expressed as milli equivalent peroxide per kilogram of sample according to AOCS Official Method Cd 8b-90.

### **Free fatty acid value**

The value of free fatty acid (FFA) was determined according to the method described by Rahman *et al.* (2015).

### **Feder No.**

The Feder number was estimated according to the method of Pearson (1970), as follows:

$$\text{Feder number} = \text{moisture (\%)} / (\text{non-fatty organic matter (\%)})$$

Where non-fatty organic matter = 100 - (% fat + % ash + % moisture).

### **Protein-water coefficient (PWC)**

Protein-water coefficient (PWC) was estimated according to the method of Maslova, & Kulakova (2021) as in the following equation:

$$\text{PWC} = (\text{Protein \%})/(\text{Moisture \%})$$

### **Protein-water-fat coefficient (PWFC)**

The protein-water-fat coefficient (PWFC) was estimated according to the method of Maslova, & Kulakova (2021) according to the following equations:

$$\text{PWFC} = (\text{Protein \%})/(\text{Moisture \%} + \text{Fat \%})$$

### **Statistical analysis:**

Statistical analysis was performed using three replicates and entered into the Minitab 14 statistical program, and the means and standard deviation of these results were calculated. In the first stage of the work, a one-way analysis of variance (ANOVA) was used according to a completely randomized design, and the comparison between the means was carried out by calculating the least significant difference (LSD) at a confidence level of 0.05. In the second phase of the work, an analysis of variance (ANOVA) test was conducted as a factorial experiment with a completely randomized design, using the general linear model test, and the Tukey test was followed to determine the significant differences at a confidence level of 0.05.

## **Results and Discussion**

### **Chemical composition of fresh chicken meat**

Meat is considered a food with high and important nutritional value, and an essential source of many nutrients important for the growth of body tissues, such as proteins, fats, vitamins, and mineral elements, and also a good source of vitamins such as niacin and the vitamin B group. In addition, it contains fats, saturated and monounsaturated fatty acids. Meat is considered rich in essential amino acids, but it is subject to significant damage and spoilage as a result of the oxidation of the fats present in it due to its biological nature (Williams *et al.*, 2006). Studying the chemical composition of meat is of great importance to estimate the quality of meat that can be used in the manufacture of meat products. Table (1) shows the chemical composition of fresh chicken breast meat, where it was 69.63, 25.20, 0.58, 1.11, 3.48% for each of moisture, protein and crude fat, total ash and carbohydrates respectively.

## Oxidative stability of chicken meat

Some measures of the oxidative stability of chicken meat that indicate the quality of the meat were estimated, and included peroxide values expressed as milli equivalent peroxide per kilogram of sample, total acidity (FFA) expressed as (%), and the Feder number, where the values obtained were (0.66, 0.45, 2.42) for each of The peroxide number, free fatty acids, and the feder number, respectively Table 1). These results indicate that the meat used was in good condition and within the acceptable range. For example, the feder number (2.42), which indicates the quality of the meat, according to what Pearson (1970) indicated, where he explained Good quality meat products must have a feder number of less than 4.

## PWC and PWFC

Some physical analyzes of the meat were conducted, including the protein and water coefficient (PWC) and the protein, water and fat coefficient (PWFC), which are used as a marker for muscle building and tenderness in meat and its products. The values obtained were (0.361, 0.358) for both PWC and PWFC, respectively (Table 1). El-Dashlouty (1978) explained that: The tenderness of meat and meat products increases with decreasing values of PWC, PWFC.

Table (1): chemical composition, PWC, PWFC and PV of fresh chicken meat

Parameters	Values (%)	Parameters	Values (%)
Moisture	69.63 ±1.18	PWC	0.361 ±0.03
Protein	25.20 ±0.41	PWFC	0.358 ±0.02
Fat	0.58 ±0.06	PV	0.66 ±0.04
Ash	1.11 ±0.09	FFA	0.47 ±0.02
Carbohydrates	3.48 ±0.11	Feder No.	2.42 ±0.04

Values are expressed as mean ± standard deviation of three replicates.

## Effect of rosemary leaves extract on the oxidative stability of chicken meatballs

Table (2) shows the effect of rosemary leaves extract on the oxidative stability of chicken meatballs. The results obtained showed the effect of the extract used on measuring the oxidative stability of chicken meat manufactured in the form of balls. Some measures of oxidative stability were estimated, which were the measurement of (peroxide number and

free fatty acids). The results obtained indicated that there was a significant difference in the effect of the rosemary leaves extract on peroxide value and on free fatty acids. Rosemary leaves extract led to a significant decrease in the both peroxide value and free fatty acids of fresh chicken meat made into balls when compared to the raw sample of fresh chicken meat without the rosemary leaves extract added to it. The decrease in the peroxide value when compared to the control sample may be due to this plant containing many active substances that inhibit oxidation. There are many studies that have indicated the effectiveness of aromatic plants, their extracts, and essential oils in influencing measures of the oxidative stability of meat in general. These results are consistent with what was indicated by Momen et al. (2008), where adding rosemary extract to fresh beef led to a decrease in the value of the peroxide value, and the active compounds in aromatic plants act as antioxidants that inhibit or delay fat oxidation.

Table (2): Effect of volatile oil of rosemary leaves on some oxidative stability of fresh chicken meatballs.

Concentration (%)	PV	FFA
0.0	0.66 <sup>a</sup>	0.47 <sup>a</sup>
0.5	0.53 <sup>b</sup>	0.37 <sup>b</sup>
1.5	0.38 <sup>c</sup>	0.25 <sup>c</sup>
2.0	0.29 <sup>d</sup>	0.18 <sup>d</sup>

Values are expressed as mean  $\pm$  standard deviation of three replicates. Values in the same column with the same letter superscript are not significantly different at  $P \geq 0.05$

The effective effects of aromatic herbs and spices on the stability of foods containing fats have been known for many years, and the difference in the significant effect on these measures is due to the difference in the active compounds in the plants used. The plant extract in general from the leaves of the wreath is a natural antioxidant that contains many effective compounds with many properties as antioxidants. Rosemary contains caffeine, cineole, and camphor, which are effective antioxidants. Ahmed et al. (2009) indicated that rosemary had great effectiveness as a natural antioxidant and had an inhibitory role in oxidation in meat and fat. While Marjan & Baghat (2016) indicated that the use of aromatic

plants as natural antioxidants led to a significant decrease in the oxidative stability values of burger meat compared to the control. The volatile oil obtained from the rosemary was added to fresh chicken meatballs stored in the freezer at concentrations of “0.5%, 1.5%, 2.0%” in order to benefit from the antioxidant activity of this oil compared to the control treatment without addition, where some oxidation indicators were estimated. It included (peroxide value, free fatty acid value) a measure to track the development of oxidation and the extent of its effectiveness as a natural antioxidant, and to determine the degree of oxidative rancidity of meat fat for the sample treated with various additives and the control sample, as shown in Table (3). The volatile oil of rosemary leaves was added to fresh chicken meatballs at a concentration of (0.5%, 1.5%, 2.0%), in addition to the control treatment. The results in Table (3) showed the effect of adding different concentrations of the volatile oil of rosemary leaves at levels of (0.0, 0.5, 1.5, 2.0%) on the peroxide values of fresh chicken meat manufactured in the form of balls. The results showed that there were significant differences between the concentrations used, as a decrease in peroxide values was observed with increasing rates of addition to the volatile oil, and that the addition level (0.2%) had the advantage in affecting the peroxide number of fresh chicken meat compared to concentrations (0.5%, 1.5). % in addition to the control treatment, it is clear from this that the peroxide value of fresh chicken meat for the treatments was less than the peroxide values for the control treatment (0.66). This decrease obtained with increasing levels of addition to the volatile oil of the plant is mostly due to the role of the extracted natural antioxidants. The results showed that the lowest value was found when adding the volatile oil at the addition level (2.0%). This means that the peroxide value of fresh chicken meatballs decreased with the increase in the addition level compared to the control sample. These results are almost in agreement with Florou-Paneri, *et al* (2005) who indicated that rosemary had the ability to stabilize fat oxidation in meat, as well as with Sánchez-Escalante *et al* (2003), because rosemary contains many phenolic compounds that have high effectiveness and act as antioxidants. It was reported that the use of rosemary as a natural antioxidant resulted in lower peroxide values in beef (Zhang and Wang, 2007). The results obtained in Table (3) show that there are differences between the levels of oil addition at (0.5%, 1.5%, 2.0%) compared to the control treatment. It is noted from these results that the values of free fatty acids decreased with increasing levels of addition, and that the lowest values of free fatty acids were at the addition level (2.0%), where the values obtained were (0.36, 0.26, 0.20) for the concentrations (0.5%, 1.5%, 2.0%) respectively compared to the control sample, which was (0.46), and that the addition level (2.0%) was most influential compared to the level (0.5%, 1.5%). This means that the increase in antioxidant activity increases with increasing addition levels, which led to a decrease in the

values of free fatty acids in fresh chicken meatballs manufactured in the form of balls, this is due to the rosemary leaves having antioxidant properties (Frankel *et al.*, 1996). Sarabi *et al* (2017) indicated a decrease in the values of free fatty acids with increasing levels of rosemary addition compared to the control sample.

Table (3): Effect of volatile oil of rosemary leaves on peroxide value of fresh chicken meatballs.

Peroxide value (meq / kg)				
Concentrations	Storage period (month)			
	0	1	2	3
0.0	<sup>d</sup> 0.660 <sup>R</sup>	<sup>c</sup> 2.148 <sup>P</sup>	<sup>b</sup> 4.109 <sup>M</sup>	<sup>a</sup> 5.251 <sup>L</sup>
0.5	<sup>d</sup> 0.53 <sup>S</sup>	<sup>c</sup> 1.439 <sup>Q</sup>	<sup>b</sup> 3.66 <sup>N</sup>	<sup>a</sup> 4.131 <sup>M</sup>
1.5	<sup>c</sup> 0.38 <sup>T</sup>	<sup>b</sup> 1.216 <sup>Q</sup>	<sup>b</sup> 2.706 <sup>P</sup>	<sup>a</sup> 3.758 <sup>N</sup>
2.0	<sup>d</sup> 0.29 <sup>U</sup>	<sup>c</sup> 1.104 <sup>Q</sup>	<sup>b</sup> 2.32 <sup>P</sup>	<sup>a</sup> 3.080 <sup>O</sup>

\*Similar small letters in one row indicate that there are no significant differences, and similar large letters in one column indicate that there are no significant differences at the probability level ( $P < 0.05$ ).

The method of preserving meat by freezing is one of the most important successful means of preserving it from spoilage in order to prepare it for manufacturing and marketing. Freezing is also considered one of the most important methods used to preserve rapidly spoiling foods, as it preserves most of their natural properties and quality. Freezing also works to limit the proliferation of microbes and to reduce the degree of water activity (Al-Sharek, 1996). There are many objections to the use of artificial antioxidants to reduce fat oxidation, which causes negative effects on fat oxidation. There has been increased focus on the use of natural antioxidants to benefit from them as alternatives to artificial antioxidants that lead to negative complications on human health (Cook & Samman, 1996; Meyer *et al.*, 2002). It was shown from the results obtained in Table (3) that there are highly significant differences between the treatments, so it can be concluded that adding rosemary essential oil (2%) to chicken meatballs stored in the freezer has led to the preservation of the chemical properties of chicken meatballs. Increasing the shelf life of chicken meatballs stored in the freezer led to a reduction in the values of the oxidative stability measures under study by increasing the added levels of essential oil, and the concentration (2%) was



the best and most effective compared to the concentration (0.5%, 1.5%) and the control treatment.

The results also showed an increase in the values of oxidative stability measures with increasing storage period. The improvement in the oxidative stability measures of chicken meatballs stored in the freezer at a temperature of  $18^{\circ}\text{C}\pm 1$  as a result of rosemary oil additions may be due to the presence of some antioxidants such as: Rosmaric acid, Camosol, Rosmari diquinone, Rosmanol, Rosmaridpheno. These compounds work to delay the oxidation of fats and inhibit the formation of free radicals, thus preventing rancid compounds from developing, such as ketones, aldehydes, and carboxides (Al-Rubaie et al., 2008).

### Conclusion

The amount of phenolic content in rosemary oil was measured. The usefulness of rosemary as a natural source of antioxidant phenols is supported by this study. In summary, rosemary oil was found to be a promising source of phenolic antioxidants with additional biological potential, including as food antioxidants. Additionally, a better understanding of these organic substances may result in the creation of novel uses for food products.

### References

- Addis, M. (2015). Major Causes of Meat Spoilage and Preservation Techniques: A. changes, 41, 101-114.
- Al-Rubaie A. S, Al-Qaisi. Mahdi Sanmo, Kazem. Mohamed Moataz (2009). The effect of some natural and powerful antioxidants on ground beef during cold storage. Alexandria Journal of Food Science and Technology. 1(1), 1-16.
- Al-Sharik. Youssef. (1996). Meat and offal technology, "quality, preservation, circulation". First edition. Arab House for Publishing and Distribution. Egypt..
- AOAC., Association of Official Analytical Chemist.(2005). Official Methods of Analysis of the Association of Official Analysis Chemists.(16ED.) Washington, DC., USA.
- Chaudhary, P., Janmeda, P., Docea, A. O., Yeskaliyeva, B., Abdull Razis, A. F., Modu, B., ... & Sharifi-Rad, J. (2023). Oxidative stress, free radicals and antioxidants: potential crosstalk in the pathophysiology of human diseases. Frontiers in chemistry, 11, 1158198.
- Cook . N.C., and C. Samman .(1996). Flavonoids chemistry , metabolism , cardio protective effect and dietary sources. J.Natur Biochemistry ( 7 ):- 66 – 76.



- De Oliveira, J. R., Camargo, S. E. A., & De Oliveira, L. D. (2019). Rosmarinus officinalis L.(rosemary) as therapeutic and prophylactic agent. *Journal of biomedical science*, 26(1), 1-22.
- Domínguez, R., Pateiro, M., Gagaoua, M., Barba, F. J., Zhang, W., & Lorenzo, J. M. (2019). A comprehensive review on lipid oxidation in meat and meat products. *Antioxidants*, 8 (10), 429.
- El-Dashlouty, A. A. (1978). *Studies on the quality of some meat products* (Doctoral dissertation, Ph. D. Thesis, Fac. of Agrie, Ain Shams Univ., Cairo, Egypt).
- Firestone, D. (2009). AOCs Official Method Cd 8-53: Peroxide Value-Acetic Acid-Chloroform Method. AOCs Cd, 8-53.
- Florou-Paneri, P., Palatos, G., Govaris, A., Botsoglou, D., Giannenas, I., & Ambrosiadis, I. (2005). Oregano herb versus oregano essential oil as feed supplements to increase the oxidative stability of turkey meat. *International Journal of Poultry Science*, 4(11), 866-871.
- Frankel, E. N., Huang, S. W., Aeschbach, R., & Prior, E. (1996). Antioxidant activity of a rosemary extract and its constituents, carnosic acid, carnosol, and rosmarinic acid, in bulk oil and oil-in-water emulsion. *Journal of agricultural and food chemistry*, 44(1), 131-135.
- Hcini, K., Sotomayor, J. A., Jordán, M. J., & Bouzid, S. (2013). Chemical composition of the essential oil of Rosemary (*Rosmarinus officinalis* L.) of Tunisian origin. *Asian Journal of Chemistry*, 25(5), 2601.
- Huang, X., & Ahn, D. U. (2019). Lipid oxidation and its implications to meat quality and human health. *Food science and biotechnology*, 28, 1275-1285.
- Leouifoudi, I., Ziad, A., Amechrouq, A., Oukerrou, M. A., Mouse, H. A., & Mbarki, M. (2014). Identification and characterisation of phenolic compounds extracted from Moroccan olive mill wastewater. *Food Science and Technology*, 34, 249-257.
- Lourenço, S. C., Moldão-Martins, M., & Alves, V. D. (2019). Antioxidants of natural plant origins: From sources to food industry applications. *Molecules*, 24(22), 4132.
- Marjan . A., H. Baghaie. ( 2016 ). The effect of addition parisnip herb and its extraction on momtaz hamburger shef-life . *J. of Natural and Social sci.* 5 ( 1 ):- 132 -146.
- Maslova, T., & Kulakova, T. (2021). Chemical composition and nutritional quality of tilapia muscle tissue using the feed additive Enzimsporin. In *BIO Web of Conferences* (Vol. 37, p. 00105). EDP Sciences.
- Mesías, F. J., Martín, A., & Hernández, A. (2021). Consumers' growing appetite for natural foods: Perceptions towards the use of natural preservatives in fresh fruit. *Food Research International*, 150, 110749.
- Meyer. A.S., Suhr .K.I., Nielson.P., and Kolm.F. (2002). Minimal processing technology in the food industry. In, *Natural Food preservation* ( chapter 6 ). Woodhead publishing Ltd and CRC.press. LLC.



Mika, M., Antończyk, A., & Wikiera, A. (2023). Influence of Synthetic Antioxidants Used in Food Technology on the Bioavailability and Metabolism of Lipids-In Vitro Studies. *Polish Journal of Food and Nutrition Sciences*, 73(1), 95-107.

Momin, S and Shibli M. T (2008). Ground rosemary as an antioxidant in chicken burgers. The Fourth Mansoura Scientific Conference for Food and Dairy Science and Technology, Mansoura - Hurghada 229-242. Egypt.

Nurbaş, M., & Yeliz, B. A. L. (2005). Recovery Of Fixed And Volatile Oils From *Laurus Nobilis L.* Fruit And Leaves By Solvent Extraction Method. *Eskişehir Osmangazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi*, 18(2), 15-24.

Pathiraje, D., Carlin, J., Der, T., Wanasundara, J. P., & Shand, P. J. (2023). Generating Multi-Functional Pulse Ingredients for Processed Meat Products—Scientific Evaluation of Infrared-Treated Lentils. *Foods*, 12(8), 1722.

Pearson, D. (1970). *The Chemical Analysis of Food*. 6th (Ed.) JA Church hill. London. pp, 510-515.

Rahman, M. H., Hossain, M. M., Rahman, S. M. E., Amin, M. R., & Oh, D. H. (2015). Evaluation of physicochemical deterioration and lipid oxidation of beef muscle affected by freeze-thaw cycles. *Korean journal for food science of animal resources*, 35(6), 772.

Sánchez-Escalante, A., Djenane, D., Torresco, G., Giménez, B., Beltrán, J. A., & Roncalés, P. (2003). Evaluation of the antioxidant ability of hydrazine-purified and untreated commercial carnosine in beef patties. *Meat science*, 64(1), 59-67.

Sarabi, M., Keramat, J., & Kadivar, M. (2017). Antioxidant effect of rosemary extract and BHT on the quality of coated fried Escolar (*Lipidocybium flavobrunium*) fish fillets during frozen storage. *International Food Research Journal*, 24(2), 525.

Sohaib, M., Anjum, F. M., Arshad, M. S., Imran, M., Imran, A., & Hussain, S. (2017). Oxidative stability and lipid oxidation flavoring volatiles in antioxidants treated chicken meat patties during storage. *Lipids in Health and Disease*, 16(1), 1-10.

Williams, P. G., Droulez, V., Levy, G., & Stobaus, T. (2006). *Composition of Australian red meat 2002*. 1. Gross composition.

Zhang .W., and Wang ,S.Y.( 2007 ). Antioxidant activity and phenolic compounds in selected herbs. *J.Agric .Food.Chemis.* ( 44):- 5165 – 5170.