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Investigating the effect of nano-encapsulated peppermint essential oil on shelf life of rainbow trout fish burger during storage

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ABSTRACT

Today, due to the high nutritional value of fish, consumers' interest in using ready-to-eat foods based on fish is increasing worldwide. However, due to the presence of high amounts of protein and polyunsaturated fatty acids, aquatic products are highly sensitive to oxidation and the growth of microorganisms. The purpose of this research was to investigate the possibility of delaying oxidative and microbial spoilage and maintaining the quality and safety of rainbow salmon burgers during the storage period in the refrigerator using nano-encapsulated peppermint essential oil. Peppermint essential oil was nanoencapsulated by using a combination of gum arabic and soy protein isolate. Then it was added to the fish burger formulation at the levels of 0, 0.05, 0.1 and 0.15%. The values of pH, total volatile nitrogen bases (TVN), peroxide indices (PV) and thiobarbituric acid (TBA), and total count of bacteria were tested during the 12-day storage period at 4°C. Particle size, PDI index, zeta potential and microencapsulation efficiency of peppermint essential oil nanocapsules were 297.4 nm, 0.328 nm, -32.17 mV and 87.24%, respectively. During the storage period, pH, TVB-N, PV and TBA values of burgers increased. Peppermint essential oil nanocapsules showed significant antioxidant and antimicrobial activity and reduced the rate of fat oxidation and bacterial growth in fish burgers. There was a positive correlation between the concentration of essential oil nanocapsules and its antioxidant and antimicrobial activity. The greatest effect of inhibiting the growth of bacteria and reducing the rate of oxidation of fats was observed in the burger containing 0.15% nanocapsules. The results of this research suggest the use of peppermint essential oil nanocapsules at a concentration of 0.15% in order to maintain quality, reduce the rate of oxidation and microbial spoilage in fish burgers.

1-Introduction

Today, due to lifestyle changes, time constraints, and dietary shifts from traditional to modern, the consumption of ready-to-eat foods has become prevalent [1]. However, many convenience foods such as burgers and sausages made from ground meat contain over 30% fat. The consumption of red meat and its processed products increases the risk of colorectal cancer and cardiovascular diseases due to high levels of fat, cholesterol, sodium, and heterocyclic amines produced at high temperatures [2]. Therefore, informed consumers are striving to reduce their consumption of red meat products and opt for more seafood products, which have lower cholesterol and saturated fat content [2]. Fish burgers are a minced fish-based product rich in polyunsaturated fatty acids such as eicosapentaenoic acid and docosahexaenoic acid. The oxidation of highly unsaturated fats is a crucial factor leading to the development of undesirable flavors, odors, rancidity, and textural changes in seafood products [3]. Generally, fish and seafood products are highly perishable and require proper handling, transportation, and storage to ensure microbiological safety [4] .

Due to increasing consumer demand for higher quality and safer food products, attention has been focused on the use of plant extracts and essential oils as natural preservatives to replace various synthetic preservatives [5]. Essential oils are valuable volatile compounds that play vital roles in human health. They serve as natural preservatives in the food, pharmaceutical, and cosmetic industries, exhibiting significant antioxidant and antimicrobial activities. Essential oils are generally safe and extracted from the leaves, flowers, seeds, and peels of aromatic plants [6].

Peppermint, scientifically known as Mentha piperita L., is a plant belonging to the mint family and is rich in essential oil. In the essential oil of this plant, at least 50% of the active compound menthol is found along with lesser amounts of menthone and other terpenes. Peppermint essential oil is a colourless liquid or faintly yellow, possessing a distinct and strong aroma and flavour. It is used as a flavoring agent in various food products. Various studies have demonstrated the antioxidant, antifungal, antibacterial, anti-inflammatory, and antiviral effects of peppermint essential oil [7, 8].

Despite the potential preservative effects of plant essential oils, their direct addition to food has limitations. Essential oils have high volatility, low water solubility, high sensitivity to environmental conditions, and a distinct and strong odor. Therefore, to overcome these limitations and enhance the stability of active agents, microencapsulation can be utilized to control the release rate of bioactive compounds from nanocapsules. In the microencapsulation process, bioactive compounds are coated with various wall materials [9]. Arabic gum is one of the most commonly used wall materials for microencapsulation due to its excellent functional properties such as emulsifying ability, low cost, high water solubility, and low viscosity [10]. Soy protein isolate, also known for its low cost, high nutritional value, and suitable functional properties, has a wide range of applications in the food industry [11]. Research has shown that a combination of Arabic gum and soy protein isolate can better preserve bioactive compounds in the produced nanocapsules [12].

Food preservatives are essential compounds that improve the quality and shelf life of food products. Synthetic preservatives such as nitrates, butylated hydroxytoluene, sodium benzoate, butylated hydroxyanisole, and propyl gallate are widely used. Although these synthetic preservatives are abundant and inexpensive, their undesirable effects on human health, such as allergies, diabetes, cardiovascular diseases, and cancer, have been reported [13]. In recent decades, concerns about the consumption of synthetic preservatives have increased, leading to studies on replacing these compounds with natural preservatives [14, 15]. Essential oils have garnered attention as natural preservatives, but these compounds are volatile, hydrophilic, and sensitive to light, oxygen, and high temperatures, leading to degradation during processing and storage [16]. An effective solution to enhance the stability of these sensitive compounds is microencapsulation [17]. While extensive studies have been conducted on the use of various essential oils to increase the shelf life of fish burgers, the examination of the effects of microencapsulated peppermint essential oil on the quality and oxidative and microbiological spoilage of fish burgers, as a perishable food, during refrigerated storage period has not been investigated. Therefore, this research aims to investigate the impact of microencapsulated peppermint essential oil with a combination of Arabic gum and soy protein isolate using freeze-drying method as a natural preservative on the physicochemical properties, oxidation, and microbiological quality of rainbow trout fish burgers during refrigerated storage.

2-Materials and Methods

2.1. Materials

Peppermint essential oil was purchased from Barig Essences Company (Kashan, Iran). Arabic gum was obtained from Kian Chemistry Company (Tehran, Iran). Soy protein isolate was sourced from Crown Company (Beijing, China). Wheat flour and salt were procured from Golha Company (Tehran, Iran). Fresh rainbow trout fish was purchased from the local market. Other chemical substances were of analytical grade and obtained from Merck Germany.

2.2. Nanoencapsulation of PEO

The wall materials were a combination of equal parts Arabic gum (2/5% w/v) and soy protein isolate (2/5% w/v). Initially, the wall materials were dispersed in distilled water and stirred on a magnetic stirrer for 2 hours at 40 degrees Celsius. Then, they were kept refrigerated overnight to hydrate [12]. Peppermint essential oil was gradually added to Tween 20 emulsifier at a level of 4% w/w and homogenized using a magnetic stirrer. Subsequently, it was added to the wall materials and stirred for half an hour on a magnetic stirrer. Then, homogenization was carried out using an Ultraturrax (IKA T25, Germany) in two stages, each lasting 5 minutes (at speeds of 12000 and 21000 rpm, respectively). To further reduce the particle size of the capsules, an ultrasonic probe device (UP 400A, Iran) was employed with 6 cycles (each cycle lasting 30 seconds with a 15-second pause between cycles) at a temperature of 45 degrees Celsius and a frequency of 20 kHz. The resulting nanoemulsion was then frozen at -20 degrees Celsius for 24 hours and subsequently freeze-dried using a freeze dryer (ZIRBUS VACO 5, Germany) at -57 degrees Celsius for 48 hours under a pressure of 0.017 millibar. The nanocapsules were converted into a soft powder and stored refrigerated [18].

2.3. Characterization of PEO nanocapsules

The particle size, polydispersity index (PDI), and zeta potential of the nanocapsules were measured using a Zetasizer device (Malvern, UK). The encapsulation efficiency was determined by calculating the total initial phenol content and the total final phenol content of the nanocapsules. The morphology (microstructure) of the nanocapsules was examined using scanning electron microscopy (LEO 1450, Germany).

2.4. Preparation of fish burgers

The fish were transported to the laboratory under cold conditions and washed. The skin and excess parts were separated and then minced. To prepare fish burgers, a mixture consisting of 10% wheat and corn flour (in a ratio of 2:3), 0.2% garlic powder, 1.2% sodium chloride, 0.6% sugar, and 0.2% onion powder was added to the minced fish (87.8%). Different levels of peppermint essential oil nanocapsules, including 0, 0.05%, 0.10%, and 0.15%, were added to the burger dough. The burger doughs were divided into groups weighing 50 grams each and molded into dimensions of 8 × 100 mm. The burgers were refrigerated for 12 days, and they were tested every 4 days [3, 17].

2.5. pH measurement

To ascertain the pH, 10 grams of each burger sample was homogenized with 100 milliliter of distilled water. Subsequently, the pH of the burgers was measured at room temperature using a calibrated pH meter [19].

2.6. Determination of Total Volatile Basic Nitrogen (TVB-N)

For this purpose, 10 grams of the sample and 2 grams of magnesium oxide were transferred to a Kjeldahl flask along with 300 milliliters of distilled water, and then the flask was heated. At the end of the Kjeldahl system, a receiving flask (250 milliliters) containing 25 milliliters of 2% boric acid solution and several drops of methyl red indicator were placed. Distillation continued for about 45 minutes from the boiling point of the contents of the flask, and approximately 100 milliliters of liquid were collected. Titration continued until the appearance of a red color using 0.1 normal sulfuric acid. The amount of nitrogen compounds in the burgers was determined at the end using the equation (Total Nitrogen Compounds = Volume of Acid Used × 14) and reported in milligrams of nitrogen per 100 grams [20].

2.7. Determination of thiobarbituric acid (TBA) and Peroxide value

The peroxide index of the burgers was determined using the methodology outlined by Hashemi et al. (2023) [17]. Meanwhile, the thiobarbituric acid index of the burgers was measured employing the approach described by Romyani and Shamaei (2021) [21].

2.8. Microbial analysis

Initially, a 10-gram portion of the burger sample was combined with 90 grams of sterile physiological saline solution, constituting a solution containing 0.1% sodium chloride. Subsequently, the mixture underwent homogenization for 2 minutes using a stomacher device. From this homogenized suspension, various dilution series were prepared. For the enumeration of viable bacteria, the plate count agar medium and surface culture method were employed, followed by an incubation at 30 degrees Celsius for 72 hours [22].

2.9. Statistical analysis of data

The experiments were conducted with three repetitions. For statistical analysis of the data, SPSS version 22.0 software was used, and the statistical design of analysis of variance (ANOVA) was employed. To express significant differences between the samples, the Duncan's multiple range test at a 95% confidence level was utilized. The results were reported as mean ± standard deviation.

3- Results and discussion

3.1. Characteristics PEO nanocapsules

The characteristics of peppermint essential oil nanocapsules prepared using a combination of Arabic gum and soy protein isolate and by freeze-drying, were determined. The particle size, polydispersity index (PDI), zeta potential, and encapsulation efficiency of the produced nanocapsules were 297.4 nm, 0.328, 32.17 mV, and 87.24%, respectively. Zeta potential indicates the presence of repulsive forces between droplets and reflects the tendency of droplets to aggregate. Higher zeta potential signifies greater repulsive forces between them and less inclination to aggregate [23]. Considering the zeta potential value, the produced nanoparticles in this study were stable and showed a slight tendency to aggregate. The particle dispersity index (PDI) is typically utilized to determine the particle size distribution in suspension. A smaller PDI indicates a more homogeneous particle size distribution, thereby indicating desirable uniformity in diameter [24]. Based on the PDI value, the produced nanoparticles in this study exhibited a homogeneous particle size distribution and were stable. Additionally, the peppermint essential oil nanoparticles showed high encapsulation efficiency. Rajkumar et al. (2020) focused on developing peppermint essential oil encapsulated nanoparticles using chitosan and demonstrated that the produced nanoparticles had sizes less than 563 nm, a zeta potential of -12.12 mV, encapsulation efficiency of more than 64%, and loading capacity of more than 12.31% [25].

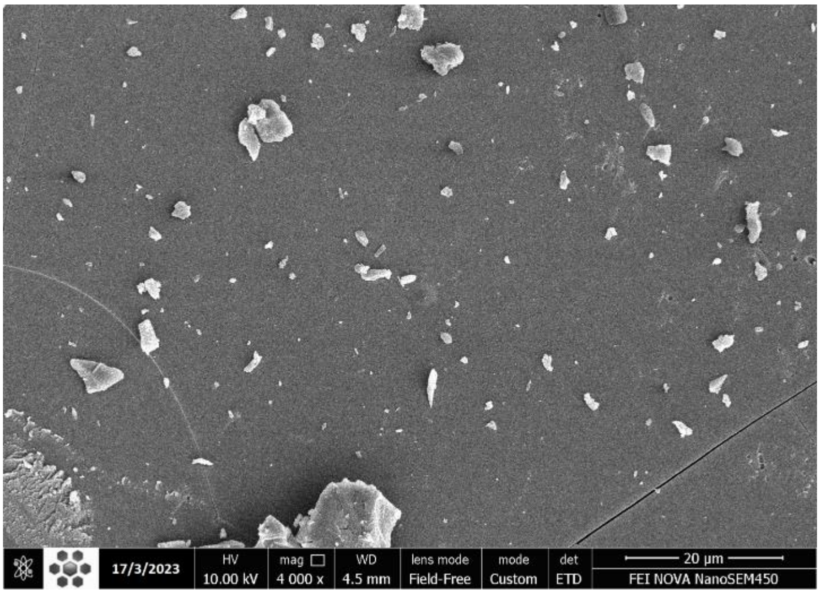
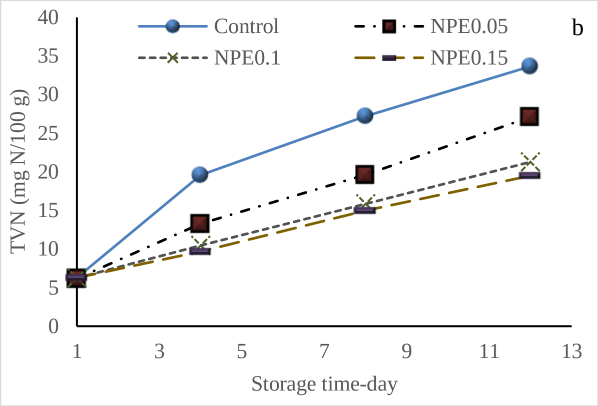


Fig 1. SEM image of encapsulated peppermint

Sheta et al. (2019) focused on the encapsulation of peppermint and green tea essential oils into chitosan nanoparticles using the method of emulsification/ionic gelation. They observed that both nanoparticle systems had spherical shapes, with average particle sizes ranging from 20 to 60 nanometers [26]. Figure 1 illustrates the scanning electron microscopy image of the produced peppermint essential oil nano-capsules. The produced nano-capsules exhibited non-uniform and asymmetric shapes, and as expected, no aggregation was observed in these nanoparticles due to their desirable stability. The non-uniformity in the shape of the prepared particles by freeze-drying has also been reported by previous researchers [24, 27].

3.2. Changes in pH of fish burgers

The results obtained from the statistical analysis of the data showed that the effects of the treatments (different levels of peppermint essential oil nano-capsules) and storage time, as well as the interaction effect of treatment and time, on the pH values of fish burgers were statistically significant ($p<0.05$). The changes in the mean pH values of different treatments of fish burgers during the 12-day storage period at 4°C are illustrated in Figure 1a. At the beginning of the storage period, there was no statistically significant difference between the pH values of different treatments of fish burgers ($p<0.05$), and the addition of different levels of peppermint essential oil nano-capsules did not significantly affect the pH of fish burgers on this day ($p<0.05$), with pH values of treatments ranging from 6.54 to 6.55. During the 12-day storage period in the refrigerator, the pH values of burger treatments increased significantly ($p<0.05$), attributed to the activity of bacteria, especially psychrophiles, which produce alkaline compounds such as ammonia through the degradation of proteins and amino acids. In the control sample, due to higher microbial growth, a higher increase in pH was observed over time, and with an increase in the level of nano-capsules from 0.05% to 0.15%, due to increased antimicrobial activity, the increase in pH over time occurred at a slower rate compared to the control. At the end of the storage period (day 12), the control sample had the highest pH value (7.13), and the lowest pH value was obtained in the burger containing 0.15% peppermint essential oil nano-capsules (6.57). Hasani et al. (2020) also reported in line with the results of the present study that adding peppermint oil nano-capsules did not have a significant effect ($p<0.05$) on the pH of fish burgers, and a decrease in the pH of the burgers was observed over time. Nano-encapsulated peppermint oil was able to reduce the rate of pH increase in fish burgers compared to the control. Hashemi et al. (2023) reported an increase in the pH of fish burgers during the storage period, attributing this increase to the production of TVB-N. Nano-encapsulated peppermint oil was able to effectively reduce the rate of pH increase in fish burgers compared to the control. Sojic et al. (2020) also reported no significant effect of adding peppermint essential oil on the pH of pork sausages. In another study, it was observed that by combining rosemary extract with the formulation of fish burgers, the production of alkaline compounds decreased, and therefore, the intensity of pH increase in fish burgers during the refrigerated storage period decreased [29].



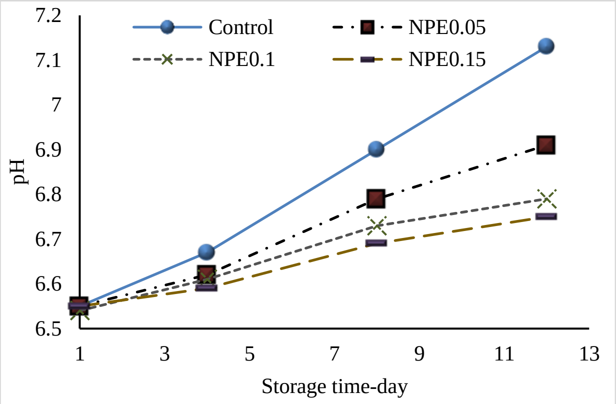


Fig 1. Change in pH (a) or TVN (b) of rainbow salmon burgers during storage at 4°C. Control: sample (no additive); NPE0.05, NPE0.1, and NPE0.15: sample containing 0.05, 0.1, and 0.15 of encapsulated peppermint essential oil.

3.3. Changes in total volatile basic nitrogen (TVB-N)

The headspace gas analysis is used to measure nitrogenous compounds produced due to the activity of microorganisms and enzymes during the storage period. Trimethylamines are produced as a result of the activity of spoilage bacteria, while dimethylamines are produced by the action of autolytic enzymes naturally present in meat. Ammonia compounds are formed due to the catabolism of nucleotides and deamination of amino acids. Generally, the production of nitrogenous volatile compounds is associated with the development of spoilage in proteinaceous food products [30].

The results obtained from the statistical analysis of the data showed that the effects of the treatments (different levels of peppermint essential oil nano-capsules) and storage time, as well as the interaction effect of treatment and time, on the levels of volatile basic nitrogen in fish burgers were statistically significant ($p \leq 0.05$). The changes in the mean levels of TVB-N of different treatments of rainbow trout fish burgers during the 12-day storage period at 4°C are illustrated in Figure 1b. At the beginning of the storage period, there was no statistically significant difference between the levels of TVB-N of different treatments of fish burgers, and the levels of TVB-N of treatments on the first day ranged from 6.6 to 18.29 milligrams of nitrogen per 100 grams. During the storage period, the levels of volatile basic nitrogen of burger treatments increased significantly ($p \leq 0.05$), which is associated with some reactions such as nucleotide degradation, amino acid oxidation, microbial activity, and amino acid deamination [31].

In the control sample, due to higher microbial growth, a greater increase in the levels of TVB-N was observed over the storage period. On the last day of storage (day twelve), the control sample had the highest levels of TVB-N (33.65 milligrams of nitrogen per 100 grams), and with the increase in the level of peppermint essential oil nano-capsules in the burgers, the levels TVB-N significantly decreased ($p \leq 0.05$). In such a way that on the last day, the lowest levels of TVB-N were obtained in the burgers containing 0.15% peppermint essential oil nano-capsules (19.49 milligrams of nitrogen per 100 grams). Generally, the control sample had the highest levels of TVB-N and since the levels TVB-N are related to spoilage and microbial growth, and peppermint essential oil has been introduced as a natural antimicrobial compound [28], therefore, adding peppermint essential oil nano-capsules to the fish burger formulation led to a reduction in microbial growth and activity of spoilage microorganisms, and consequently, the production of fewer nitrogen compounds in the burgers compared to the control. With the increase in the level of peppermint essential oil nano-capsules from 0.05% to 1.5% in the burgers, the levels of TVB-N also significantly decreased due to the increase in the level of active compounds and, consequently, the increase in antimicrobial activity ($p \leq 0.05$). In a study by Hosseini et al. (2020), consistent with the results of the current study, during an 18-day storage period, the levels of volatile basic nitrogen in fish burgers increased, but the use of lemon essential oil nanoemulsion was able to reduce the rate of TVB-N production in the burgers [3]. Pouryousef et al. (2022) also demonstrated in their study that mint essential oil, especially in nano-liposome form, could significantly reduce the rate of increase in TVB-N levels in minced fish during the storage period by reducing microbial load [32]. Overall, the levels of TVB-N are in the range of 5-20 milligrams of nitrogen per 100 grams for fresh fish, and the maximum allowable levels are 30 milligrams of nitrogen per 100 grams for human consumption. The results of the present study showed that the levels of TVB-N in the control sample exceeded the specified limit on the last day of storage, but the other treatments had levels of TVB-N lower than 30 milligrams of nitrogen per 100 grams until the last day of storage.

3.4. Changes in peroxide value

Fat oxidation is one of the key factors affecting the quality and shelf life of meat products. This chemical reaction leads to the development of undesirable color, flavor, and rancidity odor in products [33]. Peroxide value is an index used to measure the initial oxidation of fats (hydroperoxides) in products. The results obtained from the statistical analysis showed that the effect of the treatments under study (different levels of peppermint essential oil nano-capsules) and storage time, as well as the interaction effect of treatment and time, on the peroxide value of rainbow trout burgers were statistically significant ($p \leq 0.05$). The changes in the mean values of peroxide index for different treatments of fish burgers during a 12-day storage period at 4 degrees Celsius are shown in Figure 2a. At the beginning of the storage period, there was no significant difference between the peroxide index values of different treatments of fish burgers, and the peroxide index values of treatments on the first day ranged from 0.73 to 0.78 milliequivalents per kilogram. During the 12-day storage period in the refrigerator, the peroxide index values of burger treatments significantly increased ($p \leq 0.05$). In the control sample, due to the higher intensity of fat oxidation resulting from the absence of antioxidants, a further increase in the peroxide index was observed over the storage period. On the final day of storage (twelfth day), the control sample had the highest level of peroxide index (6.21 milliequivalents per kilogram), and with an increase in the level of peppermint essential oil nano-capsules in the burgers, the peroxide index values significantly decreased ($p \leq 0.05$). Consequently, on the final day, the lowest level of peroxide index was obtained in burgers containing 0.15% peppermint essential oil nano-capsules (2.34 milliequivalents per kilogram). Generally, plant essences and extracts contain various bioactive compounds, especially phenolic compounds that have hydroxyl groups in their structure. Therefore, they donate hydrogen to free radicals and neutralize these active radicals, thereby reducing the rate of fat oxidation. Hassani et al. (2020) also found that during a 12-day storage period, the peroxide index of fish burgers significantly increased, but its level was significantly lower in burgers containing encapsulated lemon essence than in the control sample [3]. Moreover, Kaur and colleagues (2020) reported that peppermint essential oil had significant antioxidant activity in meat products and could be used as a natural antioxidant [34]. In a study by Shetta et al. (2019), high antioxidant activity of peppermint essential oil nano-capsules was reported, with encapsulated oil showing twice the activity of free oil. Since the release of encapsulated essences occurs gradually and in a controlled manner, bioactive compounds are better preserved, and the antioxidant activity of the essence will be stronger during the storage period [26]. The maximum acceptable level for the peroxide index in meat products is determined to be 5. In the present study, the control sample exceeded this limit from the eighth day onwards, and in the sample containing 0.05% peppermint essential oil nano-capsules, it exceeded the limit from the twelfth day onwards.

3.5. Changes in thiobarbituric acid (TBA)

The results obtained from the statistical analysis showed that the effects of the treatments under investigation (different levels of nanoencapsulated peppermint oil essence), storage time, and their interaction on the levels of thiobarbituric acid index in fish burgers were statistically significant ($p \leq 0.05$). The changes in the mean levels of thiobarbituric acid index for different treatments of rainbow trout burgers during a 12-day storage period at 4 degrees Celsius are illustrated in Figure 2b. At the beginning of the storage period, there was no significant difference between the levels of thiobarbituric acid index for different treatments of fish burgers, and the levels of thiobarbituric acid index for treatments on the first day ranged from 0.382 to 0.393 milligrams of malondialdehyde per kilogram. During the 12-day storage period in the refrigerator, the levels of thiobarbituric acid index for burger treatments significantly increased ($p \leq 0.05$). In the control sample, due to a higher rate of lipid oxidation, a greater increase in the level of thiobarbituric acid index was observed over the storage period. On the last day of storage (twelfth day), the control sample had the highest level of thiobarbituric acid index (2.446 milligrams of malondialdehyde per kilogram), and with increasing levels of nanoencapsulated peppermint oil essence in the burgers, the levels of thiobarbituric acid index significantly decreased ($p \leq 0.05$), so that the lowest level of thiobarbituric acid index was obtained in burgers containing 0.15% nanoencapsulated peppermint oil essence on the last day (0.982 milligrams of malondialdehyde per kilogram).

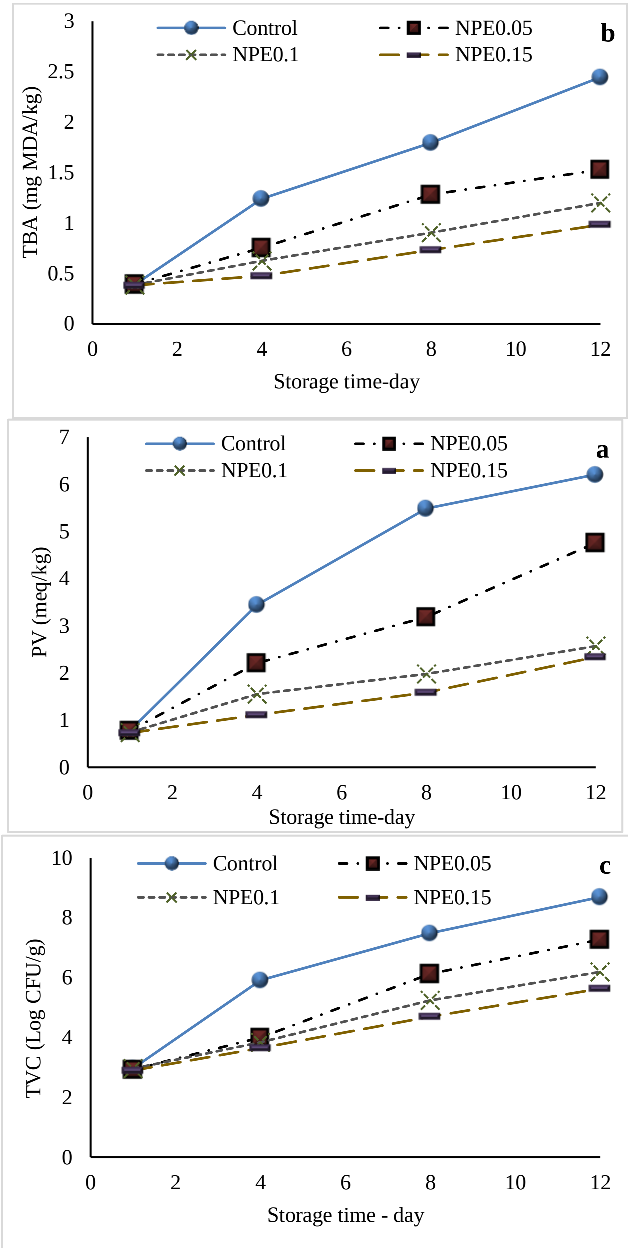


Fig 2. Change in PV (a), TBA (b) and TVC (c) of rainbow salmon burgers during 12-day storage at 4°C. Control: sample (no additive); NPE0.05, NPE0.1, and NPE0.15: sample containing 0.05, 0.1, and 0.15 of encapsulated peppermint.

Hydroperoxides are primary products of the lipid oxidation process that are odorless. However, the decomposition of hydroperoxides and their conversion into secondary products such as carbonyl compounds, furans, hydrocarbons, etc., lead to the development of off-flavors and rancid taste in the product. The creation of these undesirable organoleptic characteristics indicates food spoilage. Thiobarbituric acid index is a widely used indicator to demonstrate the level of lipid oxidation in food products [17].

Researchers have stated that terpenoids are responsible for the biological activity of peppermint essential oil, and the presence of menthol and 1,8-cineole is another reason for the high antioxidant activity of peppermint essential oil [35]. These findings are consistent with the results presented by other researchers on the addition of peppermint essential oil to the formulation of pork sausage, lemon essential oil nanoemulsions, ginger essential oil, and encapsulated lavender essential oil in fish burgers, and free and nanoencapsulated pennyroyal essential oil on lipid oxidation in minced fish meat [17, 24, 28]. In previous studies, the maximum acceptable level for thiobarbituric acid index in meat and meat products has been determined to be 2 milligrams of malondialdehyde per kilogram [36]. In the present study, the control sample exceeded this limit from the eighth day onwards, and in the sample containing 0.05% peppermint essential oil nanoemulsion, it exceeded the limit from the twelfth day onwards.

3.6. Changes in total bacterial count

The results obtained from statistical analysis showed that the effect of the treatments under investigation (different levels of peppermint essential oil nanoemulsion) and storage time, as well as the interaction effect of treatment and time, on the total bacterial count of fish burgers were statistically significant ($p \leq 0.05$). The changes in the mean total bacterial count of different treatments of rainbow trout fish burgers during a 12-day storage period at 4 degrees Celsius are illustrated in Figure c2. At the beginning of the storage period, there was no statistically significant difference in the total bacterial count among different treatments of fish burgers, and the total bacterial count of treatments on the first day ranged from 2.90 to 2.97 Log CFU/g. During the 12-day storage period at refrigerator temperature, the total bacterial count of burger treatments significantly increased due to bacterial growth and reproduction ($p \leq 0.05$). In the control sample, due to the higher intensity of bacterial growth and reproduction resulting from the absence of antimicrobial compounds, a further increase in the total bacterial count was observed over time. On the last day of storage (twelfth day), the control sample had the highest total bacterial count (8.69 Log CFU/g), and with an increase in the level of peppermint essential oil nanoemulsion in the burgers, the total bacterial count significantly decreased ($p \leq 0.05$), so that the lowest total bacterial count was obtained on the last day in the burger containing 0.15% peppermint essential oil nanoemulsion (5.63 Log CFU/g). These results are consistent with those of other researchers [17, 24, 28].

4-Conclusion

In this study, the effect of peppermint essential oil nanoemulsion encapsulated in a combination of arabic gum and isolated soy protein on the physicochemical and microbiological properties of rainbow trout fish burgers during a 12-day refrigerated storage period was investigated. The results showed that at the beginning of the storage period, adding peppermint essential oil nanoemulsions had no significant effect on the pH, nitrogenous bases, peroxide and thiobarbituric acid values, texture firmness, and total bacterial count of the fish burgers. However, over time, all the parameters increased. In the control sample, which did not contain any preservatives, the highest bacterial growth rate as well as lipid oxidation and pH changes were observed. Adding peppermint essential oil nanoemulsions and increasing their level from 0.05% to 0.15% in the fish burger treatments increased antioxidant and antimicrobial activity, significantly delaying microbial growth and lipid oxidation. The results of this study suggest the use of 0.15% level of peppermint essential oil nanoemulsions to improve the physicochemical properties of fish burgers during refrigerated storage.

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بررسی تأثیر اسانس نعناع فلفلی نانوریزپوشانی شده بر ماندگاری برگر ماهی قزل‌آلای رنگین‌کمان طی نگهداری

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چکیده

امروزه به دلیل ارزش تغذیه‌ای بالای ماهی علاقه مصرف‌کنندگان به استفاده از غذاهای آماده مصرف بر پایه ماهی در سراسر جهان در حال افزایش است. با این حال، محصولات آبزیان به دلیل حضور مقادیر بالای پروتئین و اسیدهای چرب چندغیراشباعی، در مقابل اکسایش و رشد میکروارگانیسم‌ها به شدت حساس هستند. هدف از این پژوهش، بررسی امکان به تأخیرانداختن فساد اکسایش و میکروبی و حفظ کیفیت و ایمنی برگرهای ماهی قزل‌آلای رنگین‌کمان طی دوره نگهداری در یخچال با استفاده از نانوکپسول‌های اسانس نعناع فلفلی بود. اسانس نعناع فلفلی با استفاده از ترکیب صمغ عربی و ایزوله پروتئین سویا و توسط خشک‌کن انجمادی نانوکپسوله گردید. سپس در سطوح ۰، ۰/۰۵، ۰/۱ و ۰/۱۵ درصد به فرمولاسیون برگر ماهی افزوده شد. مقادیر pH، بازهای ازته فرار کل (TVB-N)، اندیس‌های پراکسید (PV) و تیوباربیتوریک اسید (TBA)، و شمارش کلی باکتری برگرها طی دوره نگهداری ۱۲ روزه در دمای ۴ درجه سانتیگراد، مورد آزمون قرار گرفتند. لندازه ذرات، شاخص PDI، پتانسیل زتا و کارآیی ریزپوشانی نانوکپسول‌های اسانس نعناع فلفلی به ترتیب ۲۹۷/۴ nm، ۰/۳۲۸، ۳۲/۱۷ mV− و ۸۷/۲۴ ٪ بود. طی دوره نگهداری، مقادیر pH، TVB-N، PV و TBA برگرها افزایش یافت. نانوکپسول‌های اسانس نعناع فلفلی فعالیت آنتی‌اکسیدانی و ضدمیکروبی قابل توجهی از خود نشان دادند و موجب کاهش سرعت اکسایش چربی‌ها و رشد باکتری‌ها در برگرهای ماهی شدند. بین غلظت نانوکپسول‌های اسانس و فعالیت آنتی‌اکسیدانی و ضدمیکروبی آن همبستگی مثبت وجود داشت. بیشترین اثر بازدارندگی رشد باکتری‌ها و کاهش سرعت اکسایش چربی‌ها در برگر حاوی ۰/۱۵ ٪ نانوکپسول مشاهده گردید. نتایج این تحقیق استفاده از نانوکپسول‌های اسانس نعناع فلفلی در غلظت ۰/۱۵ ٪ را جهت حفظ کیفیت، کاهش سرعت اکسایشی و فساد میکروبی در برگرهای ماهی پیشنهاد می‌نماید.