A seminar paper on

Shelf Life Extension of Fish and Fishery Products Using Rosemary Extracts

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Shelf Life Extension of Fish and Fishery Products Using Rosemary Extracts[1]

By

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ABSTRACT

Fish and fishery products are highly perishable and have a short shelf life, which can lead to significant economic losses and food waste. Therefore, researchers have been exploring various natural preservatives to extend the shelf life of these products. One such promising natural preservative is rosemary extract. This study aims to assess the efficacy of rosemary extract as a natural preservative in extending the shelf life of fish and fishery products and to identify the mechanisms by which it does so. It is a commonly used culinary herb and has been found to possess antioxidant and antimicrobial properties. Studies have shown that the addition of rosemary extract to fish and fishery products can effectively inhibit the growth of spoilage and pathogenic microorganisms, thus extending their shelf life. Additionally, rosemary extract has been found to maintain the quality and sensory properties of the products during storage. It keeps all the chemical parameters like pH, total volatile basic nitrogen, peroxide value, thiobarbituric acid reactive substances within acceptable range for longer time than untreated groups. The use of rosemary extract as a natural preservative in fish and fishery products offers a safe, cost-effective, and sustainable alternative to traditional chemical preservatives. However, more research is needed to optimize the concentration and application of rosemary extract to ensure its efficacy and safety in different fish products and storage conditions.

Keywords: Fish, Fishery products, Shelf life, Quality, Rosemary extracts, Preservatives

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[1]Title of the seminar paper presented as a part of course, FIT 598 during Winter'2022

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CHAPTER I

INTRODUCTION

Fish and fishery products play an essential role in human nutrition, providing valuable protein, minerals, and vitamins. These are also better and popular than other animal meat due to its sustainable production, and cultural significance. However, the shelf life of fish and fishery products is often limited due to microbiological, enzymatic, and chemical reactions, resulting in a decrease in quality and safety (Vijayan et al., 2021). To extend the shelf life of fish and fishery products and maintain their freshness, various preservation techniques have been developed. However, these techniques have some limitations, including high cost, complexity, and adverse effects on sensory properties (Olatunde et al., 2018).

Again different types of synthetic preservatives such as sulfites, nitrates, and benzoates have been used by the food industry to preserve fish and other foods for longer periods of time. These preservatives are cheap, easy to use, and effective against a wide range of microorganisms. However, they have been associated with several health risks, including allergic reactions, asthma, and cancer. Moreover, the excessive use of synthetic preservatives has led to the development of antibiotic-resistant and pathogenic strains of bacteria, which pose a threat to public health and food safety (Saini et al., 2018). Therefore, the use of natural preservatives is recommended for fish and fishery products, as these are safer, healthier, and more environmentally friendly than synthetic preservatives (Rathod et al., 2021).

Recently, natural extracts and antioxidants have attracted much attention as a means to extend the shelf life of food products, including fish and fishery products. Among them, rosemary extract (RE) shows great potential due to its antimicrobial and antioxidant properties (Nieto et al., 2018). Rosemary (*Rosmarinus officinalis* L.) is an aromatic herb that has been used for centuries for culinary and medicinal purposes. The leaves of rosemary are rich in essential oils that are known for their preservative properties (Elyemni et al., 2022). These properties make rosemary extracts and oils suitable for extending the shelf life of fish and fishery products. The extracts are rich in polyphenolic compounds, such as carnosic acid, carnosol, and rosmarinic acid, which are effective against various microorganisms and prevent lipid oxidations. It has also been shown to enhance the sensory properties of fish products, making them more acceptable to consumers (Nieto et al., 2018).

The extracts also have numerous applications in different functional foods, medicines, and food preservation. The herb is readily available, inexpensive, and non-toxic, making it an ideal candidate for use in the food industry. Therefore, incorporating them into food products could be a valuable strategy (Nieto et al., 2018).

So from this point of view, the present study aims to investigate the effectiveness of rosemary extract in extending the shelf life of fish and fishery products. Hopefully, the study will contribute to a better understanding of the potential of natural extracts like rosemary extracts in food preservation and provide practical solutions for the fish industry.

OBJECTIVES:

Considering the facts present study was undertaken to accomplish the following objectives:

i. To assess the efficacy of rosemary extract as a natural preservative in extending the shelf life of fish and fishery products.
ii. To identify the mechanisms by which rosemary extract acts as a preservative in fish and fishery products.

CHAPTER II
MATERIALS AND METHODS

The main purpose of this seminar paper is to provide a review, and all information presented here was obtained from secondary sources. The sources used included different books, journals, reports, and internet searches. I was fortunate to receive sufficient guidance from my major professor and course instructors, which proved helpful in completing my seminar report. To acquire knowledge, I conducted searches on similar websites on the internet. The collected information was then compiled to create this seminar paper, which drew from a variety of publications, journals, and websites.

CHAPTER III

REVIEW OF FINDINGS

3.1. Chemical composition and types of rosemary extracts:

The bioactive properties of natural extracts from the Lamiaceae family, particularly rosemary, have been extensively investigated. Studies have revealed that rosemary extracts possess various biological activities, such as hepatoprotective, antifungal, insecticidal, antioxidant, and antibacterial effects. These biological properties are primarily attributed to the presence of phenolic compounds in rosemary. However, it's important to note that these properties can vary depending on several factors. Despite their beneficial effects, the use of rosemary extracts in food products is limited due to their characteristic odor, color, and taste. To overcome this limitation, various commercial methods have been developed to produce colorless and odorless antioxidant compounds from rosemary (Nieto et al., 2018).

Different types of bioactive compounds that are found from rosemary and have many positive effects on fish and fishery products preservation.

Here is a list of phenolic compounds found from rosemary:

- Carnosic acid
- Carnosol
- Methyl carnosate
- Rosmanol
- Epirosmanol
- Isorosmanol
- 12-O-Methyl carnosic acid
- Rosmanol-7-ethyl ether
- Dimethoxy-rosmanol
- Rosmadial
- Rosmariquinone (Miltirone)
- Rosmaridiphenol
- Rosmarinic acid
- Luteolin
- Luteolin-7-O-glucoside
- Homoplantaginin

(Source: Berdahl et al., 2015)

Phenolic compounds exhibit a wide range of polarities and solubilities, with carnosic acid occupying the lipophilic end of the spectrum, and rosmarinic acid being situated at the hydrophilic end. Other phenolic compounds, including diterpenoids, flavonoids, hydroxycinnamic acid derivatives, and even some essential oil constituents, demonstrate varying degrees of solubility and polarity. Extracts of rosemary possess the ability to supply

potent antioxidant species to both polar and nonpolar phases within complex food systems. In contrast to synthetic antioxidants such as butylated hydroxyanisole (BHA) or butylated hydroxytoluene (BHT), carnosic acid functions as a super-stoichiometric antioxidant (Berdahl et al., 2015).

It is capable of acting repeatedly as a reducing agent by donating hydrogen atoms in a sequential manner through a series of phenolic compounds that result from the rearrangement of the initially oxidized species (Elyemni et al., 2022).

Table no. 1: Some common forms of commercially available rosemary extracts

Extract type		Description
Liquid extracts	Oil soluble	Typically based on the nonpolar active components of rosemary with an oil carrier
	Water dispersible	Typically based on the nonpolar active components of rosemary with additional emulsifiers
	Water soluble	Typically based on the polar active components of rosemary
Powder extracts	Standard form	Similar to the oil-soluble liquid extract but in a dry form
	Concentrated form	Highly concentrated carnosic acid extracts
	Water soluble	Dried aqueous or aqueous/alcoholic extracts of rosemary containing rosmarinic acid and other water-soluble phenolics

Source: Berdahl et al., 2015

3.2. Effects of rosemary extracts in different fish and fishery Products

There are so many effects mostly positive effect on the quality and shelf life of fish and fishery products. Some of which are summarized in the following table.

Table No. 2: Overview of effects of rosemary as a preservative for different fish and fishery products

Extract/ Preservatives type	Fish/ Fishery Products	Quality attributes	References
Dehydrated rosemary	White shrimp	Lower pH, Lower thiobarbituric acid-reactive substances (TBARS) values and high content of carotenoids	Seabra et al., 2011
Rosemary essential oil	Refrigerated carp fish fingers	Lowered value of initial total bacterial count, psychrophilic bacteria, total mold and yeast, extended shelf life	Abdeldaiem et al., 2017
Rosemary essential oil	Refrigerated fish patties from Bonito fish	Reduced microbial growth, delayed chemical deterioration, improved sensory attributes, prolonged shelf life for 14 days in refrigerated storage	Guran et al., 2015
Rosemary extracts	Deep-water pink shrimp	Improved sensory quality, reduced TBARS value, prolonged shelf life	Cadun et al., 2008
Rosemary extracts	Atlantic mackerel fish fillets	Delayed chemical deterioration (lipid oxidation and TVB-N), prolonged shelf life by 3-5 days	Romdhane et al., 2017
Rosemary extracts and Butyrate hydroxyl toluene (BHT)	Fried Escolar fish fillets during frozen storage	Reduced oxidative changes in the fried fillets	Sarabi et al., 2017
Rosemary extracts and tea polyphenol combined with chitosan	Large yellow croaker	Prolonged the shelf life for 8-10 days	Li et al., 2012[a]

Rosemary extracts with icing	Sardine	Improvement of quality and safety, lower biogenic amine content, positive effect on shelf life, better sensory attributes	Özyurt et al., 2012
Rosemary extracts and onion juice	Sardine mince	Showed anti-oxidative effect, delayed oxidation	Serdaroğlu et al., 2005
Rosemary extracts and oregano extracts	Indian Mackerel steaks during ice storage	More ferric-reducing power and metal-chelating activity were found, exhibiting good antioxidant and antimicrobial activity	Kumuda et al., 2018
Rosemary, laurel, thyme, and sage essential oil	Rainbow trout during ice storage	Lowered the values of biochemical parameters and retard bacterial growth, recommended for nanoemulsion	Ozogul et al., 2017
Rosemary extracts	Cold Greater Amberjack fish fillet	Low TBARS and TVB-N values, reduced total bacterial count and psychrophilic count, improved sensory results, prolonged the stability of fish fillets to 12 days	Ibrahim et al., 2022
Rosemary extracts and tea polyphenol	Crucian carp	Sufficiently hinder microbial growth, interrupt chemical deteriorations, improved sensory quality, and prolonged shelf life for 6–8 days during refrigerated storage	Li et al., 2012[b]
Rosemary, Pomegranate and Olive Extracts	Fish patties	Less volatile compounds related oxidation of lipids, reduced microbiological growth, prolonged keeping quality for 11 days	Martínez et al., 2019

Rosemary, Olive, Citric, or Pomegranate Extracts	Clean label fish patty	Permits clean labelling, extended shelf life up to 11 days, retard chemical deterioration and microbial growth	Martínez-Zamora et al., 2020
Rosemary and thyme oil	Nile tilapia frozen fillet	Improves quality attributes and extended shelf-life for up to 2 days longer, showed strong antioxidant activity, 1.5% oil offered the finest sensory and chemical attributes	Elhafez et al., 2020
Rosemary extracts	Frozen storage of minced sea salmon	Lowered lipid oxidation, suggested as a favorable natural antioxidant	Tironi et al., 2010
Rosemary and green tea extracts	Frozen surimi gels	Higher level of yellowness and redness, increased strength	Pérez-Mateos et al., 2006
Rosemary extracts	Fish fillets	Enhanced sensory quality of both raw and cooked sardine, 2% extract was best to control lipid oxidation	Ozogul et al., 2010
Rosemary extracts combination with vacuum packing	Atlantic mackerel fish burgers	Lower peroxide value (PV) and free fatty acid (FFA) value than control group, efficiently control bacterial growth and biochemical attributes	Uçak et al., 2011
Rosemary extracts	Frozen mud shrimp	Maintained quality changes effectively, reduced TVB-N, drip loss, PV, FFA and greater lipid amount and improved sensory attributes	Shi et al., 2019
Rosemary extracts	Cooked sea bream during frozen storage	Reduced PV and TBARS development, positive effect	Özyurt et al., 2011

		on organoleptic attributes of baked sea bream	
Rosemary and sage tea extracts	Vacuum-packed and refrigerated sardine fillets	Reduced microbial growth, possesses antimicrobial and antioxidant activities, positive effect on shelf life	Kenar et al., 2010
Rosemary extracts	Filleted and minced fish during frozen storage	Slowed lipid oxidation, less Malondialdehyde (MDA) content	Vareltzis et al., 1997
Rosemary extracts	Hot-smoked and vacuum-packed fish fillets	Noteworthy effect on lactic acid bacteria, psychrophilic bacteria, yeast-mold, TBARS and PV	Çoban & Ozpolat 2013
Rosemary, Thyme, and Basil Extracts	Vacuumed packed mackerel balls	Superior sensory attributes over control group, improved microbiological, biochemical indices	Balikçi et al., 2022
Rosemary extracts with nisin	Pompano fillet during chilled storage	Enhanced biochemical parameters and sensory attributes, and lower microbial growth, significant extension of keeping quality	Gao et al., 2014

4.2. Mechanisms of action of rosemary extract in fish and fishery products

4.2.1. Rosemary as antioxidants

Rosemary extract has been shown to have multiple mechanisms of action in extending the shelf life of fish and fishery products. One of the key mechanisms is its antioxidant activity. Fish and fishery products are highly susceptible to oxidative degradation, which leads to spoilage and a decrease in quality. The phenolic compounds in rosemary act as antioxidants by donating hydrogen atoms and scavenging free radicals that can cause oxidative damage to the fish product (Nieto et al., 2018).

In case of cooked sea bream fish (*Sparus aurata*) Özyurt et al. found results suggested that the use of rosemary extract was effective in slowing down the process of oxidation during frozen storage (Özyurt et al. 2011). Another finding is the effectiveness of rosemary essential oil in preventing oxidation and inhibiting bacterial enzyme activity in fish patties can be attributed to its antioxidant properties, which stem from the presence of carnosol, carnosic acid, and rosmarinic acid (Richheimer et al., 1996; Çoban & Ozpolat 2013).

Previous studies have demonstrated that the addition of rosemary extract to Atlantic mackerel fish burgers resulted in lower oxidation levels compared to the control group, as evidenced by reduced peroxide values. These results are consistent with the findings of other studies, which also reported lower peroxide levels in groups with added rosemary oil compared to untreated groups (Quitral et al. 2009; Gao et al. 2014).

In a study conducted by Montero et al. (2005) on minced fish, it was discovered that rosemary extract demonstrated efficacy in preventing lipid oxidation, highlighting its antioxidant properties. The antioxidative effect of rosemary extract was observed by Serdaroğlu & Felekoğlu in sardine mince during frozen storage, as demonstrated by the levels of TBARS (Thiobarbituric Acid), PV (Peroxide Value), and FFA (Free Fatty Acids). These results suggest that the use of rosemary extract was effective in preventing oxidative deterioration in the sardine mince (Serdaroğlu & Felekoğlu, 2005).

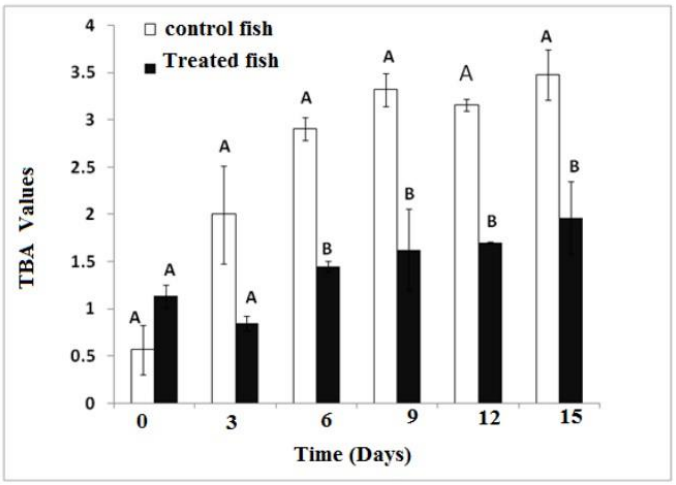

Figure no. 1: Effect of rosemary extract on fish content stored at 2℃ of TBARS (mg MDA/kg of fish meat) by Ibrahim et al., 2022.

Ibrahim et al., (2022) found that the TBARS values for rosemary treated fish are lower than untreated or control group. In a study conducted by Turhan et al. (2009), the impact of brining

with rosemary extract on the oxidative stability of anchovies stored at 4°C for 28 days was examined. The study findings demonstrated that the addition of rosemary extract during brining process delayed the lipid oxidation of anchovies. The highest antioxidant effect was observed in the brined anchovies with rosemary extract, as evidenced by the lower PV, reduced levels of TBARS, and lower oxidative rancidity scores during storage. These results suggest that rosemary extract can be utilized as a potential natural antioxidant for extending the shelf life of fish and fish products.

4.2.2. Rosemary as antimicrobials

Another mechanism of action of rosemary extract is its ability to inhibit the growth of microorganisms. Fish and fishery products are highly perishable due to the presence of spoilage-causing bacteria, fungi, and yeasts. Rosemary extract has been shown to exhibit antimicrobial activity against a wide range of microorganisms, including *Escherichia coli*, *Salmonella*, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Bacillus cereus*. This antimicrobial activity is attributed to the presence of phenolic compounds, which disrupt the cell membrane and inhibit the growth of microorganisms (Sienkiewicz et al., 2013).

In a study conducted by Guran et al. (2015), it was observed that rosemary essential oil exhibited greater effectiveness in inhibiting both enzymatic and microbial activity than other treatments. These findings are consistent with the results reported by previous studies conducted by Kenar et al. (2010), Ozogul et al. (2010), and Uçak et al. (2011).

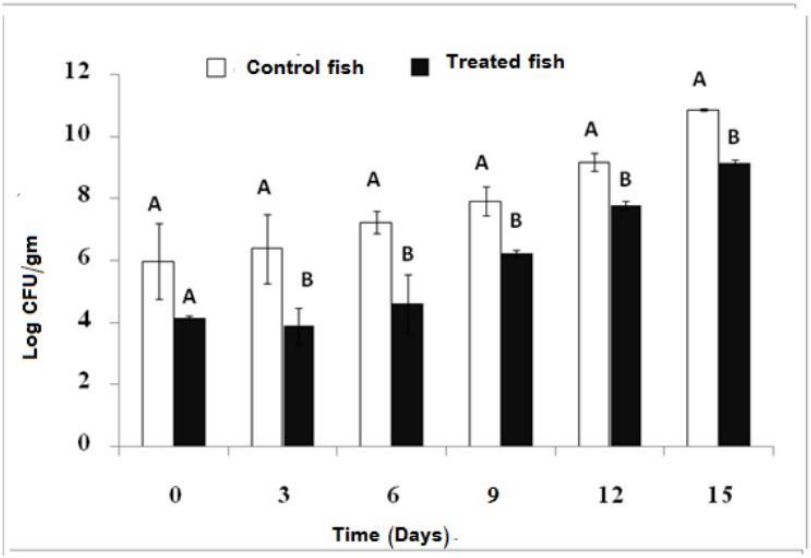

Figure no. 02: Rosemary extract on total viable count of fish fillets during cold storage (Ibrahim et al., 2022).

This figure shows the total viable count during cold storage of fish fillets *Seriola Dumeriri*. The bacterial count is significantly lower in rosemary treated group.

According to Kenar et al. (2010), the shelf life of vacuum-packed sardine fillets stored at 3±1°C was extended to seven days by dipping the fillets in an ethanolic extract of rosemary. Moreover, in a study by Ucak et al. (2011), rosemary extract (at concentrations of 0.4% and 0.8%) was found to be effective in controlling biochemical indices and bacterial growth in vacuum-packed Atlantic mackerel burgers during cold storage.

Recently, Gao et al. (2014) demonstrated a synergistic effect of rosemary extract with nisin in preventing lipid oxidation, protein degradation, nucleotide breakdown, and microbial growth in pompano fillets (*Trachinotus ovatus*) during cold storage at 4°C. These findings suggest that rosemary extract could be utilized as an effective natural preservative for enhancing the shelf life and quality of various fish and fish products.

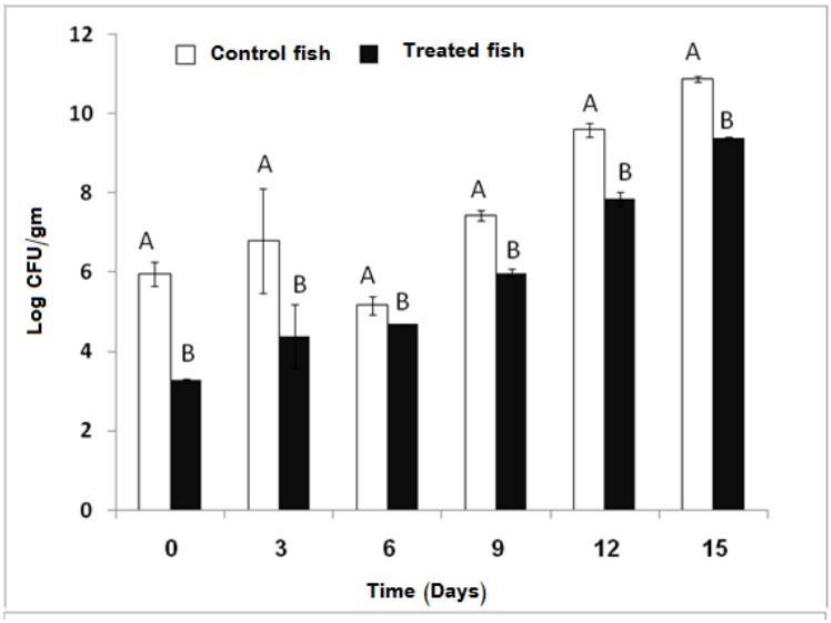

Figure no. 03: Rosemary extract treatment on total psychrophilic bacteria count on fish fillet (Ibrahim et al., 2022).

In this figure, the results indicated that the psychrotrophic bacteria (PTC) exhibited similar behavior to that of the Total Viable Count (TVC) as the control samples showed higher counts during the storage period when compared to the treated samples.

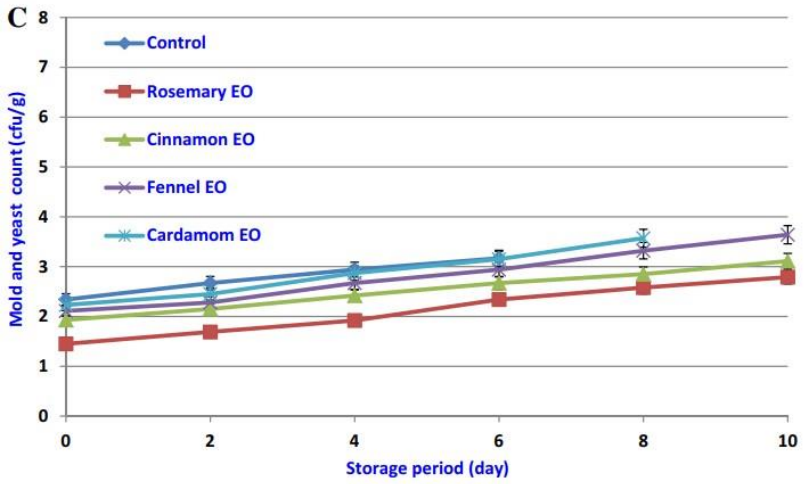

Figure no. 04: Effect of different essential oils (EO) treatment on mold & yeast count of fish fingers (Abdeldaiem et al., 2017)

When considering the antioxidant and antimicrobial properties of rosemary, it is crucial to take into account various factors that can impact these properties. These factors include the stage of fruiting, the nature of the extracts, the method of extraction, the presence of inhibitors, the potential synergistic effects with other components, and the concentration of active extract components. Therefore, a thorough understanding of these factors is necessary for effectively utilizing rosemary extract as an antioxidant or antimicrobial agent in various applications (Nieto et al., 2018).

4.2.3. Improving sensory attributes

Rosemary extract has been reported to have a masking effect on off-flavors in fish and fishery products, which can improve their sensory characteristics and consumer acceptance. This masking effect is attributed to the presence of volatile compounds in rosemary extract, which can interact with and modify the flavor compounds in fish products (Ibrahim et al., 2022). According to the findings of Guran et al., (2015) the incorporation of rosemary extract in fish patties led to an enhancement in their sensory quality. Similar outcomes have also been documented in various other fish products that were treated with rosemary extract, as reported by Uçak et al. in 2011. They found that incorporating rosemary extract in mackerel burgers resulted in an improvement in their sensory quality.

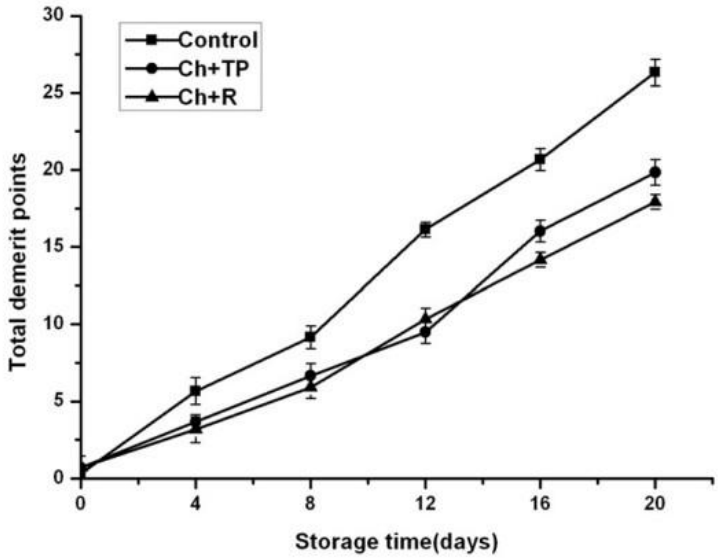

Figure no. 05: Changes in sensory attributes of large yellow croaker during refrigerated storage (Li et al., 2012[a]).

Here, Ch+TP= Chitosan + Tea Polyphenol; Ch+R= Chitosan + Rosemary

The findings of Li et al., (2012[a]) indicated that the shelf life of large yellow croaker was 12 days for untreated samples (with a sensory score of 16.13), 16 days for samples treated with Ch + TP (with a sensory score of 16.02), and 19 days for samples treated with Ch + R (with a sensory score of 16.25).

According to Ozogul et al., (2010) the findings indicated that the sensory quality of both raw and cooked sardines was enhanced by the addition of rosemary extract, with the most favorable outcome observed in sardines treated with 1% rosemary. Özyurt et al., (2011) found incorporating rosemary extract in baked sea bream fillets had a significantly positive impact on their sensory scores during frozen storage periods. These observations were further supported by the outcomes of chemical quality analysis.

Overall, the multiple mechanisms of action of rosemary extract make it a promising natural antioxidant and antimicrobial agent for extending the shelf life of fish and fishery products.

5. Effects on biochemical parameters as a result of rosemary addition in fish and fishery products

5.1. pH

The addition of rosemary extracts to fish and fishery products has been reported to have varying effects on pH levels. Some studies have demonstrated a decrease in pH values, while others have observed no significant changes. For instance, in one study, the pH of rainbow trout fillets treated with rosemary extract was observed to decrease during refrigerated storage (Ozogul et al., 2017).

However, another study reported that the pH of Atlantic salmon fillets was not significantly affected by the addition of rosemary extract (Tironi et al., 2010). These discrepancies in pH changes may be attributed to differences in the type and concentration of rosemary extract used, as well as variations in the type of fish or fishery product being studied.

5.2. Total Volatile Basic Nitrogen (TVBN)

The addition of rosemary extracts to fish and fishery products has been shown to have a positive impact on TVBN levels. It is a key indicator of seafood freshness and quality, and its increase is often associated with the spoilage of fish products (Romdhane et al., 2017). Research has suggested that rosemary extract can inhibit the production of TVBN in fish and fishery products, thereby slowing down the rate of spoilage.

Table no. 3: Changes in the TVBN content of vacuum-packed and refrigerated sardine fillets

Storage time (days)	TVB-N	
	Control	Rosemary
0	$21.34 \pm 0.62^{*a}$	21.34 ± 0.62^{a}
3	22.36 ± 0.47^{b}	17.64 ± 0.42^{a}
6	25.37 ± 0.27^{a}	21.16 ± 2.33^{a}
10	30.60 ± 0.33^{c}	20.50 ± 0.33^{a}
13	34.44 ± 0.32^{b}	23.76 ± 0.43^{a}
17	46.28 ± 0.31^{b}	25.78 ± 1.80^{a}
20	45.05 ± 0.72^{b}	29.26 ± 1.45^{a}

Source: Kenar et al., 2010

For instance, in the above table, the TVBN content of sardine fillets treated with rosemary extract was lower than that of untreated samples during storage (Kenar et al., 2010). Similarly,

another study reported that the TVBN content of large yellow cracker treated with rosemary extract was significantly lower than that of untreated samples (Li et al., 2012[a]). Here These findings suggest that the addition of rosemary extract to fish and fishery products can help to maintain their quality and extend their shelf life by reducing the production of TVBN.

5.3. Thiobarbituric Acid Reactive Substances (TBARS)

The addition of rosemary extracts to fish and fishery products has been found to reduce TBARS levels. It is a measure of lipid oxidation and are used as a marker of fish product quality. When fish products undergo lipid oxidation, their flavor and nutritional value deteriorate, resulting in off-flavors and potential health risks (Gao et al., 2014). The antioxidative properties of rosemary extracts have been shown to effectively inhibit lipid oxidation in fish products, thereby reducing TBARS levels. For example, in one study, the TBARS levels of refrigerated rainbow trout fillets treated with rosemary extract were significantly lower than those of untreated samples (Ozogul et al., 2017).

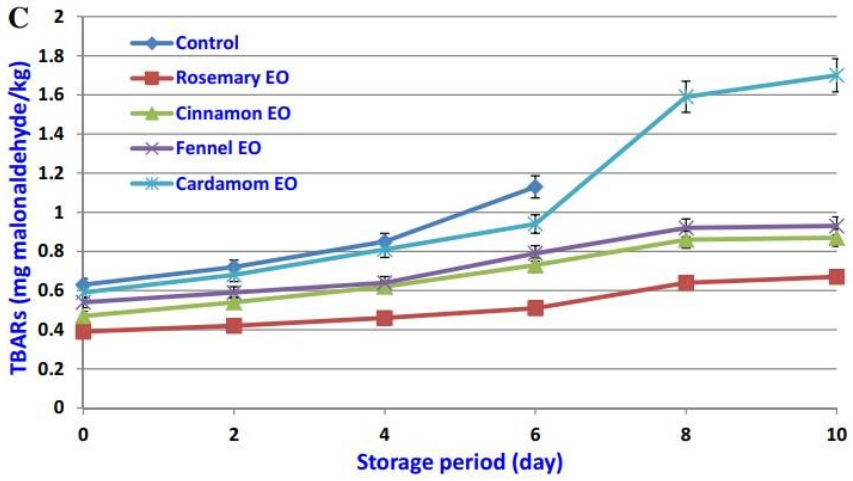

Figure no. 07: Effect of different essential oils on TBARS of refrigerated carp fish fingers (Abdeldaiem et al., 2017)

In this figure it is clearly seen that rosemary essential oil is way better than other essential oils like cinnamon, fennel or cardamom as TBARS value is lowest. Similarly, another study reported that the TBARS levels of sardine fillets treated with rosemary extract were significantly lower than those of untreated or control samples (Kenar et al., 2010). These results suggest that the addition of rosemary extract to fish and fishery products can help to maintain their quality and extend their shelf life by reducing lipid oxidation and TBARS levels.

5.4. Peroxide value

Peroxide value is an important parameter used to determine the freshness and oxidative stability of fish and fishery products. The addition of rosemary extracts to fish and fishery products can potentially reduce the peroxide value and improve their oxidative stability ().

Several studies have investigated the effect of rosemary extracts on the peroxide value of fish and fishery products. For example, a study conducted by Shahidi and Zhong (2010) found that the addition of rosemary extract to fish oil resulted in a significant reduction in peroxide value compared to the control. Similarly, a study by Lorenzo et al. (2014) found that the addition of rosemary extract to mackerel fillets reduced the peroxide value and delayed lipid oxidation.

Overall, these studies suggest that the addition of rosemary extracts to fish and fishery products can be an effective strategy to reduce peroxide value and improve their oxidative stability. However, it is important to note that the effectiveness of rosemary extracts may depend on factors such as the concentration of the extract, the type of fish or fishery product, and the storage conditions. Therefore, further research is needed to fully understand the optimal conditions for the use of rosemary extracts as an antioxidant in fish and fishery products.

6. Synergistic impacts of rosemary extracts with other natural extracts

It is worth noting that the potential synergistic effects of rosemary extract in conjunction with other natural antioxidants have yielded conflicting conclusions in the scientific literature. Resurreccion and Reynolds observed that the co-application of rosemary extract and tocopherols in meat products did not enhance the antioxidant efficacy of these individual compounds (Resurreccion & Reynolds, 1990). In contrast, Wong et al. concluded that rosemary components contribute to the regeneration of α-tocopherol, which can be used as a substitute for vitamin C to enhance the stability of vitamin E (Wong et al., 1995). Wada and Fang proposed that the synergy between both antioxidants arises from the ability of rosemary extract to provide hydrogen atoms to tocopheryl radicals (Wada & Fang, 1992). This finding supports the results obtained by Fang and Wada, who found that the antioxidant activity of the α-tocopherol-rosemary mixture on a model fish system was significantly greater than that of the individual products. Moreover, these authors discovered that the α-tocopherol molecule remained stable for an additional 10 days when co-administered with rosemary extract (Wu et al., 1982).

7. Challenges and future directions in the use of rosemary extract for shelf life extension of fish and fishery products

One of the challenges in the use of rosemary extract is its variable efficacy depending on various factors such as the type of fish, processing conditions, and storage conditions. Further research is needed to determine the optimal processing conditions for the effective use of rosemary extract. Another challenge in the use of rosemary extract is its potential impact on the sensory quality of fish and fishery products. While rosemary extract has been shown to be effective in extending the shelf life of fish products, it may also affect their flavor, aroma, and texture. Therefore, future research should focus on developing formulations that can provide both the desired shelf life extension and sensory quality of fish and fishery products.

In addition to the challenges, there are also future directions for the use of rosemary extract in fish and fishery products. More research is needed to explore the potential of combining rosemary extract with other natural preservatives to enhance their efficacy. Furthermore, the use of nanotechnology-based delivery systems can be explored to improve the stability and efficacy of rosemary extract in fish and fishery products.

CHAPTER IV

CONCLUSION

Keeping the objectives in mind, conclusion can be made by saying-

Rosemary in fish and fishery product whether as extracts or as oils can be effectively applied as it improved the quality and shelf life of products in all cases. As a natural preservative it possesses the potential to extend the shelf life of fish and fishery products. While challenges such as variable efficacy and potential impact on sensory quality exist, future research can address these issues.

The mechanisms by which rosemary act as a preservatives are well identified and is crucial for its effective use in the food industry. These includes antioxidant properties of rosemary extract, particularly its high content of phenolic compounds, have been shown to inhibit the oxidation of lipids and proteins, thereby extending the shelf life of fish and fishery products. Additionally, rosemary extract has been reported to have antimicrobial properties, which can inhibit the growth of spoilage and pathogenic microorganisms in these products. It also improves the sensory attributes of the products in most of the cases which is so much desirable to all. However further research is needed to elucidate the specific mechanisms involved and to optimize the use of rosemary extract as a natural preservative in fish and fishery products.

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