INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 16, No. 4, p. 90-101, 2020

REVIEW PAPER OPEN ACCESS

A review on Chitosan: As a potent fish preservative

Farzana Siddique[1*], Muhammad Arshad[2], Wardah Hassan[2], Zakir Hussain Shah[3], Usman Akhtar[2]

[a]*Institute of Food Science and Nutrition, University of Sargodha, Sargodha, Pakistan*

[b]*Department of Zoology, University of Sargodha, Sargodha, Pakistan*

[c]*Department of Zoology, University of Gujrat, Gujrat, Pakistan*

Key words: Chitosan, shelf life, antioxidant properties.

http://dx.doi.org/10.12692/ijb/16.4.90-101 Article published on April 14, 2020

Abstract

Due to rising awareness regarding side effects of chemical preservative of food stuff scientist are looking for innovative method of preservation of sea food that can enhance the shelf life, also improve the integrity and quality of food stuff. To address this situation, natural coatings have gained more attention. Among all-natural preservative agents, chitosan is preferable choice due to its non-toxic, biodegradable nature and excellent film forming properties. In current review, the functional antimicrobial and antioxidant properties of chitosan are highlighted with reference to extension of shelf life of sea food.

* **Corresponding Author:** Farzana Siddique ✉ farzana.siddique@uos.edu.pk

Introduction

Seafood is considered nutritious food as it provides easily digested high quality proteins (Tidwell and Allan, 2001), valuable lipids especially polyunsaturated fatty acids (PUFAs), including linolenic acid, docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) (Alishahi and Aider, 2012) carbohydrates, vitamins and minerals. DHA and EPA protect from cardiovascular diseases, various cancers like breast, colon and prostate (Duan *et al.*, 2010). Fish and fish products are thus in high demand due to their nutritious biological composition, high moisture contents (65-80%), neutral pH (6-7), high amount of non-protein nitrogen (9-18%), lipid oxidation particularly of PUFAs and autolytic enzymes which make it highly susceptible for rapid microbial growth and chemical deterioration (Jeyasekaran *et al.*, 2006) which lead to economic and serious health related problems (Fernandez-Saiz *et al.*, 2013).

Many internal and external factors influence the fish quality, including improper postmortem transformation leading to rigor mortis, which destroy the meat structure and degrade the fish quality (Ayala *et al.*, 2010). In recent decades, considerable research has been conducted to develop natural polymers as edible coatings and films offering numerous advantages as compared to chemical preservatives (Elesbee *et al.*, 2013). Although chemical preservatives (i.e. benzoic acids, parabens, nitrites, etc.) are most conventional choice to control enzyme activity and microbial propagation. However, these synthetic preservatives also release some uncertain chemical pollutants in the food (Bono *et al.*, 2012) which can create serious health problems.

Nowadays, consumer's preference for food without chemical preservatives has led to discovery of new natural antimicrobial agents (Elesbee *et al.*, 2013). Variety of biopolymers such as chitosan/chitin, starches, cellulose derivatives, gums, alginates, proteins (plants or animal-based) and lipids are used in food, pharmaceutical, textile and agriculture industry (Arvanitoyannis, 1999). Such compounds are used as thin films and coatings to preserve the fresh and processed food for extension of their storage life (Elesbee and Abdou, 2013). These coatings improve the quality of food by reducing moisture loss, discoloration, off- odors, retarding protein functionality and lipid oxidation (Arancibia *et al.*, 2015).

Chitosan

Chitosan as a natural preservative

Chitosan (poly-(-1/4)-2-amino-2-deoxy-D-glucopyranose) is cationic polysaccharide (Kong *et al.*, 2010) obtained from deacetylation of chitin which is structural component of crustacean's exoskeleton (Pereda *et al.*, 2011) and cell wall of fungi. Chitosan is considered as effective natural preservative due to its functional properties like film forming ability, chelating agent, antimicrobial, antioxidant, binding and texturizing activities (Lopez-Caballero *et al.*, 2005). Moreover, its biodegradable, biocompatible, non-toxic and mucus adhesive characteristics make it the best environment friendly preservative (Tayel *et al.*, 2016).

Chitosan form tough, flexible, long lasting and difficult to tear film on film on vegetables and fruits (Develidhere *et al.*, 2004), cheese (Duan *et al.*, 2007), eggs (Kim *et al.*, 2008) and meat (Ouattara *et al.*, 2000) thereby improve the quality and storage life of food.

Antimicrobial activity of chitosan

Chitosan is chitin derived, antifungal, and anti-microbial compound, having 50-2000 k Da average molecular weight (Liu *et al.*, 2006; Prashanth *et al.*, 2007). The antimicrobial and antifungal action of chitosan in fish food is well documented (Qin *et al.*, 2006; Li *et al.*, 2007; No *et al.*, 2007; Fernandes *et al.*, 2008).Tsai *et al.* (2002) reported that chitosan solution can extend the storage life of salmon fillets from 5 to 9 days by reducing microbial spoilage. Jeon *et al.* (2002) observed considerable reduction of microbial growth by using chitosan coating film in fresh fillets of Atlantic cod and herring during refrigerated storage. Moreover, Ramezani *et al.*

(2015) demonstrated that chitosan coating is highly effective to delay the deterioration of fresh silver carp fillets and prolong the shelf life during refrigerated storage.

Although, the exact mechanism of chitosan action against bacteria is still unclear, the mostly hypothesized mechanisms in literature are as follows; (A) positive charge of chitosan amino group may interacts with negative charge of bacterial membrane, causing leaching out of intracellular constituents i.e. proteins and nucleic acid (B) Chitosan acts as chelating agents of binding metals, then inhibits microbial growth and toxin production (C) acts as water binding agent, inhibits various enzyme activities by blocking their active sites (D) alters the cell permeability and block the entry of nutrients into the cell by formation of polymeric layer on cell surface (E) penetration of chitosan into cytosol of bacteria, which interfere synthesis of protein by blocking transcription (F) and disturb the physiological activities of microorganism causing their death (Raafar *et al*., 2008; Kong *et al*., 2012; Alishahi and Aider, 2012).

Furthermore, bactericidal efficacy of chitosan depends on many factors, that must be considered, as follows (1) microbial species, typeand cell age (2) chitosan concentration level, molecular weight, positive charge density, chelating capacity and binding characteristics (3) physical state of chitosan treatment, i.e. water soluble or solid (powder form) (4) environmental factors includes temperature, pH and contact duration of chitosan with microbes (Alishahi and Aider, 2012).

Effect of chitosan on pH value of meat

pH is most commonly used parameter to determine the spoilage index of fish (Li *et al*., 2017). However, pH alone is not enough to determine the quality of meat; different parameters are also used along with it (Dogan *et al*., 2016). The upper acceptable limit for fish is 6.8 - 7.0 by Li *et al*. (2012) and for shrimp is 7.6 (Benjakul and Nirmal, 2011). Generally, 6.7 and 7.0 is the range of pH after being caught (Li *et al*., 2013). Discrepancy is observed in initial pH values of different samples, this might be due to type of species, season, diet, muscle category, as well as level of stress during catch of fish (Li *et al*., 2013).

A linear correlation is found between TBC (total bacterial count) and pH value (Farajzadeh *et al*., 2016). Microbes are responsible for decay of food borne products such as low molecular weight amino acids present in fish muscles. This decay process leads to production of alkaline components that consequently increase the pH value (Umemura *et al*., 2006). Binding of chitosan to bacterial cell membrane causes perturbing of intracellular constituents and weakens enzyme system of bacteria which ultimately lead to bacterial death.

In the literature three major reasons have been proposed behind the drop of pH value which are as follow (Li *et al*., 2013), 1) Decomposition of glycogen 2) Production of lactic acid after death of fish 3) Dissolution of CO_2 occurs in fish samples. Rise in pH value might be attributed to the generation of volatile alkaline compound (ammonia and trimethyl amine) by either microbial or endogenous enzyme (Hu and Li, 2012). Drop in pH value is due to acidic nature of chitosan that causes inhibition of microbial growth and inhibiting the endogenous proteases activity (Fan *et al*., 2009). Chitosan action could be explained by presence of amino groups in chitosan, which cause the microbial death by depolarization of cellular membrane as well as cause disrupting the cell wall integrity by binding with it (Gomez-Estaca *et al*., 2011).

Antioxidant activity of chitosan

Marine food is rich in omega 3 PUFAs (polyunsaturated fatty acids) such as docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA) and a-linolenic acid (ALA) considered as source of healthier life by Newton (2001). DHA and EPA play an important role in prevention of different kinds of cancer including breast, prostate, colon and cardiovascular diseases. DHA is also important for proper functioning of brain in both adults and

infants. On the other hand, these compounds are more prone to the oxidation that caused undesirable change in taste, flavor, color and texture (Chan *et al*., 1988). Several researchers have also pointed out that oxidation cause loss of fat soluble vitamins, essential fatty acids and also effects functionality of protein that influence the quality of fish (Jankowski *et al.,* 2015). Additionally, in fish tissues protein bound iron exists, e.g. hemoglobin, hemosiderin, myoglobin, transferrin and ferritin. During storage iron released from these proteins that initiate oxidation of lipid (Kamil *et al*., 2002).

The antioxidant activity of chitosan shows variation is presumably due to difference in the molecular weight, concentration and degree of deacetylation of chitosan. Antioxidant activity of chitosan is directly linked to its concentration. Chitosan with high degree of deacetylation is presumably better antioxidant as highly deacetylated chitosan show more ion chelating activity than acetylated chitosan. Furthermore, it must be highlighted that, scavenging activity of low molecular weight (MW) chitosan is more as compare to high MW chitosan. According to Qin *et al.* (1993) chitosan with high molecular weight forms a strong hydrogen binding and compact structure which restricts the exposure of amino and hydroxyl group that consequently, leads to less radical scavenging activity.

Effect of chitosan on oxidation of primary lipids of fish

The quality of fish meat products is considered to be decreased by the lipid peroxidation which leads to reduction in nutritional quality, financial loss and severe health problems. Due to lipid oxidation many substances are produced, some of which gives unpleasant flavor and odor to meat (Fernandez *et al*., 2013). Peroxide value is measure of primary products of lipid oxidations like fatty acids and hydro peroxide (Ozogul *et al.,* 2010). Lipid hydro peroxide is produced by psychotropic bacteria especially pseudomonas that produced phospholipase and lipase cause increase in free fatty acids. Fatty acids further undergo oxidation process and form unstable hydro peroxide compounds (Nirmal and Benjakul, 2011). Generally, 10 meq/kg (mg Malonaldehyde kg^{-1}) of lipid is considered as the upper acceptability limit of PV (Jeon *et al*., 2002).

Thiobarbituric acid reactive substances **(**TBARS) value is widely used index to reckon the oxidation state of lipid by measuring the thiobarbituric acid (TBA) substances that are produced during second stage auto oxidation of lipid (Li *et al*., 2016). Storage of fish at a low temperature partially dehydrates the fish and increase oxidation activity of unsaturated fatty acids (Kilincceker *et al.,* 2009). Peroxides (produced during 1st stage of lipid oxidation) related with off flavor, are highly unstable compounds that undergo second stage lipid oxidation process and converted into aldehyde, ketones and alcohols (Hamilton *et al*., 1997). TBA value should be lower than 3mg MDA/Kg in case of very good sample, 5mg MDA/Kg for good sample. The maximum consumption limit is considered between 7 and 8mg MDA/Kg (Cadun *et al.,* 2008).

Total volatile basic nitrogen (TVB-N) is commonly used indicator to determine the quality and shelf life of seafood stored in refrigerator (Ragan *et al.,* 1995). It is a measurement of trimethylamine (TMA), ammonia, dimethylamine and volatile basic nitrogenous compounds, which are related with spoilage of aquatic product and impart characteristics off flavors to fish (Duan *et al*., 2010). The maximum acceptability level of TVBN value is 25 mg/100g in case of fish and 22 mg/100g for oyster (Zhou *et al*., 2011). As Chinese national shrimp sanitary standard (1994) reported that TVBN value should be less than 300mg/100g in case of shrimp.

To overcome lipid oxidative rancidity problems, chitosan has received considerable attention as environmental friendly versatile biopolymer. Chitosan is a natural antioxidant that has ability to form tough, flexible and long lasting film with biological membrane and provide a novel way to extend the shelf life of fish and its products (Ziani *et al.,* 2010). Hence, it stabilizes lipid containing

products through several different ways. 1) Chitosan coating may act as barrier against fish and surrounding air thus cutting down permeation of oxygen to fish surface (Sathivel*et al.,* 2007). 2) Lipid oxidation release volatile aldehyde such as monodialdehyde that combine with primary amino groups of chitosan and would form a stable fluorosphere (Mohan *et al.*, 2012). 3) Chitosan can prolong shelf life of fish by chelation of metal ion e.g. it eradicates the conversion of ferrous ions (exist in fish protein) into ferric ion therefore, reducing their per oxidant activity (Jeon *et al.,* 2002). 4) On the other hand, chitosan may combine with lipid and reduces oxidation process (Lin *et al.*, 1998). Chitosan coating have been approved effective to reduce the spoilage process of fish by decreasing the bacterial population, which are responsible for oxidative deamination of non-protein nitrogen containing compounds (Gram and Huss, 1996) (Table 1).

Table 1. The effect of chitosan as antibacterial agent in fishery products.

References	Fish Species	Chitosan (Ch) Coating.	Exp. Condition	pH value reduction	TVB-N reduction	TVC %age reduction	Observations
Jeon *et al.,* 2002	Atlantic cod, Herring	Chitosan different viscosities tested (360,57and 14 Cp)	12 days		TVBN value reduced 33-50% in cod, 26-51% in herring	2-3 log reduction than control	57 cp, 360 cp showed high Bactericidal effect than 14 cp, In cod for Ch14 Cp 28%, 57 Cp 52%, 360 Cp 59% less value. In herring14 Cp of Ch 25%, 57 Cp 50%, and for 360 Cp 50% lower than control observed at the end of storage.
Augustini and Sadjati, 2007	Salted dried Anchory	Ch 0.5 %, Ch 1%	4°C, for 8 weeks			69.4 % Reduction	Ch 0.5 % showed significant reduction against all bacterial types till end of storage. Shelf life increased
Vasconez *et al.,* 2009	Salmon fillets	Chitosan coating	2°C for 6 days			4-4.5 log cycles reduction	TVC significantly reduced in treated samples than control group at end of storage time, showed4-4.5 log cycles reduction for psychotrophic and aerobic bacteria after 3 days and extended shelf life.
Cao *et al.,* 2009	Pacific oyster	Ch 0.5%,1%, 5%, 10%	5±1°C for 15 days	14% reduction than initial value		Pseudomonas 73%, vibrionaceae 20%	Antibacterial activity against 13 genera was evaluated, significantly reduce in treated samples, Ch 0.5% inhibit APC till 14 days while in control at 8 day exceeded from acceptable limit 7 log cfu/g.
Duan *et al.,* 2010	Lingcod fillets	Ch3% +fish oil	2±1°C for 3 weeks,20±1°C for 3 months	Significantly reduced		Significant reduction	TVCs= 0.6-1.19 log 10cfu/g , TPCs =0.37-1.05 log cfu/g. TVCs=0.27-1.55logcfu/g, TPCs=0.50-1.13 log cfu/g reduction in cold and frozen storage, shelf life extended for 5 days
Hu *et al.,* 2012	Common Carp	Chitosan 1%	4°C, for 18 days		50% reduction	Significant Reduction	TVC not exceeded 7 log CFU/g till 14 days, TVBN acceptable till 14 days
Tsiligianii *et al.,* 2012	Sward fish	Ch+ AP,VP Ch+VP	4±0.05°C for 17 days	Significant reduction in VP, Ch-VP	Significant reduction	Significant reduction	Ch+Vp showed potent antibacterial effect due to their synergid combined action, and extended the lag phase in 1st 6-8 week. pH is maintained, TVBN value reduced
Mohan *et al.*, 2012	Indian oil Sardine	Ch 1%, Ch 2%	1-2 °C for 11 days	1% Ch 8.46, 2%Ch 7.2% rise from initial value	For 1% Ch 198%, 2% Ch 150% increase from initial value	Significant reduction	Chitosan 1% and 2% reduced TVC 2 log and 3 log than control group respectively, pH, TVBN, not exceeded permissible value till end of storage
Kuckgulmez., 2012	Eel fillets	Ch 0.1%. Ch 1%	4±1°C for 18 days			Significant reduction	TVC in Chitosan treated samples reach 7 log on 15th day while in control group 9th day of storage, shelf life enhanced 6 days.
Fernendez-saiz *et al.*, 2013	Sole and Hake fillets	Ch+ AP Ch+VP	4±0.05°C For 15 days			Significant Reduction	Chitosan +VP showed significant reduction in TVC, H_2S producing, *S. putrefacien*, LAB, Enterobacteriaceae, *L. monocytogenes* during storage
Ramezani *et al.*, 2015	Silver carp	Ch 2%,Nano ch2% sol	4°C for 12 days	Significant reduction	Significant reduction	Significant reduction	Ch, Nch showed marked reduction in TVCs, TPCs, TVB-N, Ph value not exceeded the acceptable limit till end of storage
Runka *et al.*,2016	Ribbon fish	Chitosan 1% coating	3±0.5°C for 20 days			2 log cycles reduction	Chitosan treatment showed significant reduction in Enterobacteriacae102%, Pseudomonas 33%, H_2S producing bacteria48%. Not exceeding acceptable limit. Extended shelf life 7-9 days.
Yaun *et al.*,2016	Pacific white shrimp	Ch 1%	Ice storage for 9 days	Significant reduction	Significant reduction	83% reduction	TVC, pH, TVBN significantly reduced in treated samples compared with control, and not exceeded acceptable limits till end of storage.
Yagin and Buyukyoruk, 2017	Rainbow trout	Chitosan 2% + Smoked and Vp	4°C for 26 days			TMC 34% (16d), TPC 36% (14d)	TMC significantly reduced by chitosan not exceeding acceptable limit till 26 day and TPC till 24 day. Shelf life extended 6 to 16 days.

K Value

The k value is most important indicator used for evaluation of fish freshness, which measure the degradation of ATP and its breakdown products (Ocano-Higuera *at el.*, 2011).

The K-value is defined as ratio of nonphosphorylated ATP breakdown product to total ATP degradable products according to the method of Saito *et al.* (1959). Adenine nucleotides present in muscle tissue metabolized in series of reactions as represented by scheme ATP→ADP→ AMP→ IMP→ Hx→ RHx. During storage breakdown of ATP and its related compounds are affected by microbial action and activity of endogenous enzymes which are responsible for spoilage of fish (Howgate, 2005).

Hence, the concentration of ATP and its degradation compounds have been used for calculation of k-value (Ocano-Higuera *et al.*, 2011).

Table 2. The effect of chitosan on sensory attributes in fishery products

References	Fish Species	Chitosan (Ch) Coating.	Exp. Condition	Sensory score	Observations
No *et al.*, 2002	4 grams _ve bacteria,7 gram +ve bacteria	Chitosan		Significant reduction in growth of gram positive	Chitosan 0.1% coating of all Mw showed inhibitory effect against all gram +ve bacteria than gram negative as 1106 and 224 no antibacterial activity. 746 most effective against *E. coli, P. flurescens*, 470 against *S. typhimurium, V. parahaemolyticus*
Augustini and Sadjati 2007	Salted Dried Anchory	Ch 0.5 %, Ch 1%	4°C, for 8 weeks	6.9- 7.3	Chitosan enhance the sensory quality
Fan *et al.*, 2009	Silver carp	Ch 2 % sol	-3°C for 30 days	Significant reduction	Chitosan treatment maintained good sensory quality of fish samples which till end of storage
Vasconez *et al.*, 2009	Salmon fillets	Chitosan coating	2°C for 6 days	4-4.5 log cycles reduction	TVC significantly reduced in treated samples than control group at end of storage time, showed4-4.5 log cycles reduction for psychotropic and aerobic bacteria after 3 days and extended shelf life.
Cao *et al.*, 2009	Pacific oyster	Ch 0.5%,1%, 5%, 10%	5±1°C for 15 days	Pseudomonas 73%, Vibrionaceae 20%	Antibacterial activity against 13 genera was evaluated, significantly reduce in treated samples, Ch 0.5% inhibit APC till 14 days while in control at 8 day exceeded from acceptable limit 7 log cfu/g.
Duan *et al.*,2010	Lingcod fillets	Ch3% +fish oil	2±1°C for 3 weeks,20±1°C for 3 months	78.70- 79.65%	Chitosan with fish oil incorporated coating extended shelf-life by reducing microbial proliferation and other quality parameters
Hu *et al.*, 2012	Common Carp	Chitosan 1%	4°C, for 18 days		Chitosan maintain sensory quality till end of storage and extended shelf life 14 days compared to control group.
Tsiligianii *et al.*, 2012	Sword fish	Ch+ AP, VP, Ch+VP	4±0.05°C for 17 days	Significant reduction	Sword fish remained sensory acceptable till end of storage and its shelf life was extended 8-12 days by using aerobic or vacuum packing in combination with chitosan.
Kuckgulm, 2012	Eel fillets	Ch 0.1%. Ch 1%	4±1°C for 18 days	Significant reduction	TVC in Chitosan treated samples reach 7 log on 15th day while in control 9th day, shelf life enhanced 6 days.
Mohan *et al.*, 2012	Indian oil Sardine	Ch 1%, Ch 2%	1-2 °C for 11 days	Significant reduction	Chitosan 1% and 2% till end of storage
Fernendez-saiz *et al.*, 2013	Sole and Hake fillets	Ch+ AP Ch+VP	4±0.05°C For 15 days		Chitosan with modified packaging inhibit microbial growth and maintain sensory quality to enhanced shelf life for 15 days in refrigerated storage.
Ramezani *et al.*, 2015	Silver carp	Ch 2%, Nano ch2% solution	4°C for 12 days	Significant reduction	Chitosan and nano chitosan coating maintained overall acceptability of silver carp till end of storage.
Runka *et al.*, 2016	Ribbon fish	Chitosan 1% coating	3±0.5°C for 20 days	Significant reduction	Chitosan treatment extended shelf life 7-9 days than control group.
Yaun *et al.*, 2016	Pacific white shrimp	Ch 1%	Ice storage for 9 days	significant reduction	Sensory quality maintained till end of storage
Yagin and Buyukyor, 2017	Rainbow trout	Chitosan 2% + Smoked and Vp	4°C for 26 days	TMC 82 % (16d), TPC 105% (14d)	TMC significantly reduced by chitosan not exceeding acceptable limit till 26 day and TPC till 24 day. Shelf life extended 6 to 16 days.

Generally, the initial K-value of for freshly caught should not exceed 10%, which is mainly due to endogenous enzymatic degradation (Liu *et al*., 2010). The rate and pattern of k value changes according to fish species, muscles types and storage condition. K-vale shows a good correlation with sensory evaluation of various fish products, indicates their freshness quality. The rejection level of K value is nearly 60% limits set by Ehira (1976) for fishery products.

The effect of chitosan coating on k value of different fish species was reported by many researchers. Fen *et al.* (2009) observed significant increase in k-value 43.1 % on 30th day of refrigerated storage of silver carp in control samples while due to application of 2 % chitosan coating a significant lower K-value was recorded in treated samples. Similarly, Hu *et al.* (2012) reported k value of common carp stored at 4°C coated with 1% chitosan for 18 days. The initial k value of was 10.3%, after entire storage period K-value of control and treated with 1% chitosan coating groups exceeded 80.0% on 8th and 12th day, respectively.

Li *et al.* (2013) evaluated the effects of grape seed extract and tea polyphenols combined with chitosan coating on the K-value of refrigerated red drum fillets for 20 days. A gradual increase in K-value was observed during storage period, till 0 to 12 days lower increase was recorded in all samples, and then rate of increase was faster in control samples than treated samples. The result indicated that K-value of control samples reached 62.5% at end of storage while treated sample showed lower trend.

The lower K-value of chitosan treated samples could be due to ability of chitosan to minimize the activity of 5 nucleotidase which is involve in decomposition of inosine monophosphate (Fan *et al*., 2009; Li *et al*., 2012; Li *et al*., 2013) and broad antibacterial properties of chitosan against bacteria and fungi (Ramezani *et al*., 2015; Runka *et al*., 2016).

Free fatty acids (FFA)

Free fatty acids (FFA) are formed as a result of enzymatic hydrolysis (i.e Lipase and phospholipase) of triglycerides and phospholipids (Ozyuret *et al*., 2009; Rostamzad *et al*., 2011). A gradual increase in FFA contents was observed in various fish species during refrigerated storage, reported in research literature. Nowzari *et al.* (2013) reported that chitosan- gelatin coating considerably reduced FFA and peroxide value of refrigerated rainbow trout during 16 days of refrigerated storage. At the end of entire storage period, the FFA value of treated samples was 27% lower than untreated samples. Chitosan- gelatin coating reduced FFA production hence, protecting rainbow trout fillets for further oxidation (Gomez-Estaca *et al*., 2007). High contents of FFA are responsible for undesirable taste and off-flavor of fish products (Rostemzad *et al*., 2011).

Also, Mohan *et al.* (2012) evaluated hydrolytic rancidity by FFA value of Indian oil sardine by application of 1 and 2 % chitosan for 11 days of storage. FFA value in sardine samples containing 1% and 2% chitosan was reduced by 34% and 55%, respectively than control group at 9th day of storage.

The shelf life of 1 and 2 % chitosan treated samples extended 2 and 4 days respectively than control group, indicating its efficiency to reduce lipid deterioration. This could be due to antioxidant and oxygen barrier properties of chitosan (Ojagh *et al*., 2010) on surface of fish. Similarly, reduction in lipid oxidation has also reported in chitosan coated pink salmon (Sathival *et al.,* 2007) and Alantic cod and herring (Jeon *et al*., 2002). Application of chitosan gelatin film considerably caused the decrease of FFA and peroxide value in rainbow trout during 16 days refrigerator storage. At the end of storage duration, 27% reduction in FFA value was recorded in treated samples than control sample (Nowzari *et al*., 2013).

Sensory attributes

The sensory analysis is most important parameter to assess the quality of fish meat (Mohan *et al*., 2012). A number of studies have demonstrated the antimicrobial action of chitosan as bioactive preservative for variety of fish species to control

microbes and maintaining fish quality during storage (Mitelut *et al.*, 2015) (Table 2).

Conclusion

Chitosan antimicrobial and antioxidant potency in sea food has been confirmed by numerous studies. However, these studies also indicate that chitosan action also depend upon several factors, like fish species, storage duration, chitosan concentration and its interaction with various food stuff significantly effects its antioxidant and antimicrobial properties.

References

Arancibia MY, Lopez-Caballero ME, Gomez-Guillen MC, Montero P. 2015. Chitosan coatings enriched with active shrimp waste for shrimp preservation. Food Control **54,** 259-266. https://doi.org/10.1016/j.food cont.2015.02.004

Augustini TW, Sedjati S. 2007. The effect of chitosan concentration and storage time on the quality of salted-dried Anchovy (*Stolephorus heterolobus*). Journal of Coastal Development **10,** 63-71.

Ayala MD, Abdel I, Santaella M, Martínez C, Periago MJ, Gil F, Albors OL. 2010. Muscle tissue structural changes and texture development in sea bream, (*Sparus aurata)* L., during post-mortem storage. LWT-Food Science and Technology **43,** 465-475. https://doi.org/10.1016/j.lwt.2009.08.023

Cadun A, Kışla D, Çaklı Ş. 2008. Marination of deep-water pink shrimp with rosemary extract and the determination of its shelf-life. Food Chemistry **109**, 81-87. https://doi.org/10.1016/j.foodchem.2007.12.021

Cao R, Xue CH, Liu Q. 2009. Changes in microbial flora of Pacific oysters (*Crassostrea gigas*) during refrigerated storage and its shelf-life extension by chitosan. International Journal of Food Microbiology **131,** 272-276. https://doi.org/10.1016/j.ijfoodmicro.2009.03.004

Chan PH, Chen SF, Yu AC. 1988. Induction of intracellular superoxide radical formation by arachidonic acid and by polyunsaturated fatty acids in primary astrocytic cultures. Journal of Neurochemistry **50,** 1185-1193. https://doi.org/10.1111/j.1471-4159.1988.tb10591.x

Devlieghere F, Vermeulen A, Debevere J. 2004. Chitosan: antimicrobial activity, interactions with food components and applicability as a coating on fruit and vegetables. Food Microbiology **21,** 703-714. https://doi.org/10.1016/j.fm.2004.02.008

Duan J, Cherian G, Zhao Y. 2010. Quality enhancement in fresh and frozen lingcod (*Ophiodon elongates*) fillets by employment of fish oil incorporated chitosan coatings. Food Chemistry **119,** 524-532. https://doi.org/10.1016/j.food chem .2009 .06 .055

Ehira S. 1976. A biochemical study on the freshness of fish. Bulletin of Tokai Regional Fisheries Research Laboratory.

Elsabee MZ, Abdou ES. 2013. Chitosan basededible films and coatings: A review. Materials Science and Engineering C **33,** 1819-1841. https://doi.org/10.1016/j.msec.2013.01.010

Fan W, Sun J, Chen Y, Qiu J, Zhang Y, Chi Y. 2009. Effects of chitosan coating on quality and shelf life of silver carp during frozen storage. Food Chemistry **115,** 66-70. https://doi.org/10.1016/j.foodchem.2008.11.060

Farajzadeh F, Motamedzadegan A, Shahidi SA, Hamzeh S. 2016. The effect of chitosan-gelatin coating on the quality of shrimp (*Litopenaeus vannamei*) under refrigerated condition. Food Control **67,** 163-170. https://doi.org/10.1016 /j.foodcont.2016.02.040

Fernandes JC, Tavaria FK, Soares JC, Ramos ÓS, Monteiro MJ, Pintado ME, Malcata FX.

2008. Antimicrobial effects of chitosan and chitooligosaccharides, upon *Staphylococcus aureus* and *Escherichia coli*, in food model systems. Food Microbiology **25,** 922-928. https://doi.org/10.1016/j.fm.2008.05.003.

Fernández-Saiz P, Sánchez G, Soler C, Lagaron JM, Ocio MJ. 2013. Chitosan films for the microbiological preservation of refrigerated sole and hake fillets. Food Control **34,** 61-68. https://doi.org/10.1016/j.foodcont.2013.03.047

Gómez-Estaca J, Gómez-Guillén MC, Fernández-Martín F, Montero P. 2011. Effects of gelatin origin, bovine-hide and tuna-skin, on the properties of compound gelatin–chitosan films. Food Hydrocolloid **25,** 1461-1469. https://doi.org/10.1016/j.foodhyd.2011.01.007

Gómez-Estaca J, Montero P, Giménez B, Gómez-Guillén MC. 2007. Effect of functional edible films and high-pressure processing on microbial and oxidative spoilage in cold-smoked sardine (*Sardin apilchardus*). Food Chemistry **105,** 511-520. https://doi.org/10.1016/j.foodchem.2007.04.006

Gram L, Huss HH. 1996. Microbiological spoilage of fish and fish products. International Journal of Food Microbiology **33,** 121-137. https://doi.org/10.1016/0168-1605(96)01134-8

Hamilton RJ, Kalu C, Prisk E, Padley FB, Pierce H. 1997. Chemistry of free radicals in lipids. Food Chemistry **60,** 193-199. https://doi.org/10.1016/S0308-8146(96)00351-2

Howgate P. 2005. Kinetics of degradation of adenosine triphosphate in chill-stored rainbow trout (*Oncorhynchus mykiss*). International Journal of Food Science and Technology **40,** 579-588. https://doi.org/10.1111/j.1365-2621.2005.00924.x

Hsieh RJ, Kinsella JE. 1989. Oxidation of polyunsaturated fatty acids: mechanisms, products, and inhibition with emphasis on fish. Advances in Food and Nutrition Research **33,** 233-341. https://doi.org/10.1016/S1043-4526(08)60129-1

Hu S, Luo Y, Cui J, Lu W, Wang H, You J, Shen H. 2013. Effect of silver carp (*Hypophthalmichthys molitrix*) muscle hydrolysates and fish skin hydrolysates on the quality of common carp (*Cyprinus carpio*) during 4 °C storage. International Journal of Food Science and Technology **48,** 187-194. https://doi.org/10.1111/j.1365-2621.2012.03176.x

Huss HH. 1995. Quality and quality changes in fresh fish (Vol. 348). Rome, Italy: FAO.

Jankowski P, Czarnecka D, Wolfshaut-Wolak R, Łysek R, Łukaszewska A, Bogacki P, Kawecka-Jaszcz K. 2015. Secondary prevention of coronary artery disease in contemporary clinical practice. Cardiology Journal **22,** 219-226. https://doi.org/10.5603/CJa2014.0066

Jeon YJ, Kamil JY, Shahidi F. 2002. Chitosan as an edible invisible film for quality preservation of herring and Atlantic cod. Journal of Agricultural and Food Chemistry **50,** 5167-5178. https://doi.org/10.1021/jf011693l

Jeyasekaran G, Ganesan P, Anandaraj R, Shakila RJ, Sukumar D. 2006. Quantitative and qualitative studies on the bacteriological quality of Indian white shrimp (*Penaeus indicus)* stored in dry ice. Food Microbiology **23,** 526-533. https://doi.org/10.1016/j.fm.2005.09.009

Kamil JY, Jeon YJ, Shahidi F. 2002. Antioxidative activity of chitosan of different viscosity in cooked comminuted flesh of herring (*Clupea harengus*). Food Chemistry **79**, 69-77. https://doi.org/10.1016/S0308-8146(02)00180-2

Kilincceker O, Dogan IS, Kucukoner E. 2009. Effect of edible coatings on the quality of frozen fish

fillets. LWT-Food Science and Technology **42,** 868-873.
https://doi.org/10.1016/j.lwt.2008.11.003

Kong M, Chen XG, Xing K, Park HJ. 2010. Antimicrobial properties of chitosan and mode of action: a state-of-the-art review. International Journal of Food Microbiology **144,** 51-63.
https://doi.org/10.1016/j.ijfoodmicro.2010.09.012

Kostaki M, Giatrakou V, Savvaidis IN, Kontominas MG. 2009. Combined effect of MAP and thyme essential oil on the microbiological, chemical and sensory attributes of organically aquacultured sea bass (*Dicentrarchus labrax*) fillets. Food Microbiology **26,** 475-482.
https://doi.org/10.1016/j.fm.2009.02.008

Küçükgülmez A, Yanar Y, Gerçek G, Gülnaz O, Celik M. 2013. Effects of chitosan on color, sensory and microbiological properties of European eel (*Anguilla anguilla*) fillets during refrigerated storage. Journal of Food Processing and Preservation **37,** 766-771.
https://doi.org/10.1111/j.1745-4549.2012.00701.x

Li T, Hu W, Li J, Zhang X, Zhu J, Li X. 2012. Coating effects of tea polyphenol and rosemary extract combined with chitosan on the storage quality of large yellow croaker (*Pseudosciaena crocea*). Food Control **25,** 101-106.
https://doi.org/10.1016/j.foodcont.2011.10.029

Li T, Li J, Hu W, Li X. 2013. Quality enhancement in refrigerated red drum (*Sciaenopso cellatus)* fillets using chitosan coatings containing natural preservatives. Food Chemistry **138,** 821-826.
https://doi.org/10.1016/j.foodchem.2012.11.092

Li T, Li J, Hu W, Zhang X, Li X, Zhao J. 2012. Shelf-life extension of crucian carp (*Carassius auratus*) using natural preservatives during chilled storage. Food Chemistry **135,** 140-145.
https://doi.org/10.1016/j.foodchem.2012.04.115

Li XX, Tian X, Cai LY, Lv YF, Liu XF, Li JR. 2017. Effects of Chitosan and Hawthorn Flavonoid Coating on Quality and Shelf Life of Flounder (*Paralichthyso livaceus*) Fillets during Refrigerated Storage. Journal of Food Processing and Preservation **41,** 128-131.
https://doi.org/10.1111/jfpp.12831

López-Caballero ME, Gómez-Guillén MC, Pérez-Mateos M, Montero P. 2005. A chitosan–gelatin blend as a coating for fish patties. Food Hydrocolloid **19,** 303-311.
https://doi.org/10.1016/j.foodhyd.2004.06.006

Mohan CO, Ravishankar CN, Lalitha KV, Gopal TS. 2012. Effect of chitosan edible coating on the quality of double filleted Indian oil sardine (*Sardinella longiceps*) during chilled storage. Food Hydrocolloids **26,** 167-174.
https://doi.org/10.1016/j.foodhyd.2011.05.005

Nirmal NP, Benjakul S. 2011. Retardation of quality changes of Pacific white shrimp by green tea extract treatment and modified atmosphere packaging during refrigerated storage. International Journal of Food Microbiology **149,** 247-253.
https://doi.org/10.1016/j.ijfoodmicro.2011.07.002

No HK, Meyers SP, Prinyawiwatkul W, Xu Z. 2007. Applications of chitosan for improvement of quality and shelf life of foods: a review. Journal of Food Science **72**, 87-100
https://doi.org/10.1111/j.1750-3841.2007.00383.x

No HK, Park NY, Lee SH, Meyers SP. 2002. Antibacterial activity of chitosan and chitosan oligomers with different molecular weights. International Journal of Food Microbiology **74,** 65-72.
https://doi.org/10.1111/j.1365-2621.2002.tb10314.x

Nowzari F, Shábanpour B, Ojagh SM. 2013. Comparison of chitosan–gelatin composite and bilayer coating and film effect on the quality of

refrigerated rainbow trout. Food Chemistry **141,** 1667-1672.
https://doi.org/10. 1016 /j.foodchem. 2013. 03.022

Ojagh SM, Rezaei M, Razavi SH, Hosseini SMH. 2010. Effect of chitosan coatings enriched with cinnamon oil on the quality of refrigerated rainbow trout. Food Chemistry **120,** 193-198.
https://doi.org/10.1016/j.foodchem.2009.10.006

Ouattara B, Simard RE, Piette G, Bégin A, Holley RA. 2000. Inhibition of surface spoilage bacteria in processed meats by application of antimicrobial films prepared with chitosan. International Journal of Food Microbiology **62,** 139-148.
https://doi.org/10.1016/S0168-1605(00)00407-4

Ozogul Y, Ayas D, Yazgan H, Ozogul F, Boga EK, Ozyurt G. 2010. The capability of rosemary extract in preventing oxidation of fish lipid. International Journal of Food Science and Technology **45,** 1717-1723.
https://doi.org/10.1111/j.1365-2621.2010.02326.x

Peifer JJ, Lundberg WO, Ishio S, Warmanen E. 1965. Studies of the distributions of lipids in hypercholesteremic rats: 3. Changes in hypercholesteremia and tissue fatty acids induced by dietary fats and marine oil fractions. Archives of Biochemistry and Biophysics **110,** 270-283.
https://doi.org/10.1016/0003-9861(65)90119-0

Prashanth KH, Tharanathan RN. 2007. Chitin/chitosan: modifications and their unlimited application potential—an overview. Trends in Food Science and Technology **18,** 117-131.
https://doi.org/10.1016/j.tifs.2006.10.022

Qin C, Li H, Xiao Q, Liu Y, Zhu J, Du Y. 2006. Water-solubility of chitosan and its antimicrobial activity. Carbohydrate Polymers, **63,** 367-374.
https://doi.org/10.1016/j.carbpol.2005.09.023

Qin Y. 1993. The chelating properties of chitosan fibers. Journal of Applied Polymer Science **49,** 727-731.
https://doi.org/10.1002/app.1993.070490418

Ramezani Z, Zarei M, Raminnejad N. 2015. Comparing the effectiveness of chitosan and nanochitosan coatings on the quality of refrigerated silver carp fillets. Food Control **51,** 43-48.
https://doi.org/10.1016/j.foodcont.2014.11.015

Renuka V, Mohan CO, Kriplani Y, Sivaraman GK, Ravishankar CN. 2016. Effect of chitosan edible coating on the microbial quality of Ribbonfish, (*Lepturacanthus savala)* (Cuvier, 1929) steaks. Fishery Technology **53,** 146-150.

Rhoades J, Roller S. 2000. Antimicrobial actions of degraded and native chitosan against spoilage organisms in laboratory media and foods. Applied Environmental Microbiology **66,** 80-86.
https://doi.org/10.1128/aem.66.1.80-86.2000

Rostamzad H, Shabanpour B, Shabani A, Shahiri H. 2011. Enhancement of the storage quality of frozen Persian sturgeon fillets by using of ascorbic acid. International Food Research Journal **18,** 109-116.

RosulvaI HY, Hastarini E. 2014. Application of edible coating bases extract of lindur (*Bruguieragymnor rhiza)* and chitosan on peeled off shrimp. Asian Journal of Agriculture and Food Science **2,** 73-82.

Saito T. 1958. A new method for estimating freshness of fish. Bulletin of the Japanese Society of Scientific Fisheries **24,** 749-750.
https://doi.org/10.2331/suisan.24.749

Saguy I, Karel M. 1980. Modeling of quality deterioration during food processing and storage. Food Technology (USA).

Sathivel S, Liu Q, Huang J, Prinyawiwatkul W. 2007. The influence of chitosan glazing on the quality

of skinless pink salmon (*Oncorhynchus gorbuscha*) fillets during frozen storage. Journal of Food Engineering **83,** 366-373.
https://doi.org/10.1016/j.jfoodeng.2007.03.009

Siripatrawan U, Sanguandeekul R, Narakaew V. 2009. An alternative freshness index method for modified atmosphere packaged abalone using an artificial neural network. LWT-Food Science and Technology **42,** 343-349.
https://doi.org/10. 1016/j.lwt.2008.06.008

Sriket P, Benjakul S, Visessanguan W, Kijroongrojana K. 2007. Comparative studies on chemical composition and thermal properties of black tiger shrimp (*Penaeus monodon*) and white shrimp (*Penaeus vannamei*) meats. Food Chemistry **103,** 1199-1207.

Tayel AA. 2016. Microbial chitosan as a bio preservative for fish sausages. International Journal of Biology and Macromolecules **93,** 41-46.
https://doi.org/10.1016/j.ijbiomac.2016.08.061.

Tsai GJ, Su WH, Chen HC, Pan CL. 2002. Antimicrobial activity of shrimp chitin and chitosan from different treatments and applications of fish preservation. Fisheries Science **68,** 170-177.
https://doi.org/10.1046/j.1444-2906.2002.00404.x

Tsiligianni M, Papavergou E, Soultos N, Magra T, Savvaidis IN. 2012. Effect of chitosan treatments on quality parameters of fresh refrigerated swordfish (*Xiphias gladius*) steaks stored in air and under vacuum conditions. International Journal of Food Microbiology **159,** 101-106.
https://doi.org/10.1016/j.ijfoodmicro.2012.08.010

Vásconez MB, Flores SK, Campos CA, Alvarado J, Gerschenson LN. 2009. Antimicrobial activity and physical properties of chitosan–tapioca starch based edible films and coatings. Food Research International **42,** 762-769.
https://doi.org/10.1016/j.foodres.2009.02.026

Woyewoda AD. 1986. Recommended laboratory methods for assessment of fish quality. Department of Fisheries and Oceans, Fisheries Development Branch.

Wu J, Ge S, Liu H, Wang S, Chen S, Wang J, Li J, Zhang Q. 2014. Properties and antimicrobial activity of silver carp (*Hypophthalmichthys molitrix*) skin gelatin-chitosan films incorporated with oregano essential oil for fish preservation. Food Packaging and Shelflife, **2**, 7-16.
https://doi.org/10.1016/j.fpsl.2014.04.004

Yağin C, Büyükyörü KS. 2017. The effects of chitosan, sodium lactate and sodium diacetate on the shelf life of hot smoked and vacuum-packed rainbow trout fillets. Ankara Üniversitesi Veteriner Fakültesi Dergisi **64,** 1-6.

Yuan G, Lv H, Tang W, Zhang X, Sun H. 2016. Effect of chitosan coating combined with pomegranate peel extract on the quality of Pacific white shrimp during iced storage. Food Control **59,** 818-823.
https://doi.org/10.1016/j.foodcont.2015.07.011

Zhou R, Liu Y, Xie J, Wang X. 2011. Effects of combined treatment of electrolyzed water and chitosan on the quality attributes and myofibril degradation in farmed obscure puffer fish (*Takifugu obscurus*) during refrigerated storage. Food Chemistry **129,** 1660-1666.
https://doi.org/10.1016/j.foodchem.2011.06.02