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The Effect of Modified Atmosphere Packaging on Extending Shelf-Lifes of Cold Storaged Marinated Seafood Salad

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Abstract: This study was performed to determine the shelf life of marinated seafood salad in MAP and the effect of gas mixtures (70% CO_2/30% N_2 = M1, 50% CO_2/50% N_2 = M2) on the physical, chemical, microbiological and sensoric properties of marinated seafood salads during the storage at +2±2°C. Results showed that TBA values of MAPed (M1 and M2) marinated seafood salads were quite approach to the upper limit of 8 mg malonaldehid/kg and TVB-N values of were under the limit of 35 mg/100 g given in Turkish Food Codex, the sensoric qualities of were reduced from first quality to spoiled and there was no microbial load on the 7th month of storage at +2±2°C. It was concluded that TBA values depending on the level of fatty oxidation and sensory evaluation determined the shelf-life of MAPed marinated seafood salad during storage at +2±2°C. MAPed marinated seafood salad were edible until the 7th month of storage as compared to air-packaged marinated seafood salad (the 4th month of storage). The shelf-life of marinated seafood salad could be extended 3 months by MAP as compared to air-packaging and two different gas mixture (M1 and M2) in MAP had same effect on taking to this shelf-life.

Key words: Marinated seafood salad, MAP, shelf-life, storage, air pakaging, Turkey

INTRODUCTION

The market for seafood products in Europe has grown strongly in recent years, fuelled by increases in the average unit value of seafood products (Fagan *et al*., 2004). Fish and shellfish are highly perishable because of their high a_W, neutral pH and presence of autolytic enzymes and so the shelf-life of fresh seafood is short and this represents a substantial practical problem for the distribution of these products. Spoilage reactions can be inhibited by traditional processing and preservation procedures (Huss *et al*., 1997; Gould, 1996).

Marinades are solutions including sugar, spices, oil, acids (from vinegar, fruit juice, wine) and they are used to improve tenderness, juiciness, flavour and aroma and to extend shelf life of meat, poultry, seafood and vegetables (Cadun *et al*., 2005). Marinades are semi-preserves; the preserving principal is the combination of acetic acid and salt. Keeping quality depend largely upon storage temperatures. Marinades are stored at cooler temperatures (4-6°C) keep for a long time (Clucas and Ward, 1991; Gokoglu *et al*., 2004). In general, the shelf-life and safety of non-thermally treated marinated seafood is due to the used kinds of organic acid, the NaCl concentration and the last pH value. It is well known that a pH 4.5 is enough to guarantee a high long, despite, in some cases; the products have a strong acidic taste due to the low pH value (Giuffrida *et al*., 2007). Sensory methods, microbiological, chemical and biochemical methods have been used to assess the quality of fish and marine products during handling and storage (Huss, 1995).

The packaging of food products in high-barrier materials and changing the gaseous environment to slow down respiration rates is a process called Modified-Atmosphere Packaging (MAP) (Koski, 1988). Generally, MAP is accomplished by reducing O_2 and increasing CO_2 content in the headspace. CO_2 is the major bacteriostatic factor of MAP. CO_2 may extend the lag phase and/or generation time in the logaritmic phase of growth, thus inhibiting microbial growth. The effect increases as the temperature decreases due to the increasing solubility participating of CO_2. This anti-microbial behaviour was reported for CO_2 content up to 30% (Chen *et al*., 2003). Nitrogen (N_2) is an inert and tasteless gas and is mostly

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used as a filler gas in MAP because of its low solubility in water and fat (Church and Parson, 1995). N_2 is used to replace O_2 in packages to delay oxidative rancidity and inhibit growth of aerobic micro-organisms as an alternative to vacuum packaging (Chen *et al*., 2003). MAP in combination with chill storage is an ever increasing food preservation method used for a great variety of foods (fresh meat, poultry, fish, sausages, cheese, bakery products, coffee, dry seeds, dry soups, fruits, vegetables) (Goulas and Kontominas, 2007b). Numerous studies have been published in the literature with respect to the effects of MAP on fish, mussels and fish products preservation (Boknaes *et al*., 2002; Corbo *et al*., 2005; Dalgaard *et al*., 1993; Dhananjaya and Stroud, 1994; Duyar and Eke, 2009; Goulas *et al*., 2005; Goulas and Kontominas, 2007a; Masniyom *et al*., 2005; Ordonez *et al*., 2000; Ozogul *et al*., 2000; Reddy *et al*., 1997; Ruiz-Capillas and Moral, 2001) but there is not published results on the effect of MAP in marinated seafood salad preservation. This study was performed to determine the shelf life of marinated seafood salad under MAP condition and the effect of different gas mixtures on the physical, chemical, microbiological and sensoric properties of marinated seafood salads during the storage period at +2±2°C.

MATERIALS AND METHODS

Material: In research, squid, surimi, mussel, shrimp and octopus, boiled at 85°C for 1.5 min and frozen at -40°C by IQF technique and stored at -18°C obtained from a private seafood processing plant in Bandirma/Balikesir Province of Turkey were used in the production of seafood salad.

Marination, packaging and storage: After the raw materials dissolved, they were marinated separetely. The marinating processes were performed in 4% acetic acid and salt, 4% for squid, surimi and shrimp, 6% for mussels and 2% for octopuses about at +4°C for 10 h. The temperature of marination room was at +12-13°C. pH values of the marinated materials were determined, separately. Then the marinated materials were mixed up and waited for 30 min. At the end of time, pH value of marinated seafood salad was determined. Marinated products were divided into three groups. First group were filled up into the 250 g and 50 g of non-barier polypropilene dishes (LINPACK, 187×137×36 mm) at the rate of 65% marinated material and 35% sunflover oil (control group, air packaging). The remaining two groups were packed under MAP conditions by using two different food grade gas mixture, (Oslo, Norway), 70% CO_2 /30% N_2 = M1, in second group and 50% CO_2 /50% N_2 = M2, in third group were introduced into the package, Sudpac PVC+PE as first sheet and Oriente Poliamid PE+EVC antifogy material as second sheet onto non-barier polypropilene dishes on a automatic packaging machine (INAUEN Maschinen AG, CH-9199 Type VC999). The final gas/sample ratio was about 2:1 (v/w) for MAP conditions. Air packaged and modified atmosphere packaged (MAPed) (M1 and M2) marinated seafood salad were stored at +2±2°C.

Methods: Triplicate homogenized samples were taken for analyses after 1, 4, 7 days and monthly after packaging. Results are recorded as the arithmetic means of the values.

Physical and chemical analysis: pH values, salt (%) (Ludorff and Meyer, 1973), Thiobarbituric Acid (TBA) as mg malonaldehyde/kg (Varlik *et al*., 1993) and total volatile base-nitrogen (TVB-N) as mg N/100 g (Schormuller, 1968) of MAPed marinated seafood salad were determined.

Microbiological analysis: About 25 g of MAPed marinated seafood salad was aseptically weighed and transferred into 225 mL of sterile buffered peptone water (Oxoid CM509) and homogenized by Stomacher 400 Lab Blender (Seward Medical, UK) for 2 min. After the decimal dilutions prepared, Total Aerobic Mesophilic Bacteria (TMAB) and Psychrotrophic Bacteria (PB) Counts (Plate Count Agar (PCA) Oxoid CM463), Total Coliform Bacteria (TCB) Count (Violet Red Bile Agar (VRBA) Oxoid CM107), *Escherichia coli* (*E.coli*) (Tryptone Bile X-glucuronide (TBX) Medium Oxoid CM945), *Salmonella* sp. (Rappaport Vassiliadis (RVS) Broth Oxoid CM0866, Selenite Cystine Broth Oxoid CM0699, Brilliant Green Phenol Red Agar Oxoid CM0263, Salmonella-Shigella (SS) Agar Oxoid CM0099, Xylose Lysine Deoxycholate (XLD) Agar Oxoid CM0419), *Listeria monocytogenes (L. monocytogenes)* (Listeria Enrichment Broth Oxoid CM897, Listeria Selective Enrichment Supl. SR141, Listeria Selective Agar Oxoid CM856, Listeria Selective Supplement SR140), *Staphylococcus aureus* (*S. aureus*) (Baird-Parker Agar (BP) Oxoid CM 275+SR054C), *Vibrio parahaemolyticus* (*V. parahaemolyticus*) and *Vibrio cholerae* (*V. cholerae*) (Thiosulfate Citrate Bile Sucrose (TCBS) Agar Oxoid CM0333) and *Lactobacillus* sp. (Man Rogosa Sharpe Agar (MRS) Oxoid CM361) and Sulphite Reducing Anaerobes (SRA) (Sulphite Polymyxine Sulphadiazine (SPS) Agar Merck 1.10235) were determined (FDA, 2000; USDA/FSIS, 2000; ISO, 2001).

Sensory analysis: Sensory evaluation of MAPed marinated seafood salad was performed as described by

Schormuller (1968) and were conducted by five previously trained panellists who were asked to evaluate appearance, odour, flavour and texture by using a form. According to the scoring table, a total score of sensory attributes of 15 means first quality, scores from 14.9-13 indicate second quality, scores from 12.9-11.0 indicate third quality and scores from 10.9-6.0 indicate fourth quality and a score of 6 or less corresponds to spoiled products.

Statistical analysis: Statistical comparison based on 6 samples for each treatment for each specific storage time. Analysis of Variance (ANOVA) was performed with Minitab 14 (Minitab Inc., US) using General Linear Model with Tukey's HSD test at level $p<0.05$ (95%). The analyses determined the main effects of the experimental variables (time and packaging method) on the responses.

RESULTS AND DISCUSSION

The shelf life of fresh fish products is influenced by several factors such as initial microbiological quality, season, handling, and feeding (Howgate, 1987). The effectiveness of MAP for seafood preservation is in direct correlation to specific composition and initial quality of each seafood product and varies with the different gas mixtures used as well as on specific storage conditions used (Goulas, 2007). In research, the results of physical, chemical and microbiological analysis of marinated seafood salad samples used as research material were shown in Table 1 and 2. All the results were in agreement to the maximum limits given by Turkish Manual of Seafood Quality Control Limits (Anonymous, 2008).

In marinated products, pH value should not be >4.8 (Rehbein and Oehlenschlager, 1996). The average pH value of marinated seafood salad was 4.48±0.035 on day 0 (Table 3). The higher final pH values, an average 4.79±0.045 were observed for the samples of control group on the 4th month of storage at +2±2°C ($p<0.05$) (Table 1).

It is well documented that an increase of pH values during storage may be attributed to the production of basic compounds such as ammonia, dimethylamine, trimethylamine as well as other biogenic amines as a result of fish spoilage bacterial action (Goulas and Kontominas, 2007a, b). In contrast, the lowest pH values were recorded in the samples of M1, an average 4.14±0.085 and in the samples of M2, an average 4.17±0.07, on the 7th month of storage at +2±2°C ($p<0.05$) (Table 1).

This is probably due to both to dissolution of CO_2 in the marinated seafood salad which is associated with increased carbonic acid production (Sivertsvik *et al*., 2004) and to the lower production of basic compounds in this lot of samples as a result of the preservative effect of CO_2 (Silvertsvik *et al*., 2002; Farber, 1991). No statistical importance were between the average pH values in the samples of M1 and M2 obtained from each

Table 1: Physical and chemical quality changes of air and MAPed (M1 and M2) marinated seafood salad during storage period

	Parameters							
	pH		Salt (%)		TBA (mg/malonaldehyde/kg)		TVB-N (mg N/100 g)	
Time	Air	MAP (M1 and M2)	Air	MAP (M1 and M2)	Air	MAP (M1 and M2)	Air	MAP (M1 and M2)
Day 0	4.48±0.035		3.92±0.015		0.06±0.015		6.27±0.08	
Day 1	4.47±0.035^{a}	4.45±0.035^{ab}	3.95±0.037^{f}	3.94±0.035^{cd}	0.09±0.015^{a}	0.12±0.025^{a}	6.32±0.08^{a}	6.34±0.08^{a}
		4.46±0.035^{a}		3.97±0.03^{c}		0.15±0.02^{a}		6.37±0.04^{a}
Day 4	4.49±0.09^{ab}	4.46±0.05^{a}	4.21±0.02^{a}	4.16±0.025^{a}	0.85±0.07^{b}	0.81±0.05^{b}	7.72±0.11^{b}	7.77±0.13^{b}
		4.47±0.06^{a}		4.15±0.02^{ab}		0.83±0.03^{b}		7.69±0.15^{b}
Day 7	4.46±0.05^{a}	4.48±0.04^{a}	4.17±0.03^{ab}	4.18±0.025^{a}	1.47±0.035^{bc}	1.5±0.05^{bc}	8.25±0.08^{bc}	8.52±0.11^{c}
		4.47±0.035^{a}		4.16±0.025^{a}		1.42±0.06^{bc}		8.46±0.14^{c}
Month 1	4.49±0.085^{a}	4.45±0.045^{ab}	4.05±0.03^{d}	4.09±0.03^{b}	2.21±0.055^{c}	2.16±0.035^{c}	9.16±0.065^{cd}	9.35±0.17^{d}
		4.46±0.04^{a}		4.07±0.035^{b}		2.12±0.016^{c}		9.27 ±0.15^{cd}
Month 2	4.51±0.04^{ab}	4.41±0.035^{b}	3.93±0.015^{fg}	4.02±0.025^{bc}	3.67±0.017^{de}	2.42±0.04^{cd}	10.65±0.12^{e}	10.76±0.14^{ef}
		4.45±0.085^{ab}		4.0±0.025^{c}		2.48±0.065^{cd}		10.65±0.15^{e}
Month 3	4.63±0.045^{cd}	4.38±0.07^{bc}	3.85±0.045^{h}	3.96±0.015^{c}	5.93±0.06^{g}	3.07±0.06^{d}	12.51±0.135^{g}	11.93±0.145^{fg}
		4.41±0.065^{b}		3.94±0.02^{cd}		3.04±0.055^{d}		12.15±0.12^{fg}
Month 4	4.79±0.045^{fg}	4.34±0.085^{c}	3.76±0.03^{i}	3.87±0.045^{d}	7.43±0.055^{hi}	3.85±0.07^{e}	15.77±0.16^{ij}	12.55±0.11^{g}
		4.39±0.075^{bc}		3.89±0.04^{d}		3.91±0.065^{e}		12.77±0.14^{g}
Month 5	-	4.29±0.05^{d}	-	3.78±0.03^{e}	-	4.54±0.06^{ef}	-	14.08±0.12^{hi}
		4.31±0.065^{cd}		3.81±0.035^{e}		4.59±0.065^{ef}		14.24±0.125^{hi}
Month 6	-	4.21±0.075^{ef}	-	3.72±0.025^{ef}	-	6.22±0.085^{g}	-	16.52±0.1^{j}
		4.23±0.065^{e}		3.7±0.03^{f}		6.27±0.08^{g}		16.13±0.12^{ij}
Month 7	-	4.14±0.085^{fg}	-	3.64±0.035^{fg}	-	7.62±0.075^{hi}	-	18.86±0.145^{lm}
		4.17±0.07^{f}		3.63±0.03^{fg}		7.54±0.065^{hi}		18.52±0.155

[1]* Means with different upper case superscripts in the column are significant different by ANOVA

Table 2: Microbiological quality changes of air and MAPed (M1 and M2) marinated seafood salad during storage period

	TMAB (cfu g^{-1})		TCB (MPN g^{-1})		*E.coli* (MPN g^{-1})		*Salmonella* sp. (25 g)		*L.monocytogenes* (25 g)		*S. aureus* (cfu g^{-1})		PB (cfu g^{-1})		*Lactobacillus* sp. (cfu g^{-1})		SRA(cfu g^{-1})	
Packaging style Time	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2	Air	MAP M1-M2
Day 0	---<10-----		----<3------		------<3-----		------Not found-----		------Not found--------		-----<10--------		-----10-----		----<10-------		------<10-----	
Day 1	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Day 4	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Day 7	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 1	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 2	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 3	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 4	<10	<10	<3	<3	<3	<3	Not found	Not found	Not found	Not found	<10	<10	<10	<10	<10	<10	<10	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 5	-	<10	-	<3	-	<3	-	Not found	-	Not found	-	<10	-	<10	-	<10	-	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 6	-	<10	-	<3	-	<3	-	Not found	-	Not found	-	<10	-	<10	-	<10	-	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10
Month 7	-	<10	-	<3	-	<3	-	Not found	-	Not found	-	<10	-	<10	-	<10	-	<10
		<10		<3		<3		Not found		Not found		<10		<10		<10		<10

* Means with different upper case superscripts in the column are significantly different by ANOVA

Table 3: pH values of marinated raw materials and marinated seafood salad

Marinated raw materials	pH
Tube squid	4.39±0.021
Big squid	4.42±0.019
Surimi	4.51±0.023
Mussel	4.54±0.016
Shrimp	4.37±0.014
Arms of octopus	4.46±0.015
Seafood salad	4.48±0.035

analysis time of storage period. Almost all food poisoning and most of the growth of spoilage bacteria may be prevented at pH 4.8 (McLay, 1972) but pH value is not a criterion of spoilage.

It has to be supported by other chemical and sensory analyses (Ludorff and Meyer, 1973; Schormuller, 1968; Varlik *et al*., 1993). Salt contents of the marinated seafood salad samples were reduced from an average 3.92±0.015% to an average 3.76±0.03% ($p<0.05$) in control group on the 4th month of storage at +2±2°C and to an average 3.64±0.035% in the M1 samples and to an average 3.61±0.03% in the M2 samples on the 7th month of storage at +2±2°C ($p<0.05$) (Table 1).

No statistical importance were between the average salt values in the samples of M1 and M2 obtained from each analysis time of storage period. Pastoriza *et al*. (1998) reported that a delay in chemical, microbiological and sensorial alterations was found in comparison with MAP when sodium chloride was combined with MAP, this was also reflected by a significantly higher water binding capacity of NaCl-dipped MAP-stored samples. Same researches also noticed that sodium chloride dipping significantly increased the time at which MAP-stored samples were rejected due to the development of off-odours. This finding was in aggrement to odour results in the study. Off-flavour in some degree were experienced by the panellists in the samples of MAPed (M1 and M2) marinated seafood salad on the 6th month of storage at +2±2°C whereas the samples of control group were rejected 3 months before the samples under MAP conditions.

TBA analysis is an important quality index, indicating fat oxidation. Oxidative rancidity is a complex spoilage and especially occurs in fatty fishes (Connell, 1980). In perfect quality material, TBA value should be <3 mg malonaldehyde/kg and in good quality material, TBA value should not be more than 5 mg malonaldehyde/kg. Consumption limits are from 7-8 mg malonaldehyde/kg (Schormuller, 1968, 1969).

As it is shown in Table 1, initial TBA value of marinated seafood salad was determined as an average 0.06±0.015 mg malonaldehyde/kg and increased to an average 7.43±0.055 mg malonaldehyde/kg in control group on the 4th month of storage at +2±2°C ($p<0.05$) and to an average 7.62±0.075 mg malonaldehyde/kg in the M1 samples and to an average 7.54±0.065 mg malonaldehyde/kg in the M2 samples on the 7th month of storage at +2±2°C ($p<0.05$). There were more significant differencies in TBA values of the control group and MAPed (M1 and M2) marinated seafood salad samples on 3rd and 6th month than the other months, respectively. No statistical importance were between the average TBA values in the samples of M1 and M2 obtained from each analysis time of storage period. It was reported that there was a correlation between the TBA value and sensory evaluation in many researches (Barnetti *et al*., 1991; Ramanathan and Das, 1992). In the study, results of TBA analysis were parallel to sensory analysis. Much more rancidity was experienced by the panellists on the 4th month of storage in the control group samples (Table 4) and on the 7th month of storage in the samples of MAPed (M1 and M2) marinated seafood salads (Table 5 and 6).

According to the TBA results, marinated seafood salad could not be consumed on the 4th month of storage and on the 7th month of storage in control group and MAPed marinated seafood salad, respectively, since fat oxidation had intensely progressed. Under MAP conditions (M1 and M2), the shelf-lifes of marinated seafood salads were extended up to 3 months as compared to control group. TVB-N value is a quality index for unprocessed fishery products indicative of fish spoilage as a result of metabolic activity of fish spoilage bacteria and endogenous enzymes action (Connell, 1990; EC, 1995).

The result of this action is the formation of off-flavouring compounds including ammonia, monoethylamine, dimethylamine as well as trimethylamine (Goulas and Kontominas, 2007a, b). A level of 35 mg/100 g has been upper limit above which fishery products are considered to be unfit for human consumption (Ludorff and Meyer, 1973; Schormuller, 1968). In marine fish, TVB-N values of 15-20 mg N/100 g show good quality, whereas TVB-N values of 50 mg N/100 g show poor quality (Connell, 1980). Crustaceans may have high TVB-N values peculiar to themselves (Oehlenschlager, 1997).

Initial TVB-N value of marinated seafood salad was an average 6.27±0.08 mg N/100 g and increased to an average 15.77±0.016 mg N/100 g in the control group samples on the 4th month of storage at +2±2°C ($p<0.05$) and to an average 18.86±0.145 mg N/100 g in the samples of M1 and to an average 18.52±0.155 mg N/100 g in the samples of M2 on the 7th month of storage at + 2±2°C ($p<0.05$) (Table 1). No statistical importance were between the average TVB-N values in the samples of M1 and M2 obtained from each analysis time of storage period. According to the TVB-N results, marinated seafood salad packaged both under air and MAP conditions were rated good quality as described by Connell, 1980. There were more significant differencies in TVB-N values of the control group and MAPed (M1 and M2) marinated seafood salad samples on months 3rd and 4th and on months 6th and 7th than the other months, respectively. No statistical importance were between the average TVB-N values in the samples of M1 and M2 obtained from each analysis time of storage period.

The results of microbiological analysis of control and MAPed marinated seafood salads showed that no microbial load was detected during storage at + 2±2°C (Table 2). This was probably due to, the application of sufficient heating procedure to raw materials before the marination, the adequate acetic acid/salt ratio in marination of all raw materials and the dissolution of CO_2 in the marinated seafood salad which is associated with increased carbonic acid production and with reduced pH level. And these results showed that no microbial contaminations were in the entire production procedures of marinated seafood salad.

Gram *et al*. (1987) reported that the high concentration of CO_2 (40%) and the low residual oxygen delayed microbial growth especially of psychrotrophic Gram-negative and H_2S producing bacteria which are considered to be responsible for fresh seafood spoilage in air and under the modified atmosphere. CO_2 inhibits the

Table 4: Sensory evalutions of air packaged marinated seafood salads during storage period

	Storage period						
	Days			Months			
Sensory evaluation	1	4	7	1	2	3	4
Apperance	5.5^{a}	5.5^{a}	5.5^{a}	5.1^{b}	4.7^{bc}	3.9^{d}	2.8^{fg}
Odour	1.0^{a}	1.0^{a}	1.0^{a}	0.9^{a}	0.8^{ab}	0.6^{c}	0.3^{cd}
Flavour	5.5^{a}	5.5^{a}	5.5^{a}	5.2^{ab}	4.9^{b}	4.2^{cd}	2.7^{fg}
Texture	3.0^{a}	3.0^{a}	3.0^{a}	2.8^{ab}	2.7^{ab}	2.2^{bc}	0.9^{e}
Total	15.0	15.0	15.0	14.0	13.1	10.7	6.7
Quality Class	1.0	1.0	1.0	2.0	2.0	4.0	4.0

*Means with different upper case superscripts in the column are significant different by ANOVA

Table 5: Sensory evalutions of MAPed (M1) marinated seafood salads during storage period

	Storage period									
	Days			Months						
Sensory analysis	1	4	7	1	2	3	4	5	6	7
Apperance	5.5^{a}	5.5^{a}	5.5^{a}	4.7^{bc}	4.4^{c}	4.1^{d}	3.9^{d}	3.4^{e}	2.8^{fg}	2.1$^{\acute{y}}$
Odour	1.0^{a}	1.0^{a}	1.0^{a}	0.9^{a}	0.9^{a}	0.8^{a}	0.7^{a}	0.5	0.4^{c}	0.3^{cd}
Flavour	5.5^{a}	5.5^{a}	5.5^{a}	5.1^{b}	4.7^{bc}	4.5^{c}	4.3^{cd}	4.1^{d}	3.2^{ef}	2.4^{g}
Texture	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}	2.9^{a}	2.6^{b}	2.5^{b}	2.2^{b}	1.5	1.1^{e}
Total	15.0	15.0	15.0	13.7	12.9	12.0	11.4	10.2	7.9	5.9
Quality class	1.0	1.0	1.0	2.0	3.0	3.0	3.0	4.0	4.0	Spoiled

*Means with different upper case superscripts in the column are significant different by ANOVA

Table 6: Sensory evalutions of MAPed (M2) marinated seafood salads during storage period

	Storage period									
	Days			Months						
Sensory analysis	1	4	7	1	2	3	4	5	6	7
Apperance	5.5^{a}	5.5^{a}	5.5^{a}	4.8^{bc}	4.5^{c}	4.0^{d}	3.8^{de}	3.2^{ef}	2.7^{fg}	2.0^{i}
Odour	1.0^{a}	1.0^{a}	1.0^{a}	0.9^{a}	0.9^{a}	0.8^{ab}	0.8^{ab}	0.6^{c}	0.5^{c}	0.3^{cd}
Flavour	5.5^{a}	5.5^{a}	5.5^{a}	5.2^{ab}	4.8^{bc}	4.5^{c}	4.2^{cd}	3.9^{d}	3.0^{f}	2.2^{gh}
Texture	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}	2.9^{a}	2.6^{b}	2.4^{b}	2.1^{c}	1.6^{d}	1.2^{de}
Total	15.0	15.0	15.0	13.9	13.1	11.9	11.2	9.8	7.8	5.7
Quality class	1.0	1.0	1.0	2	2	3	3	4	4	Spoiled

*Means with different upper case superscripts in the column are significant different by ANOVA growth of many spoilage bacteria with the inhibition effect is being increased with increasing CO_2 concentration in the atmosphere. In addition, CO_2 is highly soluble in water and fat and the solubility increases greatly with decreased temperature. The effectiveness of the gas is always conditioned by the storage temperature with increased inhibition of bacterial growth as temperature is decreased (Knoche, 1980; Silvertsvik *et al*., 2002).

A certain amount (depending on the foodstuff) of CO_2 has to dissolve into the product to inhibit bacterial growth (Gill and Penney, 1988). The ratio between the volume of gas and volume of food product (G/P ratio) should usually be 2:1 or 3:1 (volume of gas two or three times the volume of food). This high G/P ratio is also necessary to prevent package collapse because of the CO_2 solubility in wet foods. Dissolved CO_2 takes up much less volume compared with CO_2 gas and after packaging a product in CO_2 atmosphere, under-pressure is developed within the package and package collapse may occur. In the study G/P ratio was 2:1. No package collapse occured during storage period. It is seen that sensory evalutions of control group and MAPed (M1 and M2) marinated seafood salads during storage at +2±2°C were taken place in Table 4-6. When all sensory criteria were taken into consideration, the samples of control group were determined as fourth quality at months 3 and 4 (Table 4). Evaluations indicated that the samples of MAPed (M1 and M2) marinated seafood salad were spoiled on month 7 (Table 5 and 6).

Much more softness in shrimps, hardness and chewing difficulty in the arms of octopus, browny color, acidic odour and off-flavour were experienced by the panellists in the MAPed (M1 and M2) marinated seafood salad samples on the 7th month than on the 6th month of storage at +2±2°C. According to the sensory evaluations, control group and MAPed marinated seafood salads rejected on the 4th month and on the 7th month of storage at +2±2°C, respectively. Statistical comparisons between the results from sensoric changes during the storage period showed that there were significant differencies for reducing values depended on the storage period ($p<0.05$). In addition, it was found that statistical importance between the values of apperance, odour, flavour and texture were higher in month 4th and months 6th and 7th than in the other months in the samples of control group, and M1 and M2 marinated anchovy, respectively.

CONCLUSION

It was concluded that TBA values depending on the level of fatty oxidation and sensory evaluation determined the shelf-life of MAPed marinated seafood salad during storage at +2±2°C. MAPed marinated seafood salads were edible until the 7th month of storage as compared to air-packaged marinated seafood salad (the 4th month of storage). The shelf-life of marinated seafood salad could be extended 3 months by MAP as compared to air-packaging, and two different gas mixture (M1 and M2) in MAP had same effect on taking to this shelf-life.

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