



- RESEARCH ARTICLE -

The Effects of Sous-Vide Cooking Method on Rainbow Trout by Adding Natural Antioxidant Effective Sage: Basic Quality Criteria

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Abstract

The sage (*Salvia officinalis*, Linnaeus 1753) after grinding was applied on the fillet surface. The vacuum packaged fillets were sous-vide cooked, and rapidly cooled, then stored in the refrigerator. Total antioxidant effect of sage was $110.90 \pm 1.46\%$. The treatments applied to fish have not significant effects on the ash, protein, and total lipid values of samples. The decrease in the moisture content of the sage applied group (SAG) was found significant. The heat treatment significantly increased the pH values of samples. TVB-N values were determined between 13.03 ± 0.22 and 22.69 ± 0.15 mg/100g in SAG. TBARS values were lower in the SAG compared to the sous vide processed fish (SUG). The lowest sensorial values were obtained in the SAG for color, odor, texture and general appreciation on the 45th day, and for appearance and juiciness on the 40th day. With the sage treatment, the shelf life and acceptability of the samples were extended to at least 5 days. Application sage as the natural antioxidant had no negative effects with regard to sensory and nutritional criteria.

Keywords:

Fatty acid, *Oncorhynchus mykiss*, quality change, sensory quality, total antioxidant capacity

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Introduction

For a healthy life, the sustainability of vital human activity as well as daily energy intake, the protein, lipid, minerals and vitamins intake with the sufficient amount is a necessity. FAO Standing Advisory Committee founded in 1948 has declared the necessity of food and energy is the first and foremost issue for a human (FAO, 2003). In the world, despite enough sufficient intake of energy intake, insufficient animal protein intake leads to malnutrition (Dölekoğlu, 2002; Direk et al.,

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2008). Today the relationship between food and illness and their preventive effects are actual and most popular subject (FAO, 2003).

The desire for a healthy and long life is a commonly accepted merit for humankind. The numbers of health problems are rising in both developed and developing countries with increasing population. The focused research on plant-based diets and functions of phytochemicals for nutrition and ageing brought clarity to progress (Poyrazoğlu & Velioglu, 2005; Meskin et al., 2008). The studies showed polyphenols and carotenoids have risk-reducing effects of certain cancers and cardiovascular diseases besides health-promoting properties (Meskin et al., 2008). The prolonged life together with growing population is the most important success of humankind from prehistoric times to the present. The rate of infant death is almost equal to zero in developed countries parallel to studies for a prolonged average lifetime (Timiras, 2008).

Nowadays, consumers highly demand fresh tasty, high-quality, slightly salted, non-additives and food prepared in a short time. The significant increase in producing less processed foods, which can be heated in a microwave, are ready to eat, have a prolonged shelf life with chilling foods in the USA and EU markets. Such processed products which are comprised of vacuum packaged and (sous-vide) processed foods are called as new generation chilled products (Novak et al., 2003).

The Sage is an herb member of Labiatae (Lamiaceae) family and is also frequently used in traditionally pharmaceutical, cooking and food industry due to their potential antimicrobial and antioxidant effects (Baydar, 2009; Yanishlieva et al., 2006; Gutierrez et al., 2009; Razavi et al., 2014; Erkan et al., 2015). Also, sage is used as a natural preservative for meat, poultry, fish, and condiments (Razavi et al., 2014).

The sous-vide technology is a pasteurization application in vacuum packaged foods. If this packaging technology is applied with chill, stocking provides a longer shelf life of food. Therefore, the importance of this processing method is increasing every day. In this technology, foods are cooked with or without their packaged spices and sauces. Then, they can be served after simple heating in hot water or microwave oven. In this sense, the method can function effectively for ready food industry. At the same time, the method was useful for the preservation of fast perishable foods. Since the fish and fish products spoils very fast, they are appropriate foods for sous-vide technology application (Mol & Özturan, 2009). In this study, it was aimed to determine the quality changes of sous-vide cooked rainbow trout, and sage applied, during chilling storage.

Material and methods

Sample preparation

In the study, the effects of vacuum packaging, sous vide application, and sous vide application with sage treatment on the nutrition features of rainbow trout, were which determined on the initial and change along the storage period, were examined. The study was conducted in order to identify the changes and effects on four fish groups that were used; vacuumed fish (FFV), sous vide processed fish (SUG), and sage applied and sous vide processed fish groups (SAG). The Fresh, FFV, and SUG data in this study were previously used in Çetinkaya et al. (2017) for comparison and control.

The fish used in the study were obtained from Suleyman Demirel University fish farming ponds. They were transported in ice cubes to the laboratory and then were filleted. Then, the fillets

were divided in equal weights (150 g) and were stored in deep freeze ($-18\pm 1^{\circ}\text{C}$). The dried sage was obtained from Suleyman Demirel University, the Faculty of Agriculture and was stored in a dry and shadowy place until use.

Vacuum packages were obtained from a commercial company (Apack Ambalaj Makine Sanayi ve Tic. Lts. Sti. Istanbul - Türkiye). O₂ permeability of the vacuum package material (cast PP) was 22.56 cc/m²/day (24°C), its packaged O₂ permeability was 2.71 cc/day (24°C), its CO₂ permeability was 95.64 cc/m²/day (24°C), its packaged CO₂ permeability was 11.48 cc/day (24°C), its heat resistancy was $-25/150^{\circ}\text{C}$, and total thickness was 0.88 mm.

Freezed fillets were thawed under tap water. In the study, one group fillet was packaged with the vacuum only, one group fillet was packaged with the vacuum and sous-vide processed, and in another group the dust ground sage 0.1% of fillet weight (Selmi & Sadok, 2008) was applied on the fillet surface, and then was packaged with the vacuum and sous-vide processed. Sous vide cooking was made in a benmari (85°C) for 35 minutes (SVAC, 1991; Peck, 1997). Then, the packaged fillets were removed out of benmari and was cooled to 3-4°C for 30 minutes in the bucket which is composed 1/3 water plus 2/3 ice. All the packages were stored in the refrigerator ($3\pm 1^{\circ}\text{C}$).

Chemical analysis

Total antioxidant effect of sage was determined by β -carotene-linoleic acid assay (Dapkevicius et al., 1998; Diri, 2006a). Free radical scavenging capacity was determined 1,1-difenil-2-pikrilhidrazil (DPPH system) (Tepe et al., 2005; Diri, 2006b; Selmi & Sadok, 2008). Total phenolic content of sage was determined by Folin-Ciocalteu assay (Oktay et al., 2003; Diri, 2006b).

For proximate composition the ash and total lipid content were determined according to Lovell (1981). The moisture content was determined through automatic moisture analyzer (AND MX-50 Shimadzu, Japan). The total nitrogen amount of the samples was studied by Velp UD-20 (Italy) protein pre-burning unit and full automatic Velp UDK 142 protein distillation unit, according to Kjeldahl method (Nx6.25) (AOAC, 2000). The rate of pH was measured by (WTW 320 set digital) pH meter in a beaker samples diluted with ratio 1/10 w/v (Varlik et al., 2007). Total volatile basic nitrogen was analyzed through the method reported by Nicholas (2003). The thiobarbituric acid substances were determined as described by Erkan & Özden (2008) that reported method from Weilmeier & Regenstein (2004) and Khan et al. (2006).

Fatty acids analysis was conducted by Perkin Elmer Clarus 500 (GC) in fresh fish and SAG. For this purpose, a flame ionization detector (FID) and a silica AGE colon (30m x 0.32 mm ID x 0.25 μm , BP20 0.25 μm , USA) and Supelco FAME 37 mix were used.

The sensory analysis was done to reflect consumer preferences. The 10 panelists were requested to assess the samples for color, odor, flavor, texture, appearance, and at the same time, compare them with fresh rainbow trout features, juiciness sense while chewing, and general appreciation feeling were identified. The groups, when they are equal to 2 points or lower, were accepted as the spoiled (Huss, 1995; Altuğ & Elmaci, 2005; Diaz et al., 2009; Shakila et al., 2009).

Statistical analysis

Analysis and measurements were carried out in triplicate. For every 5 days, the analysis of the FFV, SAG and SUG groups was carried out until the spoilage. The data were analyzed by ANOVA

(Özdamar, 2001) using SPSS 15. The differences appeared by the treatments (0th day) which are distinct to fresh fish, and the samples on the storage period for intragroup were determined by Duncan test. Also, the effects of sage between SUG and SAG for the TVB-N and TBARS were determined by t-test on the storage period, and marked on the tables as + (significant), and – (insignificant).

Results

The sage was used as a natural antioxidant in this study. Total antioxidant effect, free radical scavenging capacity and total phenolic content of sage were determined as %110,90±1,46, %10,57±1,67, 128,95±0,00 mg/l gallic acid equivalent, respectively.

The effects of sage to proximate composition and quality of sous-vide cooked rainbow trout were investigated throughout the study. The ash content of fresh fish was determined as 1.63±0.1%, whereas for SAG as 1.83±0.21%. The vacuuming did not affect ash contents of samples, but sous vide treatment increased insignificantly ($p>0.05$). The moisture content significantly ($p<0.05$) decreased as a result of sage treatment, and sous vide cooking. Also, the moisture content of FFV and SUG did not significantly ($p>0.05$) changed compared to fresh fish. The protein and lipid content of samples were not affected by vacuum packaging, sous vide cooking, or sage treatment compared to fresh fish.

The initial pH for fresh fish was measured as 6.29±0.01 (Table 1). The vacuuming did not affect the pH value, but the sous vide cooking was significantly affected by the pH ($p\leq 0.05$). Also, the sage application did not have any effect on the pH.

The TVB-N value of the vacuum packaged fish was significantly lower than fresh fish. The TVB-N values of heat treated samples did not change compared to the fresh fish. When the FFV samples were spoiled in the 10 days, the TVB-N value was determined as 18.32±1.98 mg/100g. The TVB-N value was 15.80±0.69 mg/100g for the spoiled SUG sample, whereas 22.69±0.15 mg/100g for the spoiled SAG sample (Table 2). The differences among the data obtained on the 10th and 40th days of analysis were not statistically significant ($p>0.05$) for the SAG, and except the 45th day for SUG. Moreover, the determined differences were found significant ($p\leq 0.05$) on the other days. Insignificant differences were observed all the values in the SAG until 45th days ($p>0.05$). The differences of the sage treatment were shown significant between SUG and SUG on the 20th, 25th, and 35th days.

Table 1. The chemical composition (%) and pH values of samples before and after sous vide cooking, and sage treatment

	Ash	Moisture	Protein	Total lipid	pH
Fresh	a 1.63±0.11	a 78.36±0.18	a 16.49±0.20	a 3.37±0.30	a 6.29±0.01
FFV	a 1.62±0.02	a 78.80±0.40	a 16.89±0.07	a 3.31±0.21	a 6.30±0.27
SUG	a 1.86±0.45	a 78.83±0.23	a 16.39±0.23	a 3.29±0.30	b 6.46±0.01
SAG	a 1.83±0.21	b 77.44±0.24	a 16.43±0.20	a 3.53±0.02	b 6.47±0.00

*Values in the same column with same the lowercase statistically insignificant ($p > 0.05$)

Table 2. TVB-N (mg/100g) values of samples on the storage days

Days	Fresh	FFV	SUG	SAG	Sig. t test
	a	Ab	BCa	Aa	
0	14.71±0.17	11.68±0.47	15.55±0.55	14.62±1.14	-
		A	AB	A	
5		14.04±0.61	14.20±0.34	13.28±0.51	-
		B	A	A	
10		18.32±1.98	12.69±0.34	13.95±1.03	-
			A	A	
15			13.45±0.22	14.54±0.67	-
			A	A	
20			13.70±0.08	13.03±0.22	+
			CD	A	
25			16.14±0.52	13.45±0.22	+
			D	A	
30			17.31±0.83	14.20±1.09	-
			CD	A	
35			16.39±0.44	14.79±0.08	+
			CD	A	
40			15.80±0.69	15.13±0.00	-
				B	
45				22.69±0.15	NT

* The same lowercase for treatment and the same capital letter for the storage period are statistically insignificant ($p > 0.05$). The effects of sage treatment were marked as + (significant), and – (insignificant). *NT (Not Tested)

The obtained value for TBARS in all groups was close to each other at the beginning. Also, statistically significant differences on the TBARS for the treatments were not determined ($p > 0.05$). The TBARS values in the SAG were lower than the SUG throughout the storage period after the 15th sampling days. The highest TBARS values were determined as $1.38 \pm 0.05 \mu\text{g MDA/g}$ for the SUG, and $1.00 \pm 0.10 \mu\text{g MDA/g}$ for the SAG. The TBARS value was lower in the SUG than the SAG on the 10th day of analysis. Among the TBARS values significant differences ($p \leq 0.05$) were seen in all the groups (Table 3). As a result of the sage treatment significant differences were shown between the SUG and the SAG on all the days except the 0, 5th, and 30th days.

Table 3. TBARS ($\mu\text{g MDA/g}$) values of samples on the storage days

Days	Fresh	F	F	V	SUG	SAG	Sig. t test
	a		Aa		Aa	ABa	
0	0.25±0.03	0.32±0.03	0.32±0.03		0.35±0.04	0.27±0.00	-
			A		A	B	
5		0.43±0.04	0.43±0.04		0.31±0.08	0.15±0.02	-
			B		A	EF	
10		1.29±0.10	1.29±0.10		0.43±0.07	0.75±0.07	+
					B	BC	
15					0.80±0.03	0.36±0.00	+
					BC	CD	
20					0.92±0.05	0.52±0.03	+
					C	DE	
25					1.00±0.05	0.61±0.03	+
					BC	EF	
30					0.93±0.04	0.77±0.06	-
					D	G	
35					1.38±0.05	1.00±0.10	+
					C	BC	
40					1.01±0.04	0.43±0.03	+
						FG	
45						0.89±0.09	NT

* The same lowercase for treatment and the same capital letter for the storage period are statistically insignificant ($p > 0.05$). The effects of sage treatment were marked as + (significant), and – (insignificant). *NT (Not Tested)

20 fatty acids were determined in the fresh fish and SAG. 6 of them are SFA (saturated fatty acid). Also, 7 is MUFA (monounsaturated fatty acid), and 7 is PUFA (polyunsaturated fatty acid) (Table 4).

Color, odor, flavor, texture, appearance, juiciness and general appreciation were evaluated as sensory parameters of samples. The obtained odor points for the SAG exceeded the deterioration point on the 45th day (Table 5).

Table 4. Fatty acid profile of fresh fish and SAG during the storage period

Days	/	Fresh	0	5	10	15	20	25	30	35	40	45
C12:0		e 1,02±	a 0,69±	c 0,98±	a 0,75±	b 0,88±	h 1,53±	d 1,09±	f 1,32±	b 0,92±	a 0,75±	h 1,43±
		b 0,06	ab 0,00	ab 0,01	ab 0,01	ab 0,03	b 0,07	b 0,01	ab 0,02	ab 0,02	b 0,01	a 0,02
C14:0		2,08±	1,92±	1,95±	1,92±	2,00±	2,05±	2,01±	1,97±	1,85±	2,03±	1,79±
		ab 0,11	ab 0,04	ab 0,01	ab 0,01	ab 0,11	ab 0,13	ab 0,04	ab 0,01	ab 0,02	b 0,01	a 0,01
C14:1		0,07±	0,06±	0,06±	0,06±	0,07±	0,07±	0,06±	0,07±	0,06±	0,07±	0,06±
		a 0,01	ab 0,00	ab 0,00	ab 0,00	b 0,01	ab 0,01	ab 0,00	ab 0,01	a 0,00	a 0,00	ab 0,01
C16:0		12,4±	12,0±	12,2±	12,3±	12,8±	11,9±	2,05±	12,0±	11,9±	12,1±	12,1±
		c 0,68	abc 0,02	bc 0,09	c 0,06	a 0,82	ab 0,03	a 0,01	abc 0,00	abc 0,10	abc 0,05	ab 0,15
C16:1		2,73±	2,60±	3,05±	3,21±	2,32±	2,38±	2,31±	2,75±	2,65±	2,97±	2,38±
		a 0,15	b 0,00	a 0,39	a 0,00	a 0,10	a 0,10	a 0,01	b 0,09	a 0,11	a 0,10	a 0,27
C17:0		0,85±	0,08±	0,05±	0,05±	0,05±	0,06±	0,05±	0,08±	0,05±	0,06±	0,06±
		a 0,01	a 0,00	a 0,00	a 0,01	a 0,00	a 0,01	a 0,00	b 0,01	a 0,00	a 0,01	a 0,01
C17:1 (Cis-10)		0,95±	0,08±	0,08±	0,08±	0,08±	0,08±	0,08±	0,16±	0,08±	0,09±	0,11±
		a 0,01	c 0,00	bc 0,01	bc 0,01	bc 0,01	ab 0,01	bc 0,00	ab 0,01	bc 0,00	bc 0,00	bc 0,04
C18:0		3,16±	3,81±	3,62±	3,58±	3,57±	3,42±	3,66±	3,39±	3,72±	3,61±	3,71±
		bc 0,41	c 0,01	ab 0,01	ab 0,01	abc 0,19	c 0,18	c 0,00	a 0,05	c 0,02	c 0,04	ab 0,01
C18:1n7		2,59±	2,67±	1,96±	1,89±	2,26±	2,58±	2,74±	1,82±	2,71±	2,81±	1,86±
		abcd 0,05	def 0,03	ef 0,05	f 0,12	cdef 0,51	ab 0,08	abcde 0,03	bcdef 0,04	abc 0,02	ef 0,06	a 0,01
Cis-C18:1n9		22,6±	23,1±	23,3±	23,8±	23,0±	21,8±	22,4±	22,9±	21,9±	23,2±	21,4±
		de 10,19	cd 0,01	fg 0,37	g 0,14	ef 0,12	b 0,13	fg 0,06	g 0,12	bc 0,06	cd 0,15	a 0,10
C18:2n6		22,6±	22,1±	22,6±	22,9±	22,5±	21,6±	22,6±	22,8±	21,9±	22,0±	21,0±
		c 0,23	a 0,01	abc 0,09	bc 0,04	abc 0,21	bc 0,03	bc 0,02	ab 0,05	ab 0,04	abc 0,07	a 0,10
C18:3n3		3,32±	2,94±	3,11±	3,09±	3,21±	3,16±	3,17±	3,23±	3,05±	3,09±	2,95±
		a 0,17	a 0,02	a 0,02	a 0,00	a 0,11	a 0,13	a 0,02	a 0,01	a 0,00	a 0,03	a 0,01
C20:0		0,10±	0,10±	0,10±	0,11±	0,10±	0,10±	0,09±	0,09±	0,09±	0,10±	0,08±
		b 0,01	a 0,00	ab 0,01	b 0,00	ab 0,00	ab 0,01	a 0,00	ab 0,00	ab 0,01	ab 0,02	ab 0,01
C20:1n9		0,99±	1,02±	1,08±	1,16±	1,07±	1,08±	1,02±	1,06±	1,08±	1,09±	1,06±
		abc 0,05	bce 0,00	a 0,01	abc 0,01	bcd 0,04	de 0,05	abc 0,00	ab 0,00	cd 0,00	abc 0,00	e 0,01
C20:2cis		0,51±	0,54±	0,49±	0,51±	0,54±	0,59±	0,51±	0,49±	0,56±	0,51±	0,63±
		c 0,03	ab 0,00	ab 0,01	a 0,00	c 0,02	d 0,03	c 0,00	bc 0,01	c 0,00	bc 0,00	d 0,00
C20:4n6		2,53±	2,42±	2,42±	2,31±	2,70±	2,91±	2,62±	2,56±	2,69±	2,57±	2,89±
		e 0,14	cde 0,00	de 0,02	cde 0,01	e 0,09	bcd 0,12	bc 0,01	bc 0,01	bc 0,02	ab 0,02	cde 0,03

C20:5n3	2,16± 0,12 b	2,09± 0,00 ab	2,14± 0,01 ab	2,09± 0,09 b	2,24± 0,07 b	1,97± 0,08 ab	1,90± 0,01 ab	1,92± 0,08 ab	1,80± 0,01 b	2,05± 0,07 b	1,68± 0,00 a
C22:1n9	0,11± 0,00 ab	0,10± 0,00 abc	0,10± 0,02 ab	0,11± 0,00 c	0,11± 0,01 abc	0,10± 0,01 abc	0,09± 0,00 abc	0,10± 0,01 abc	0,11± 0,01 abc	0,12± 0,01 bc	0,07± 0,01 a
Cis- C22:2	0,12± 0,08 e	0,20± 0,00 cd	0,20± 0,03 bc	0,26± 0,01 a	0,22± 0,01 d	0,21± 0,01 f	0,21± 0,00 e	0,22± 0,04 de	0,22± 0,01 f	0,24± 0,01 ab	0,18± 0,00 g
C22:6n3	10,2± 0,07 abc	10,9± 0,00 a	10,5± 0,07 abc	9,95± 0,04 abc	11,1± 0,09 bc	13,2± 0,06 c	11,6± 0,01 abc	11,4± 0,01 abc	12,9± 0,05 abc	10,2± 0,09 ab	15,2± 0,04 bc
Total	90,2± 0,43 abc	89,6± 0,01 c	90,1± 0,07 abc	90,1± 0,00 abc	90,9± 0,74 bc	91,0± 0,96 a	90,4± 0,00 abc	90,4± 0,02 abc	90,3± 0,58 abc	89,8± 0,52 bc	90,8± 0,19 ab
Unidentified	9,78± 0,43 a	10,4± 0,01 a	9,88± 0,07 a	9,88± 0,00 a	9,09± 0,74 a	9,00± 0,96 a	9,60± 0,00 a	9,58± 0,02 a	9,64± 0,58 a	10,2± 0,52 a	9,18± 0,19 a
SFA	18,86 bc	19,15 d	19,50 d	19,32 c	20,00 b	19,67 b	19,45 bc	19,42 bc	19,10 bc	19,25 d	19,74 a
MUFA	28,85 bc	29,67 a	29,68 a	30,31 a	28,94 b	28,15 cd	28,73 b	28,84 b	28,62 bc	30,36 a	27,00 d
PUFA	43,05	41,30	41,49	41,08	42,53	43,75	42,74	42,69	43,19	40,74	44,62

* Values in the same line the with same lowercase are statistically insignificant (p > 0.05)

Table 5. Sensory evaluation of fresh fish during storage period

Parameters	Groups	0. day	5. days	10. days	15. days	20. days	25. days	30. days	35. days	40. days	45. days	
Color	FFV	7.3± 0.37 ab	8.10± 0.48 a	2.00± 0.15 a	-- a	-- a	-- a	-- a	-- ab	-- b	--	
		SUG	6.3± 0.54 a	7.40± 0.45 a	6.90± 0.38 a	7.75± 0.63 a	7.20± 0.47 a	7.00± 0.56 ab	6.40± 0.31 a	6.30± 0.52 b	4.90± 0.28 b	-- b
	SAG		6.8± 0.51 b	8.00± 0.49 a	7.30± 0.52 c	7.75± 0.25 a	7.10± 0.28 a	6.40± 0.56 a	7.00± 0.58 a	5.10± 0.57 a	5.10± 0.43 a	5.10± 0.23 b
		Odor	FFV	7.10± 0.59 abc	8.50± 0.22 a	1.70± 0.34 bc	-- ab	-- abc	-- bc	-- c	-- bc	-- d
	SUG			6.4± 0.40 b	8.00± 0.26 a	5.90± 0.43 b	7.25± 0.48 b	6.50± 0.52 b	6.10± 0.67 b	4.80± 0.65 b	5.70± 0.63 b	1.90± 0.23 b
			SAG	6.8± 0.47 a	8.60± 0.40 a	6.80± 0.47 b	6.50± 0.87 a	6.50± 0.52 a	6.40± 0.52 a	6.40± 0.48 a	5.90± 0.43 a	5.80± 0.65 a
Flavor	FFV			-- bc	-- a	-- bc	-- a	-- ab	-- bc	-- c	-- c	-- d
		SUG	6.0± 0.47 ab	8.00± 0.39 a	6.10± 0.46 ab	7.75± 0.48 ab	6.90± 0.50 ab	5.80± 0.59 b	5.10± 0.60 b	5.30± 0.37 b	2.30± 0.21 b	-- c
	SAG		6.6± 0.60 a	8.00± 0.49 a	6.60± 0.54 b	6.75± 0.25 a	6.30± 0.73 a	5.90± 0.28 a	5.90± 0.67 a	5.00± 0.58 a	5.80± 0.68 a	2.40± 0.22 c
		Texture	FFV	7.5± 0.37 a	8.40± 0.56 a	2.90± 0.53 a	-- a	-- a	-- a	-- a	-- ab	-- b
SUG	6.90± 0.64 ab			8.00± 0.45 a	6.90± 0.59 abc	8.00± 0.41 ab	7.10± 0.50 ab	6.80± 0.55 bcd	7.30± 0.30 abc	6.30± 0.37 abc	5.00± 0.49 cd	-- d

Appearance	SAG	7.20± 0.51 a	8.00± 0.47 a	6.80± 0.61 b	7.25± 0.63 a	7.30± 0.47 ab	5.90± 0.46 ab	6.70± 0.37 ab	6.90± 0.43 b	5.60± 0.37 d	4.60± 0.27 d
	FFV	7.40± 0.54 ab	8.30± 0.47 ab	3.20± 0.61 b	--	--	--	--	--	--	--
	SUG	6.80± 0.59 ab	7.70± 0.40 a	6.20± 0.61 ab	8.25± 0.75 a	7.40± 0.40 ab	7.30± 0.50 ab	7.30± 0.26 ab	6.40± 0.78 b	3.00± 0.26 b	-- b
	SAG	6.90± 0.50 a	7.80± 0.42 a	7.00± 0.52 b	8.25± 0.48	7.00± 0.33	6.80± 0.47	6.60± 0.54	5.70± 0.52	5.40± 0.75	5.90± 0.38
	FFV	7.50± 0.45 abc	8.70± 0.37 a	3.33± 0.80 bc	--	--	--	--	--	--	--
	SUG	7.20± 0.61 ab	8.20± 0.42 a	6.30± 0.67 abc	7.50± 0.96 ab	7.30± 0.54 bc	5.50± 0.48 c	6.90± 0.38 abc	6.70± 0.65 abc	3.70± 0.40 d	-- bc
Juiciness	SAG	7.50± 0.62 b	8.00± 0.47 a	6.80± 0.39 c	7.75± 0.63 ab	6.00± 0.47 abc	6.30± 0.56 cd	6.50± 0.58 bcd	6.70± 0.63 d	5.60± 0.52 e	6.00± 0.33 bc
	FFV	7.00± 0.58 bcd	8.50± 0.40 a	1.90± 0.23 cd	--	--	--	--	--	--	--
	SUG	6.60± 0.54 b	8.30± 0.45 a	6.10± 0.50 b	7.75± 0.63 b	7.40± 0.45 b	6.00± 0.45 b	6.50± 0.34 b	5.60± 0.37 b	2.70± 0.50 b	-- c
	SAG	7.00± 0.58	8.50± 0.40	6.80± 0.53	7.00± 0.41	6.70± 0.60	6.30± 0.34	6.80± 0.42	5.60± 0.52	5.40± 0.54	2.00± 0.21

* Values in the same line the with same lowercase are statistically insignificant ($p > 0.05$)

Discussion

Nutritional composition of fish was affected by intrinsic (genetical factors e.g. length, sex, life stage) and extrinsic (environmental conditions and nutrition) factors. While the mineral piled up in the rainbow trout by means of water and foods, the trace element density is related to food sources, biological differences, seasonal effects, and environmental conditions (Fallah et al., 2011). In our study, unequal changes of the obtained value may be due to those features.

The sage addition, as a natural antioxidant, does not have a significant effect ($p > 0.05$) on the ash content of samples (Table 1). Özturan (2009) notified the ash contents of sous vide cooked bonito and whiting did not show any differences ($p > 0.05$). Garcia-Linares et al., (2004) found the ash content of sous vide cooked samples were greater than that of samples obtained from the traditional cooking method. In our study, obtained ash contents did not show significant differences ($p > 0.05$) like as results were obtained by Özturan (2009). Çakli (2007) reported ash content of fisheries products were about 0.5-1.8%. The ash values of the samples were compatible with the reported values by Çakli (2007).

The moisture value significantly decreased ($p < 0.05$) in the SAG (Table 1). Fagan & Gormley (2005) reported that the surrounded moisture of samples in the pocket affected texture and flavor, but during the different heat-time treatment of the processing had not effect on the moisture content. On the other hand, the moisture content decreases were reported by heat

treatment and sous vide application (Garcia-Linares et al., 2004; Gonzales-Fandos et al., 2004; Özturan, 2009).

The protein contents was not changed by vacuuming, heat treatment or sage application (Table 1). Garcia-Linares et al., (2004) reported that the protein contents of sous vide processed salmon and rainbow trout decreased, and at the end of storage period they increased significantly ($p < 0.05$). Gonzales-Fandos et al., (2004) determined that protein content of the fresh rainbow trout is 16.04 ± 0.52 g/100 g. This value was the compatible with our results.

Vacuuming, heat treatment, or sage application did not affect the total lipid contents of the sample (Table 1). The lipid content of cooked samples with traditional methods is significantly lower than that of sous vide cooked samples which were reported (Garcia-Linares et al., 2004). The fish is grouped according to fat content; these are lean fish (<3%), mildly fatty fish (3-8%) and, fatty fish (>8%). Also, the fat contents of fish changed between 1-25%, depending on the life stage of fish (Bilen, 2009). The fish whose fat content obtained by us was lean fish.

The frequently used pH for freshness detection was not enough in the quality determination of products, and the obtained values for this purpose and the results of other analysis evaluated at the same time were reported (Bilen, 2009). In our study, the pH values changed significantly ($p < 0.05$) by heat treatment and the sage application (Table 1). Diaz, et al., (2011) were reported the pH was not effective for the cooked rainbow trout deterioration.

According to our value, a decrease was seen on the TVB-N value of vacuumed samples compared to fresh fish. The same decline was not seen on the other group. Also, the TVB-N value of heat treated samples was similar to fresh fish. The TVB-N values of SAG did not show significant differences ($p > 0.05$) until the samples deteriorate. For the freshness determination of fishery products, the analysis of TVB-N was deposited on the meat, which is one of the highly used deterioration parameter (Ruiz-Capillas et al., 2001). TVB-N comprises all of volatile amines (Çakli & Kiliç, 2003) and increases with storage time (Erdem et al., 2005). Cadun et al., (2005) reported 15-20 mg N/100 g TVB-N value is a good quality, and 50 mg N/100 g TVB-N value is a bad quality. Also, Dokuzlu (1997) reported quality ranking of TVB-N content of fish in the 100 g fish meat up to 25 mg as very good, up to 35 mg as good and marketable, more than 35 mg as degraded. Cosansu et al., (2011a, b) specified TVB-N limit value as 30 mg/100g. Since the FFV, SUG, SAG deteriorated, the TVB-N values were determined as 18.32 ± 1.98 mg/100g, 15.80 ± 0.69 mg/100g and 22.69 ± 0.15 mg/100g respectively. Vacuuming, heat treatment and cold storage were effective for this case. Significant differences ($p > 0.05$) were not seen in the intragroup value of SAG until 45th day (Table 2).

At the beginning of the study, the TBARS values of samples were similar to each other. However, on the 5th day, the TBARS value was determined lower than the value of the first day. Significant differences ($p < 0.05$) were seen in the obtained values for the groups on different days. On the other hand, the TBARS values were very low since the beginning of the study. This situation had appeared due to vacuum packaging, and permeability features of vacuum pouches. While examining the values obtained from the SAG and SUG, only when individual differences are excluded in fish, the effect which lipid oxidation reduced almost 50% was seen between the obtained values of that day. For example, the highest value was obtained as 1.38 ± 0.05 μ g MDA/g for SUG group on the 35th day. On the other hand, by the end of storage the TBARS value was

determined as 0.89 ± 0.09 $\mu\text{g MDA/g}$ for the SAG group (Table 3). The TBA value was a significant scale of rancidity because of oil oxidization (Cadun et al, 2005). The appearance of the secondary metabolites as pentanal, hexanal, 4-hydroxynonenal and malondialdehyde (MDA) substrate reacting by TBA with the deterioration of food is called as TBARS (not all MDA) and was determined by TBA test that are based on pink color appearance (Fernandez et al., 1997). The determination of appearance rancidity in the animal foods and the determination of MDA content display a more reliable relation than the peroxide value ($r_s=0,92$), but that the peroxide value displays a good relation with TBA to the oil content with 2-3 double bonds fatty acids was reported (Fernandez et al., 1997). Fernandez et al., (1997) notified that the use of the antioxidant is effective and vacuum packing besides the permeability were affected by the prevention of fish from the lipid oxidization (Vareltzis et al., 1997).

In our study, antioxidant efficiency on the appearance of TBA was seen in the studies completed by Selmi & Sadok (2008) and Bilen (2009). After the heat treatment that the TBA content showed no significant change ($p>0.05$) was reported (Cosansu et al., 2011b; Diaz et al., 2011). Shakila et al., (2012) specified the TBA values were lower and under the limit at the 20°C storage. However, in the conducted studies it was determined that the limit value exceeded most rapidly with the increased heat of storage (Mol et al., 2012 a, b). These values obtained by Cosansu et al., (2011a, b), Diaz et al., (2011) and Mol, et al., (2012a, b) were higher than the ones obtained by us. The reason for this position may be differences of fish species (sea fish and freshwater fish).

The change of total SFA value of SAG was not significant along the storage period (Table 4). These fatty acids were most stable. But, total value of both MUFA and PUFA were signified fluctuant change. The change in these fatty acids is statistically significant. Because of antioxidant properties, the application of sage had prevented the fatty acids significantly to change relatively during storage compared to fresh fish. In general, fatty acid values were changed in the opposite direction to TBARS values for total SFA and MUFA according to days.

Sensory evaluation is the most significant parameters for the quality assessment of fishery products. If it does not have a sensorial demand, even a product gets very high scores for all quality parameters, it will not be consumed (Dokuzlu, 1997; Özden et al., 2001). Alasalvar et al (2011) specified, when the fishery products were consumed, the appreciation level relating to quality when the appeared as sensory and perceptual, as conscious and subconscious were based on the appearance, odor, flavor, texture, and in most cases appearance was effective at the appreciation level. In our study, the panelist was asked to evaluate the samples in terms of color, odor, flavor, texture compared with fresh fish and newly cooked the rainbow trout, also in terms of the juiciness, and at the same time, the appearance of products, the juiciness level during the chewing in order to reflect general appreciation level for their evaluating parameters.

In the color assessment, the SAG obtained higher appreciation points than the SUG. When low points are obtained for the color parameter in all the groups of samples, it is higher than the limit value, and even deterioration is seen.

Odor parameter was effective to deteriorate the decision of panelists for all the samples. It was decided that the samples should have deteriorated and should not have been suitable for human consumption by the sensorial evaluation on the 10th day for TFF, on the 40th day for SUG, and on

the 45th day for SAG. Also, the sensorial evaluation points of samples, the limit value for the deterioration is 2 points, equal or lower to limit value on those days.

The SUG obtained lower sensorial points than the SAG for the flavor parameter. When the deterioration occurred, the lowest points were obtained (Table 5).

The texture points showed a rapid decrease in the FFV when the deterioration was seen on the 10th day. Same decreases were not seen in other groups of samples. The obtained points for other sample group were in the limit values (Table 5).

The highest points of appearance for all the samples, except for the FFV, were obtained by evaluations on the 15th day. On the 20th, 25th, and 30th days, higher appearance points for the SUG were obtained than that for the SAG (Table 5).

The values of juiciness did not show significant ($p>0.05$) differences among the sample group. It showed unequal change (Table 5).

The general appreciation decreased during the storage period. The SAG has been the most popular groups. When the samples deteriorated, the points for the SUG and the SAG were determined as 2.70 ± 0.50 and 2.00 ± 0.21 , respectively (Table 5).

High heat treatment reduced the sensory quality, so the application of 60-80°C heat was suggested (Cosansu et al. 2011a). They declared that the fish treated at 70°C had a good quality for the sensorial evaluation. Diaz et al. (2009) emphasized that basically odor and flavor values of sous vide cooked fish were affected, the texture parameter was least affected, and the juiciness decreased significantly during the cold storage. The time-heat applications were not effective on the texture value of vacuum-packaged cooked samples (Fagan & Gormley, 2005).

The high scores of sensorial analysis on the initial study decreased depending on the storage temperature and the treatment during the storage period (Shakila et al., 2009; Mol et al., 2012a). Our results for sensorial evaluation were similar to the other studies. The high sensorial scores for the initially showed reduction depending on the storage time.

Conclusion

In this study, the sous vide processing method was applied to the rainbow trout, and fresher appearance, appropriateness for taste, readiness for eating foods with newly marketing opportunities were obtained. Also, with the sage treatment, the shelf life of samples was extended for 5 more days. The sage, which were known to have the natural antioxidant and antimicrobial features, and were used with sous vide processed samples, should have been evaluated for the determination of health benefits of the samples, which the studies are required to do.

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References

- Alasalvar, C., Shahidi, F., Miyashita, K. & Wanasundara, U. (2011). Seafood quality, safety and health application. In Alasalvar, C., Shahidi, F., Miyashita, K., Wanasundara, U. (Ed.), *Handbook of Seafood Quality, Safety and Health Application*, (1-10). Blackwell Publishing, 542 p, UK.
- Altuğ, T. & Elmacı, Y. (2005). *Gıdalarda Duyusal Değerlendirme*. Meta Basım Matbacılık Hizmetleri, 130s, İzmir, Türkiye.
- AOAC, (2000). AOAC official method 940.25 Nitrogen (Total) in Seafood. First Action 1940, *Official Methods of Analysis of AOAC International*, 17th Ed.
- Baydar, H. (2009). *Tıbbi ve aromatik bitkiler bilimi ve teknolojisi*. (3. Baskı). Süleyman Demirel Univ. Yay. No:51. SDÜ Basımevi, 348s, Isparta.
- Bilen, G. (2009). Dondurulmuş balığın kalitesinde doğal antioksidanların etkisi. İstanbul Üniversitesi Fen Bilimleri Enstitüsü, Su Ürünleri Avlama ve İşleme Anabilim Dalı İşleme Teknolojisi Programı. Yüksek Lisans Tezi, 98s, İstanbul, Türkiye.
- Cadun, A., Cakli, S. and Kisla, D. (2005). A study of marination of deep water pink shrimp (*Parapenaeus longirostris*, Lucas, 1846) and its shelf life. *Food Chemistry*, 90:53-59.
- Cosansu, S., Mol, S., Alakavuk, D. U. & Ozturan, S. (2011a). The effect of lemon juice on shelf life of sous vide packaged whiting (*Merlangius merlangus euxinus*, Nordmann, 1840). *Food Bioprocess Technol.* 6(1):283-289 doi:10.1007/s11947-011-0572-0. Published online: 12 April 2011.
- Cosansu, S., Mol, S., Alakavuk, D. U. & Ozturan, S. (2011b). the effect of lemon juice on bonito (*Sarda sarda*, Bloch, 1793) preserved by sous vide packaging. *International Journal of Food Science and Technology*, 46(2):395-401. doi:10.1111/j.1365-2621.2010.02507.x
- Çaklı, S. & Kılınç, B. (2003). Sardalya balığından (*Sardina pilchardus*) marinat yapımı ve raf ömrü üzerine bir çalışma. Proje Sonuç Raporu, Tubitak, Proje No: VHAG-1839 (101V130). 77s, İzmir, Türkiye.
- Çaklı, Ş. (2007). *Su ürünleri işleme teknolojisi*. 1. Ege Üniv. Yay. Su Ürünleri Fak. Yay. No:76 Ege Üniv. Basımevi İzmir, ISBN: 978-975-483-761-2.
- Çetinkaya, S., Bilgin, Ş. & Ertan, Ö. O. (2017). Increasing Shelf Life of SousVide Cooked Rainbow Trout by Natural Antioxidant Effective Rosemary: Basic Quality Criteria. *Journal of Limnology and Freshwater Fisheries Research*, 3 (2): 69-77 doi: [10.17216/limnofish.318327](https://doi.org/10.17216/limnofish.318327)
- Dapkevicius, A., Venskutonis, R., van Beek, T. A. & Linssen, J. P. H. (1998). Antioxidant activity of extracts obtained by different isolation procedures from some aromatic herbs grown in Lithuania. *Journal of the Science of Food and Agriculture*, 77(1):140-146. doi:10.1002/(sici)1097-0010(199805)77:1<140::aid-jsfa18>3.3.co;2-b
- Diaz, P., Nieto, G., Banon, S. & Garido, M. D. (2009). Determination of shelf life of sous vide salmon (*Salmo Salard*) based on sensory attributes. *Journal of Food Science*, 74(8): 371-376. doi:10.1111/j.1750-3841.2009.01317.x

- Diaz, P., Garrido, M. D. & Banon, S. (2011). Spoilage of sous vide cooked salmon (*Salmo salar*) stored under refrigeration. *Food Science and Technology International*, 17, 31-37.
- Direk, M., Kan, A. & Sert, D. (2008). Hazır yemek sektörünün pazarlama yapısının irdelenmesi. *Türkiye 10. Gıda Kongresi*. 21-23 Mayıs, Erzurum, Türkiye.
- Diri, M. (2006a). *Coridothymus capitatus* (L.) Reichb. uçucu yağının analizi, su ve etanol ekstraktlarının antioksidant aktivitelerinin belirlenmesi. Muğla Üniversitesi Fen Bilimleri Enstitüsü Kimya Anabilim Dalı, Yüksek Lisans Tezi, 101 s, Muğla.
- Diri, H. A. (2006b). *Salvia candidissima* Vahl. Uçucu Bileşenlerin Karakterizasyonu ve Antioksidant Aktivitelerinin Belirlenmesi. Muğla Üniversitesi Fen Bilimleri Enstitüsü, Kimya Anabilim Dalı, Yüksek Lisans Tezi, 119 s, Muğla.
- Dokuzlu, C. (1997). Marinat hamsi üretimi sırasında kullanılan asit - tuz oranlarının ürünün mikrobiyolojik ve organoleptik kalitesi üzerine etkileri ve raf ömrünün belirlenmesi. *Pendik Veteriner ve Mikrobiyoloji Dergisi*, 28(1):81-90.
- Dölekoğlu, C. Ö. (2002). Tüketicilerin işlenmiş gıda ürünlerinde kalite tercihleri, sağlık riskine karşı tutumları ve besin bileşimi konusunda bilgi düzeyleri (Adana örneği). Çukurova Üniversitesi Fen Bilimleri Enstitüsü Tarım Ekonomisi Anabilim Dalı, Doktora Tezi, 171 s, Adana, Türkiye.
- Erdem, M. E., Bilgin, S. & Çağlak, E. (2005). Tuzlanmış ve marinasyon yöntemleri ile işlenmiş istavrit balığı'nın (*Trachurus mediterraneus*, Steindachner, 1868) muhafazası sırasında kalite değişimleri. *Ondokuz Mayıs Üniversitesi Ziraat Fakültesi Dergisi*, 20(3):1-6.
- Erkan, N. & Özden, Ö. (2008). Quality assessment of whole and gutted sardines (*Sardina pilchardus*) stored in ice. *International Journal of Food Science and Technology*, 43(9):1549–1559. doi:10.1111/j.1365-2621.2007.01579.x.
- Erkan, N., Doğruyol, H., Günlü, A. & Genç, İ. Y. (2015). Use of natural preservatives in seafood: Plant extracts, edible film and coating. *J Food Health Sci*. 1(1):33-49. doi: 10.3153/JFHS15004
- Fagan, J. D. & Gormley, T. R. (2005). Effect of sous vide cooking, with freezing, on selected quality parameters of seven fish species in a range of sauces. *European Food Research and Technology*, 220(3-4):299-304. doi:10.1007/s00217-004-1028-9
- Fallah, A. F., Saei-Dehkordi, S. S. & Nematollahi, A. (2011). Comparative assessment of proximate composition, physicochemical parameters, fatty acid profile and mineral content in farmed and wild rainbow trout (*Oncorhynchus mykiss*). *International Journal of Food Science and Technology*, 46(4):767-773. doi:10.1111/j.1365-2621.2011.02554.x
- Food & Agriculture Organization, (2003). *Food energy-methods of analysis and conversion factors*. Report of a Technical Workshop Rome, 3–6 December 2002. Food Nutrition Paper 77. 87 p.
- Fernandez, J., Perez-Alvarez, A. J. & Fernandez-Lopez, J. A. (1997). Thiobarbituric acid test for monitoring lipid oxidation in meat. *Food Chemistry*, 59(3):345-353. doi:10.1016/s0308-8146(96)00114-8

- Garcia-Linares, M. C., Gonzales-Fandos, E., Garcia-Fernandez, M. C. & Garcia-Arias, M. T. (2004). Microbiological and nutritional quality of sous vide or traditionally processed: Influence of fat content. *Journal of Food Quality*, 27(5):371-387. doi:10.1111/j.1745-4557.2004.00676.x
- Gonzales-Fandos, E., Garcia-Linares, M. C., Villarino-Rodriguez, A., Garcia-Arias, M. T. & Garcia-Fernandez, M. C. (2004). Evaluation of the microbiological safety and sensory quality of rainbow trout (*Oncorhynchus mykiss*) processed by the sous vide method. *Food Microbiology*, 21(2):193-201. doi:10.1016/s0740-0020(03)00053-4
- Gutierrez, J., Barry-Ryan, C., & Bourke, P. (2009). Antimicrobial activity of plant essential oils using food model media: Efficacy, synergistic potential and interaction with food components. *Food Microbiology*, 26(2):142-150. doi:10.1016/j.fm.2008.10.008
- Gülyavuz, H. & Ünlüsayın, M. (1999). *Su ürünleri işleme teknolojisi*. Süleyman Demirel Üniversitesi Egirdir Su Ürünleri Fak. Ders Kitabı, Şahin Matbaası, 366s, Ankara, Türkiye.
- Huss, H. H. (1995). *Quality and quality changes in fresh fish*. Fao Fisheries Technical Paper-348, 172 p, Rome.
- Lovell, R. T. (1981). *Laboratory manuel for fish feed analysis and fish nutrition studies*. Department of Fisheries and Allied Aquacultures International Center for Aquaculture, Auburn University, 65 p, Alabama.
- Meskin, S. M., Bidlack, R. W. & Randolph, R. K. (2008). *Phytochemicals aging and health*. CRC Press, 205 p, Boca Raton, USA.
- Mol, S. and Özturan, S. (2009). Sous-vide teknolojisi ve su ürünlerindeki uygulamalar. *Journal of Fisheriesciences.com*, 3(1): 68-75. DOI: 10.3153/jfsc.com.2009010
- Mol, S., Ozturan, S. & Cosansu, S. (2012a). Determination of the quality and shelf life of sous vide packaged bonito (*Sarda sarda*, Bloch, 1793) stored at 4 and 12 C. *Journal of Food Quality*, 35(2):137-143. doi:10.1111/j.1745-4557.2011.00430.x.
- Mol, S., Ozturan, S. & Cosansu, S. (2012b). Determination of the quality and shelf life of sous vide packaged whiting (*Merlangius merlangus euxinus*, Nordman, 1840) stored at cold (4C) and temperature abuse (12C). *Journal of Food Processing and Preservation*, 36(6):497-503 doi:10.1111/j.1745-4549.2011.00616.x
- Nicholas, T.A. (2003). Antimicrobial use of native and enzymatically degraded chitosans for seafood applications. The University of Maine the Graduate School, Master Thesis 130p, Maine.
- Novak, J. S., Sapers, G. M. & Juneja, V. K. (2003). *Microbial Safety of Minimally Processed Foods*. CRC Press LLC, 343p, Boca Raton, USA.
- Oktay, M., Gülçin, İ., & Küfrevioğlu, Ö. (2003). Determination of in vitro antioxidant activity of fennel (*Foeniculum vulgare*) seed extracts. *LWT - Food Science and Technology*, 36(2), 263-271. doi:10.1016/s0023-6438(02)00226-8
- Özdamar, K. (2001). *SPSS ile Biyoistatistik*. Kaan Kitabevi, 452s, Eskişehir, Türkiye.
- Özden, Ö., Metin, S., Baygar, T. & Erkan, N. (2001). Vakum paketlenmiş marine balıkların kalitesinin belirlenmesinde yağ asitleri ve aminoasit bileşimindeki değişimlerin

- incelenmesi. Proje Sonuç Raporu, Tübitak, Proje No: VHAG-1713/ADP, 29s. İstanbul, Türkiye.
- Özturan, S. (2009). Vakum ambalajda pişirilmiş (sous vide) balıkta kalite ve raf ömrünün belirlenmesi. İstanbul Üniversitesi Fen Bilimleri Enstitüsü, Avlama ve İşleme Teknolojisi Anabilim Dalı İşleme Teknolojisi Programı, Yüksek Lisans Tezi, 94 s, İstanbul, Türkiye.
- Peck, M. W. (1997). *Clostridium botulinum* and the safety of refrigerated processed foods extended durability. *Trends in Food Science and Technology*, 8, 186-192.
- Poyrazoğlu, S. & Velioglu, S. (2005). Beta karotenin oksidasyonuna sıcaklık, ışık, süre ve gallik asitin etkisi. *Gıda Mühendisliği Dergisi*, 20, 50-54.
- Razavi, S. M. A., Cui, S. W., Guo, Q. & Ding, H. (2014). Some physicochemical properties of sage (*Salvia macrosiphon*) seed gum. *Food Hydrocolloids*, 35 453-462
<http://dx.doi.org/10.1016/j.foodhyd.2013.06.022>
- Ruiz-Capillas, C., Gillyon, C. M. & Horner, W. F. A. (2001). Determination of different volatile base components as quality control indices in fish by official methods and flow injection analysis. *Journal of Food Biochemistry*, 25(6):541-553. doi:10.1111/j.1745-4514.2001.tb00813.x.
- Selmi, S. & Sadok, S. (2008). The Effect of natural antioksidant (*Thymus vulgaris* (Linnaeus)) on flesh quality of tuna (*Thunnus thynnus* (Linnaeus)) during chilled storage. *Pan- American Journal of Aquatic Sciences*, 3(1): 36-45.
- Shakila, J. R., Jeyasekaran, G., Vijayakumar, A. & Sukumar, D. (2009). Microbiological quality of sous-vide cook chill fish cakes during chilled storage (3°C). *International Journal of Food Science and Technology*, 44(11):2120-2126. doi:10.1111/j.1365-2621.2009.02047.x
- Shakila, R. J., Raj, B. E. & Felix, N. (2012). Quality and safety of fish curry processed by sous vide cook chilled and hot filled technology process during refrigerated storage. *Food Science and Technology International*, 18(3):261-269. doi:10.1177/1082013211415177.
- SVAC, (1991). *Code of Practice for Sous Vide Catering System*. Tetbury, Gloucestershire, UK.
- Tepe, B., Daferera, D., Sokmen, A., Sokmen, M. & Polissiou, M. (2005). Antimicrobial and antioxidant activities of the essential oil and various extracts of *Salvia tomentosa* Miller (Lamiaceae). *Food Chemistry*, 90(3):333-340. doi:10.1016/j.foodchem.2003.09.013
- Timiras, S. P. (2008). Technophysiology, evolution, and aging toward a new image of aging. In Meskin, S. M., Bidlack, R. W., Randolph, R. K. (Ed.) *Phytochemicals Aging and Health*. (1-17). CRC Press, 205 p, Boca Raton, USA.
- Vareltzis, K., Koufidis, D., Gavriilidou, E., Papavergou, E. & Vasiliadou, S. (1997). Effectiveness of a natural rosemary (*Rosmarinus officinalis*) extract on the stability of filleted and minced fish during frozen storage. *Z Lebensm Unters Forsch A*, 205, 93-96.

- Varlık, C., Özden, Ö., Erkan, N. & Alakavuk, D. Ü. (2007). *Su Ürünlerinde Temel Kalite Kontrol*. İstanbul Üniversitesi Yayın No. 4662, Fakülte Yayın No:8 202 s, İstanbul, Türkiye.
- Yanishlieva, N. V., Marinova, E. & Pokorny, J. (2006). Natural antioxidants from herbs and spices. *European Journal of Lipid Science and Technology*, 108(9): 776-793. doi: 10.1002/ejlt.200600127