Influence of Sumac Extract on the Physico-chemical Properties and Oxidative Stability of Some Cold Pressed Citrus Seed Oils

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Abstract: The acidity values changed between 1.03 mgKOH/100g (control) and 1.11 mgKOH/100g (0.1% extract) for orange oil, 1.06 mgKOH/100g (0.5% extract) and 1.13 mgKOH/100g (0.1% extract) and 1.25 mgKOH/100g (0.5% extract) and 1.31 mgKOH/100g (control) for mandarin oil. The peroxide values were determined between 1.37 meqO₂/kg (0.5% extract) and 1.43 meqO₂/kg (0.1% extract) for orange oil, between 1.24 meqO₂/kg (control) and 1.27 meqO₂/kg (0.1% extract) for lemon and 1.60 meqO₂/kg (0.5% extract) and 1.71 meqO₂/kg (control) in mandarin oil samples. The viscosity values of samples changed between 0.051 Pa.S (control) and 0.065 Pa.S (0.5% extract) for orange, 0.051 Pa.S (control) and 0.067 Pa.S (0.5% extract) for lemon and 0.044 Pa.S (control) and 0.057 Pa.S (0.5% extract) in mandarin oil samples. At the end of storage study (28th day), the acidity values significantly changed, and their values ranged between 2.28 mgKOH/100g (0.5% extract) and 3.64 mgKOH/100g (control) in orange, 1.67 mgKOH/100g (0.5% extract) and 2.28 mgKOH/100g (control) in lemon and 1.74 mgKOH/100g (0.5% extract) and 2.36 mgKOH/100g (control) in mandarin oil samples. While peroxide values vary between 11.68 meqO₂/kg (0.5% extract) and 32.57 meqO₂/kg (control) for orange, 12.55 meqO₂/kg (0.5% extract) and 34.63 meqO₂/kg (control) for lemon and between 17.56 meqO₂/kg (0.5% extract) and 37.81 meqO₂/kg (control) for mandarin oils, viscosity values after 28 day storage changed between 0.123 Pa.S (0.5% extract) and 0.675 Pa.S (control) in orange, 0.257 Pa.S (0.5% extract) and 0.697 Pa.S (control) in lemon and 0.215 Pa.S (0.5% extract) and 0.728 Pa.S (control) in mandarin oil samples.

Key words: sumac extract, citrus oils, oxidative stability, viscosity, storage, cold press

1 Introduction

Sumac (*Rhus coriaria* L.) is traditionally being used as a natural medication. The use of the plant in seasonings and flavoring agents has been the mainstay of indigenous remedies in different dietary cultures around the globe¹. Sumac is used as a spice, and has been used in cooking for millennia. About 2000 years ago, the Greek physician Pedenius Dioscorides wrote in his voluminous "De Materia Medica" about the healthful properties of sumac, principally as a diuretic and anti-flatulent². The leave, stick and seeds of sumac plant contain substantial amounts of several biologically important components, and the most important of those are the phenolic compounds^{1, 3-8}. Sumac is one of the major sources of phenolic, bioactive phytochemical compound and its functional ingredients have widespread

and potential usability in chemical and pharmaceutical industries⁹. Candan and Sökmen¹⁰ reported that antioxidative capacity of *R. coriaria* fruits has been evaluated using *in vitro* systems. The IC₅₀ value of the sumac extracts, for lipid peroxidation inhibition, was estimated as 1200 µg/mL in the Fe²⁺-ascorbate system¹⁰. A previous study about stabilizing food products using sumac extracts included the use of a methanolic extract of the fruits added to sunflower oil stored at 70°C and peroxide values of the stored oil was measured at regular intervals. Sumac extract was found to be very effective in stabilizing the sunflower oil¹¹. Antioxidant properties for stabilizing peanut was also reported in which methanol extracts of *R. coriaria* fruits and leaves were added to peanut oil at concentration of 1 to 5% (w/v) and it was observed that the formation of hydroperoxide

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Accepted January 21, 2020 (received for review November 17, 2019)

Journal of Oleo Science ISSN 1345-8957 print / ISSN 1347-3352 online

<http://www.jstage.jst.go.jp/browse/jos/> <http://mc.manuscriptcentral.com/jjocs>

was inhibited during the initial 7 day storage, however after 28 day storage, the antioxidant potential of sumac extract substantially decreased in comparison to BHA controls³⁾. Ferik *et al.*¹²⁾ estimated the antioxidant effect of sumac to be 50 fold more than vitamin C and E. Antioxidant capacity and radical scavenging activity of sumac water extract were significantly higher than that of ethanol extract¹³⁾. Sumac water extract was more effective than BHT, and could be added to meat products (sausage) to enhance the overall product quality¹⁴⁾. The aim of current study was to investigate the effect of sumac extracts on physico-chemical properties and oxidative stability of cold pressed orange, lemon and mandarin seed oils.

2 Material and Methods

2.1 Material

In this study, orange (Barile cv.), lemon (Interdonato cv.) and mandarin (Clementine cv.) cultivated in Adana and Mersin provinces in Turkey were used to obtain seed oil. Seed from these fruits were separated from pulp manually, and washed with distilled water and dried at room temperature. The dried kernels were milled in laboratory to pass through 60-mesh sieve, and the samples were kept at 4°C before further processing and analyses. Ripened Sumac (*Rhus coriaria* L.) fruits were collected from Mersin (Gülner-Büyükeceli) province in Turkey during September 2018 and dried at room temperature. They were ground to a powdered form using a lab scale grinder.

2.2 Method

2.2.1 Cold press

Citrus seed oils from orange, lemon and mandarin were obtained using cold screw extraction process at room temperature, where the initial rotation was 1500 rpm and the final one was approximately 3600 rpm. After broken or damaged citrus seeds and other impurities such as stem and skin were removed, whole seeds were extracted with cold screw press (2-6 liter/h capacity) without heat treatment. The impurities were removed to ensure high quality oil. After pressing, the oil was purified from solid impurities by sedimentation for one week. Sedimentation process followed filtration and storage of the purified oil in hermetically closed colored bottle under the nitrogen at -18°C.

2.2.2 Extraction from sumac fruit

About 10g of ground sumac (*Rhus coriaria* L.) sample was extracted using Soxhlet apparatus for 5h and methanol was used as solvent. The extracts were filtered using filter paper, and the solvent was removed using rotary evaporator (40°C + Vacuum). In experiment, three different levels (0.1%, 0.3% and 0.5%) of sumac extracts were used as additives to three different citrus seed oils. Sumac extracts at a concentration of 0.1%, 0.3% and 0.5% were added

into each 50 mL citrus oil in three petri plates, respectively. Then the oil in the petri plate was thoroughly mixed and kept at 50°C for 28 days. Analyses were carried out at weekly intervals.

2.2.3 Analysis

The acid value, iodine value, peroxide value, saponification value, unsaponifiable matter, density, refractive index, and viscosity of citrus seed oils were determined using standard methods¹⁵⁾.

2.2.4 Statistical analyses

The analysis of variance (ANOVA) was performed by using JMP version 9.0 (SAS Inst. Inc., Cary, N.C.U.S.A.). All analyses were carried out three times and the results are mean $\pm$ standard deviation (MSTAT C) of citrus oils and sumac extract concentrations¹⁶⁾.

3 Results and Discussion

The physico-chemical properties of citrus oils treated with sumac fruit extracts are presented in Table 1. The results showed differences depending on extract concentrations and storage periods of citrus oils. Generally, acidity, peroxide values, refractive index, saponification values of treated oil samples decreased with increase of extract concentration at the beginning of storage. While acidity values change between 1.03 mgKOH/100g (control) and 1.11 mgKOH/100g (0.1% extract) in case of orange oil, 1.06 mgKOH/100g (0.5% extract) and 1.13 mgKOH/100g (0.1% extract) in case of lemon oil, 1.25 mgKOH/100g (0.5% extract) and 1.31 mgKOH/100g (control) in mandarin oil, peroxide values varied between 1.37 meqO₂/kg (0.5% extract) and 1.43 meqO₂/kg (0.1% extract) in case of orange oil, 1.24 meqO₂/kg (control) and 1.27 meqO₂/kg (0.1% extract) in lemon oil and 1.60 meqO₂/kg (0.5% extract) and 1.71 meqO₂/kg (control) in mandarin oil at the beginning of storage. Depending on extract concentrations, density and viscosity values of oil samples increased. The density values were between 0.884 mg/mL (control) and 0.899 (0.5% extract) in orange oil, 0.857 (control) and 0.868 mg/mL (0.5% extract) in lemon oil and 0.876 mg/mL (control) and 0.886 mg/mL (0.5% extract) in mandarin oil. The viscosity values ranged between 0.051 Pa.S (control) and 0.065 Pa.S (0.5% extract) in orange seed oil, 0.051 Pa.S (control) and 0.067 Pa.S (0.5% extract) in lemon seed oil and 0.044 Pa.S (control) and 0.057 Pa.S (0.5% extract) in mandarin seed oil.

Physico-chemical properties of citrus oils treated with different sumac extract concentrations showed remarkable changes after 7th day of storage. The acidity values were between 1.18 mgKOH/100g (0.5% extract) and 1.38 mgKOH/100g (control) for treated orange oil, 1.38 mgKOH/100g (0.5% extract) and 1.48 mgKOH/100g (0.1% extract) lemon oil and 1.47 mgKOH/100g (0.5% extract)

Table 1 Effect of sumac extract addition at different concentrations (0.1-0.5%) on physico-chemical properties of cold pressed orange, lemon and mandarin oils during storage.

Storage time (0 th day)	Orange (Barile) oil with sumac extract				Lemon (Interdonato) oil with sumac extract				Mandarin (Clementine) oil with sumac extract			
Parameter	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%
Acidity (mgKOH/100g)	1.03 ± 0.13*d	1.11 ± 0.09a**	1.09 ± 0.07b	1.05 ± 0.011c	1.07 ± 0.21c	1.13 ± 0.09b	1.15 ± 0.07a	1.06 ± 0.15c	1.31 ± 0.05c	1.37 ± 0.03a	1.33 ± 0.18b	1.25 ± 0.21d
Peroxide value (meqO ₂ /kg)	1.38 ± 0.18b	1.43 ± 0.13a	1.39 ± 0.15b	1.37 ± 0.18c	1.24 ± 0.09cd	1.27 ± 0.07a	1.25 ± 0.11c	1.26 ± 0.13ab	1.71 ± 0.03a	1.66 ± 0.18b	1.65 ± 0.11c	1.60 ± 0.08d
Refractive Index (n ²⁰ D)	1.541 ± 0.004a	1.537 ± 0.009b	1.511 ± 0.011c	1.503 ± 0.013d	1.514 ± 0.003a	1.512 ± 0.008ab	1.509 ± 0.007c	1.501 ± 0.003d	1.491 ± 0.005a	1.487 ± 0.003b	1.481 ± 0.005c	1.478 ± 0.003d
Iodine value (gI ₂ /100g)	98.74 ± 0.17b	98.81 ± 1.26a	98.69 ± 1.13c	98.67 ± 1.32cd	111.73 ± 0.28c	112.13 ± 0.29a	111.91 ± 1.13b	111.31 ± 0.98d	105.71 ± 0.56a	105.32 ± 0.62b	104.61 ± 0.45c	104.17 ± 0.13d
Saponification value (mgKOH/100g)	193.8 ± 1.45a	193.4 ± 1.57a	192.9 ± 1.63c	194.1 ± 1.87a	194.81 ± 1.33a	194.12 ± 1.42a	193.83 ± 1.38b	193.24 ± 1.25b	193.52 ± 1.53a	193.11 ± 1.73b	192.87 ± 1.27c	192.64 ± 1.19d
Unsaponifiable matter (%)	1.71 ± 0.13b	1.74 ± 0.09a	1.70 ± 0.15c	1.69 ± 0.11d	1.83 ± 0.13a	1.80 ± 0.27b	1.78 ± 0.23c	1.77 ± 0.09cd	1.19 ± 0.07a	1.17 ± 0.32b	1.13 ± 0.14c	1.10 ± 0.07d
Density (mg/mL; 25°C)	0.884 ± 0.003d	0.889 ± 0.001c	0.893 ± 0.005b	0.899 ± 0.003a	0.857 ± 0.001d	0.859 ± 0.003c	0.863 ± 0.002b	0.868 ± 0.001a	0.876 ± 0.002d	0.879 ± 0.002c	0.883 ± 0.001b	0.886 ± 0.003a
Viscosity (Pa.S; 25°C)	0.051 ± 0.003d	0.057 ± 0.005c	0.061 ± 0.007b	0.065 ± 0.003a	0.051 ± 0.003d	0.059 ± 0.005c	0.064 ± 0.009b	0.067 ± 0.005a	0.044 ± 0.001d	0.047 ± 0.003c	0.051 ± 0.007b	0.057 ± 0.003a
Storage time (7th day)	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%
Acidity (mgKOH/100g)	1.38 ± 0.09a	1.29 ± 0.07b	1.21 ± 0.01c	1.18 ± 0.03d	1.41 ± 0.05c	1.48 ± 0.01a	1.45 ± 0.11b	1.38 ± 0.05d	1.59 ± 0.03b	0.63 ± 0.01a	1.55 ± 0.07c	1.47 ± 0.03d
Peroxide value (meqO ₂ /kg)	5.27 ± 0.16a	4.93 ± 0.18b	2.71 ± 0.09c	2.63 ± 0.11cd	6.35 ± 0.07a	5.58 ± 0.09b	5.33 ± 0.13c	4.61 ± 0.17d	7.98 ± 0.21a	6.37 ± 0.15b	5.89 ± 0.11c	5.07 ± 0.13d
Refractive Index (n ²⁰ D)	1.540 ± 0.003a	1.532 ± 0.001c	1.520 ± 0.001d	1.538 ± 0.005b	1.511 ± 0.003a	1.509 ± 0.001bc	1.510 ± 0.003ab	1.508 ± 0.001bc	1.490 ± 0.003b	1.495 ± 0.003a	1.490 ± 0.001b	1.482 ± 0.005c
Iodine value (gI ₂ /100g)	98.60 ± 1.21ab	98.73 ± 1.17a	98.57 ± 1.28b	98.61 ± 1.31ab	111.61 ± 1.46b	111.69 ± 1.57a	111.67 ± 1.84ab	111.20 ± 1.43c	105.21 ± 1.32a	105.18 ± 1.57b	105.13 ± 1.78c	105.17 ± 1.64bc
Saponification value (mgKOH/100g)	193.51 ± 1.67a	193.14 ± 0.98b	192.97 ± 0.78c	192.86 ± 1.32d	194.50 ± 1.23a	194.32 ± 1.56c	194.15 ± 1.87d	194.42 ± 1.36a	193.29 ± 1.54a	193.07 ± 0.87b	192.96 ± 0.65c	192.95 ± 0.98cd
Unsaponifiable matter (%)	1.70 ± 0.34a	1.69 ± 0.36b	1.68 ± 0.45c	1.67 ± 0.33d	1.80 ± 0.27b	1.79 ± 0.13c	1.77 ± 0.23d	1.81 ± 0.36a	1.17 ± 0.45a	1.15 ± 0.09b	1.13 ± 0.11bc	1.16 ± 0.07ab
Density (mg/mL; 25°C)	0.883 ± 0.001d	0.887 ± 0.003c	0.893 ± 0.001b	0.899 ± 0.005a	0.855 ± 0.003d	0.861 ± 0.001c	0.869 ± 0.002b	0.875 ± 0.001a	0.875 ± 0.001d	0.879 ± 0.003c	0.885 ± 0.001b	0.892 ± 0.003a
Viscosity (Pa.S; 25°C)	0.093 ± 0.001a	0.104 ± 0.005b	0.109 ± 0.007c	0.103 ± 0.003d	0.105 ± 0.001a	0.111 ± 0.003b	0.117 ± 0.001c	0.106 ± 0.003d	0.098 ± 0.001d	1.127 ± 0.005a	1.015 ± 0.001b	1.003 ± 0.005c
Storage time (14th day)	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%
Acidity (mgKOH/100g)	1.63 ± 0.13a	1.47 ± 0.09b	1.39 ± 0.07c	1.28 ± 0.11d	1.74 ± 0.15a	1.71 ± 0.09b	1.68 ± 0.03c	1.57 ± 0.05d	1.83 ± 0.17b	1.87 ± 0.13a	1.77 ± 0.21c	1.56 ± 0.09d
Peroxide value (meqO ₂ /kg)	12.76 ± 0.45a	9.63 ± 0.36b	8.77 ± 0.93c	6.48 ± 0.74d	15.67 ± 0.65a	13.86 ± 0.58b	11.73 ± 0.69c	8.64 ± 0.43d	18.46 ± 0.52a	16.35 ± 0.38b	14.58 ± 0.21c	11.44 ± 0.78d
Refractive Index (n ²⁰ D)	1.531 ± 0.003a	1.527 ± 0.001bc	1.519 ± 0.001c	1.528 ± 0.005b	1.510 ± 0.001d	1.513 ± 0.003c	1.517 ± 0.003b	1.521 ± 0.005a	1.488 ± 0.001b	1.496 ± 0.005a	1.491 ± 0.003d	1.485 ± 0.001c
Iodine value (gI ₂ /100g)	98.33 ± 1.24a	98.26 ± 1.32c	98.11 ± 0.98d	98.29 ± 0.76b	111.59 ± 0.58b	111.57 ± 1.16c	111.49 ± 1.27d	111.61 ± 1.37a	105.08 ± 1.46ab	105.01 ± 1.32c	104.97 ± 1.48d	105.09 ± 1.23a
Saponification value (mgKOH/100g)	192.94 ± 1.45a	192.81 ± 1.38b	192.77 ± 1.21c	192.44 ± 1.56d	194.32 ± 1.73a	194.15 ± 1.49c	194.01 ± 2.56d	194.20 ± 1.76b	193.17 ± 1.38a	193.05 ± 1.71b	192.87 ± 1.64c	192.83 ± 1.59d
Unsaponifiable matter (%)	1.69 ± 0.13a	1.60 ± 0.21b	1.57 ± 0.09c	1.63 ± 0.07d	1.84 ± 0.05a	1.80 ± 0.11b	1.75 ± 0.23b	1.78 ± 0.27c	1.16 ± 0.09a	1.14 ± 0.05c	1.12 ± 0.09d	1.15 ± 0.07b
Density (mg/mL; 25°C)	0.882 ± 0.001a	0.888 ± 0.003b	0.895 ± 0.001c	0.897 ± 0.002cd	0.852 ± 0.001d	0.857 ± 0.003c	0.868 ± 0.001b	0.877 ± 0.003a	0.873 ± 0.001d	0.878 ± 0.005c	0.884 ± 0.003b	0.893 ± 0.001a

Table 1 Continued.

Storage time (0 th day)	Orange (Barile) oil with sumac extract				Lemon (Interdonato) oil with sumac extract				Mandarin (Clementine) oil with sumac extract			
Parameter	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%
Viscosity (Pa.S; 25°C)	0.138 ± 0.013d	0.157 ± 0.011b	0.169 ± 0.021a	0.145 ± 0.033c	0.174 ± 0.017c	0.187 ± 0.015a	0.184 ± 0.013b	0.151 ± 0.015d	0.150 ± 0.009b	0.161 ± 0.018a	0.138 ± 0.021c	0.127 ± 0.015d
Storage time (21st day)	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%
Acidity (mgKOH/100g)	1.87 ± 0.03a	1.65 ± 0.13b	1.58 ± 0.09c	1.43 ± 0.07d	1.91 ± 0.05a	1.87 ± 0.03b	1.76 ± 0.01c	1.63 ± 0.05d	1.99 ± 0.11b	2.07 ± 0.23a	1.88 ± 0.17c	1.61 ± 0.09d
Peroxide value (meqO ₂ /kg)	24.76 ± 1.34a	13.98 ± 1.21b	12.28 ± 1.18c	8.57 ± 0.67d	28.44 ± 1.32a	17.28 ± 1.18b	13.48 ± 0.97c	10.26 ± 0.38d	31.67 ± 1.56a	25.86 ± 1.58b	21.58 ± 1.27c	14.97 ± 1.32d
Refractive Index (n ²⁰ D)	1.529 ± 0.003a	1.525 ± 0.001b	1.526 ± 0.003b	1.527 ± 0.001b	1.509 ± 0.003d	1.511 ± 0.005c	1.514 ± 0.003b	1.518 ± 0.001a	1.486 ± 0.005a	1.483 ± 0.001c	1.485 ± 0.003ab	1.486 ± 0.007a
Iodine value (gI ₂ /100g)	98.30 ± 0.56a	98.25 ± 0.61c	98.19 ± 0.73d	98.27 ± 0.81b	111.57 ± 0.98ab	111.55 ± 0.77c	111.48 ± 0.65cd	111.58 ± 0.57a	105.03 ± 0.96a	104.97 ± 0.86c	104.95 ± 0.83cd	105.01 ± 0.91b
Saponification value (mgKOH/100g)	192.91 ± 1.38a	192.87 ± 1.57b	192.75 ± 1.62c	192.40 ± 1.46d	194.10 ± 1.78a	193.90 ± 1.53c	193.87 ± 1.78cd	194.08 ± 1.25ab	193.50 ± 1.39a	193.48 ± 1.32ab	193.07 ± 1.45b	192.97 ± 1.67c
Unsaponifiable matter (%)	1.69 ± 0.13a	1.65 ± 0.09b	1.61 ± 0.10c	1.59 ± 0.11d	1.81 ± 0.09	1.79 ± 0.13b	1.77 ± 0.05bc	1.80 ± 0.13a	1.15 ± 0.07a	1.13 ± 0.05bc	1.11 ± 0.03d	1.14 ± 0.09ab
Density (mg/mL; 25°C)	0.881 ± 0.003d	0.888 ± 0.001c	0.895 ± 0.003b	0.901 ± 0.005a	0.853 ± 0.003d	0.858 ± 0.001c	0.861 ± 0.003b	0.879 ± 0.005a	0.872 ± 0.007d	0.874 ± 0.003c	0.876 ± 0.005b	0.880 ± 0.001a
Viscosity (Pa.S; 25°C)	0.257 ± 0.13a	0.203 ± 0.21c	0.187 ± 0.18da	0.221 ± 0.15b	0.286 ± 0.32c	0.293 ± 0.15b	0.297 ± 0.09a	0.287 ± 0.11c	0.311 ± 0.23a	0.287 ± 0.13b	0.251 ± 0.18c	0.178 ± 0.15d
Storage time (28th day)	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%	Control	0.1%	0.3%	0.5%
Acidity (mgKOH/100g)	3.64 ± 0.34a	3.37 ± 0.51b	3.13 ± 0.29c	2.28 ± 0.45d	2.28 ± 0.13a	2.01 ± 0.18b	1.88 ± 0.27c	1.67 ± 0.15d	2.36 ± 0.17a	2.11 ± 0.23b	1.88 ± 0.21c	1.74 ± 0.18d
Peroxide value (meqO ₂ /kg)	32.57 ± 1.27a	24.36 ± 2.34b	18.44 ± 1.18c	11.68 ± 1.67d	34.63 ± 1.36a	25.47 ± 1.13b	18.78 ± 1.28c	12.55 ± 1.134d	37.81 ± 1.56a	30.64 ± 1.63b	23.87 ± 1.28c	17.56 ± 1.17d
Refractive Index (n ²⁰ D)	1.527 ± 0.003a	1.524 ± 0.001c	1.526 ± 0.005b	1.526 ± 0.001b	1.508 ± 0.001c	1.510 ± 0.003bc	1.511 ± 0.003b	1.517 ± 0.005a	1.484 ± 0.001b	1.480 ± 0.003d	1.483 ± 0.001c	1.485 ± 0.005a
Iodine value (gI ₂ /100g)	98.27 ± 1.32a	98.25 ± 1.21b	98.22 ± 1.18c	98.25 ± 1.27b	111.55 ± 1.46a	111.51 ± 1.53b	111.47 ± 1.58c	111.55 ± 1.61a	105.00 ± 1.56a	104.95 ± 1.73bc	104.91 ± 1.49c	104.98 ± 1.38b
Saponification value (mgKOH/100g)	192.90 ± 1.25a	192.88 ± 1.18b	192.84 ± 1.61c	192.68 ± 1.45d	194.07 ± 1.32a	193.91 ± 1.57b	193.86 ± 1.49c	194.05 ± 1.35ab	193.45 ± 1.37a	193.41 ± 1.65b	193.32 ± 1.53c	193.21 ± 1.38d
Unsaponifiable matter (%)	1.68 ± 0.13a	1.64 ± 0.17b	1.62 ± 0.09c	1.58 ± 0.05d	1.80 ± 0.07a	1.77 ± 0.18b	1.75 ± 0.11bc	1.79 ± 0.21ab	1.14 ± 0.09a	1.11 ± 0.05bc	1.07 ± 0.03c	1.12 ± 0.05b
Density (mg/mL; 25°C)	0.880 ± 0.001d	0.887 ± 0.003c	0.892 ± 0.005b	0.899 ± 0.007a	0.851 ± 0.003d	0.859 ± 0.005c	0.864 ± 0.005b	0.876 ± 0.001a	0.870 ± 0.009d	0.874 ± 0.005c	0.875 ± 0.005b	0.879 ± 0.001a
Viscosity (Pa.S; 25°C)	0.675 ± 0.013a	0.476 ± 0.015b	0.389 ± 0.021c	0.123 ± 0.017d	0.697 ± 0.009a	0.613 ± 0.007b	0.583 ± 0.023c	0.257 ± 0.018d	0.728 ± 0.029a	0.547 ± 0.031b	0.326 ± 0.019c	0.215 ± 0.009d

*mean ± standard deviation; **Values within each row followed by different letters are significantly different ($p < 0.05$)

and 1.63 mgKOH/100g (0.1% extract) for mandarin oil. Peroxide values at the 7th day of storage changed between 2.63 meqO₂/kg (0.5% extract) and 5.27 meqO₂/kg (control) for orange oil, 4.61 meqO₂/kg (0.5% extract) and 6.35 meqO₂/kg (control) for lemon oil and 5.07 meqO₂/kg (0.5% extract) and 7.98 meqO₂/kg (control) in case of mandarin oil. Partial significant differences were observed in case of refractive index and iodine values of treated oils depending on extract concentrations. The density values were between 0.883 mg/mL (control) and 0.899 mg/mL (0.5% extract) in case of orange oil, 0.855 mg/mL (control) and 0.875 mg/mL (0.5% extract) in lemon oil and 0.875 mg/mL

(control) and 0.892 mg/mL (0.5% extract) for mandarin oil. The viscosity values were found between 0.093 Pa.S (control) and 0.109 Pa.S (0.3% extract) in orange oil, 0.105 Pa.S (control) and 0.117 Pa.S (0.3% extract) in lemon oil and 0.098 Pa.S (control) and 1.127 Pa.S (0.1% extract) in mandarin oil.

After 14th day of storage, the acidity values varied between 1.28 mgKOH/100g (0.5% extract) and 1.63 mgKOH/100g (control) in orange oil, 1.57 mgKOH/100g (0.5% extract) and 1.74 mgKOH/100g (control) in lemon oil and 1.56 mgKOH/100g (0.5% extract) and 1.83 mgKOH/100g (control) in case of mandarin oil. The perox-

Fig. 1 Acidity values of citrus oils treated by sumac extract at different concentrations.

ide values changed between 6.48 meqO₂/kg (0.5% extract) and 12.76 meqO₂/kg (control) in orange oil, 8.64 meqO₂/kg (0.5% extract) and 15.67 meqO₂/kg (control) in lemon oil and 11.44 meqO₂/kg (0.5% extract) and 18.46 meqO₂/kg (control) in mandarin oil after 14th day. Partially significant differences were observed among refractive index, iodine and saponification values of sumac treated citrus oils at the 14th day of storage. The saponifiable values of treated oil samples partially decreased with increasing extract concentration. The density values varied between 0.882 mg/mL (control) and 0.897 mg/mL (0.5% extract) in orange oil, between 0.852 mg/mL (control) and 0.877 mg/mL (0.5% extract) in lemon oil and between 0.873 mg/mL (control) and 0.893 mg/mL (0.5% extract) in mandarin oil after treatment with sumac extract. The viscosity values of samples varied between 0.138 Pa.S (control) and 0.169 Pa.S (0.3% extract) in orange oil, 0.151 Pa.S (0.5% extract) and 0.187 Pa.S (0.1% extract) in lemon oil and 0.127 Pa.S (0.5% extract) and 0.161 Pa.S (0.1% extract) in mandarin oil samples.

The analytical results on 21st day of storage showed that acidity values remained 1.43 mgKOH/100g (0.5% extract) to 1.87 mgKOH/100g (control) in orange oil, 1.63 mgKOH/100g (0.5% extract) to 1.91 mgKOH/100g (control) in lemon oil and 1.61 mgKOH/100g (0.5% extract) to 2.07 mgKOH/100g (0.1% extract) in mandarin oil samples. The peroxide values were found between 8.57 meqO₂/kg (0.5% extract) and 24.76 meqO₂/kg (control) in orange oil, 10.26 meqO₂/kg (0.5% extract) and 28.44 meqO₂/kg (control) in lemon oil and 14.97 meqO₂/kg (0.5% extract) and 31.67 meqO₂/kg (control) in mandarin oil samples. The unsaponifiable matter values were determined between 1.59% (0.5% extract) and 1.69% (control) in orange oil and 1.77%

(0.3% extract) and 1.81% (control) in lemon oil. The density values were 0.881 mg/mL (control) to 0.901 mg/mL (0.5% extract) in orange oil, 0.853 mg/mL (control) to 0.879 mg/mL (0.5% extract) in lemon oil and 0.872 mg/mL (control) to 0.880 mg/mL (0.5% extract) in mandarin oil. The viscosity values varied between 0.187 Pa.S (0.3% extract) and 0.257 Pa.S (control) in orange oil, 0.178 Pa.S (0.5% extract) to 0.311 Pa.S (control) in lemon oil.

At the 28th day of storage, acidity values were detected between 2.28 mgKOH/100g (0.5% extract) and 3.64 mgKOH/100g (control) in orange oil, 1.67 mgKOH/100g (0.5% extract) and 2.28 mgKOH/100g (control) in mandarin oil and 1.74 mgKOH/100g (0.5% extract) and 2.36 mgKOH/100g (control) in mandarin oil samples after addition of sumac extracts (Fig. 1). The peroxide values were found between 11.68 meqO₂/kg (0.5% extract) and 32.57 meqO₂/kg (control) in orange oil, 12.55 meqO₂/kg (0.5% extract) and 34.63 meqO₂/kg (control) in lemon oil and 17.56 meqO₂/kg (0.5% extract) and 37.81 meqO₂/kg (control) in mandarin oil samples (Fig. 2). The unsaponifiable matter values of oil samples changed between 1.58% (0.5% extract) and 1.68% (control) for orange, 1.75% (0.3% extract) and 1.80% (control) for lemon, and 1.07% (0.3% extract) and 1.14% (control) for mandarin oil samples. The density values of citrus seed oils treated with sumac extract at different concentrations also showed changes, and varied between 0.880 mg/mL (control) and 0.899 mg/mL (0.5% extract) for orange, 0.851 mg/mL (control) and 0.876 mg/mL (0.5% extract) for lemon and 0.870 mg/mL (control) and 0.879 mg/mL (0.5% extract) for mandarin seed oil samples (Fig. 3). The viscosity values of samples changed between 0.123 Pa.S (0.5% extract) and 0.675 Pa.S (control) in orange, between 0.257 Pa.S (0.5%

Fig. 2 Peroxide values of citrus oils treated by sumac extract at different concentrations.

Fig. 3 Density values of citrus oils treated by sumac extract at different concentrations.

extract) and 0.697 Pa.S (control) in lemon and from 0.215 Pa.S (0.5% extract) and 0.728 Pa.S (control) in mandarin oil samples (Fig. 4).

Depending on storage periods of citrus seed oils, the acidity values changed between 1.03 mgKOH/100g (0th day) and 3.64 mgKOH/100g (28th day) for orange oil samples. The acidity values of orange oil containing 0.5% sumac extract were determined to be 1.05 mgKOH/100g (0th day) and 2.28 mgKOH/100g (28th day). The acidity values of lemon oils for control group varied between 1.07 mgKOH/100g (0th day) and 2.28 mgKOH/100g (28th day) while that of samples treated with 0.5% sumac extract changed between 1.06 mgKOH/100g (0th day) and 1.67

mgKOH/100g (28th day). The acidity values of mandarin oils for control group changed between 1.31 mgKOH/100g (0th day) and 2.36 mgKOH/100g (28th day) whereas in case of oil sample with 0.5% sumac extract concentration, acidity value varied between 1.25 mgKOH/100g (0th day) and 1.74 mgKOH/100g (28th day).

During storage of citrus oils treated with sumac extracts at varying concentrations, peroxide values were observed in the ranges of 1.38 (0th day) and 32.57 meqO₂/kg (28th day) in orange control, 1.24 meqO₂/kg (0th day) and 34.63 meqO₂/kg (28th day) in lemon control group and 1.71 meqO₂/kg (0th day) and 37.81 meqO₂/kg (28th day) in mandarin control samples. The peroxide values of citrus oils with 0.5%

Fig. 4 Viscosity values of citrus oils treated by sumac extract at different concentrations.

sumac extract were determined between 1.37 meqO₂/kg (0th day) and 12.55 meqO₂/kg (28th day) for orange, 1.26 meqO₂/kg (0th day) and 12.55 meqO₂/kg (28th day) for lemon and 1.60 meqO₂/kg (0th day) and 17.56 meqO₂/kg (28th day) for mandarin seed oils. The refractive index values changed between 1.541 (0th day) and 1.527 (28th day) for orange control while that of lemon oils with 0.5% sumac extract varied between 1.514 (0th day) and 1.517 (28th day) and in case of mandarin control, 1.491 (0th day) and 1.484 (28th day). The refractive index values of mandarin oil with 0.5% extract varied between 1.478 (0th day) and 1.485 (28th day). Depending on storage periods, the density values of control orange oils were measured between 0.884 mg/mL (0th day) and 0.880 mg/mL (28th day) while the density values of orange oils with 0.5% sumac extract were between 0.899 mg/mL (0th day) and 0.899 mg/mL (28th day). The density values were between 0.857 mg/mL (0th day) and 0.851 mg/mL (28th day) control lemon oil whereas that of lemon oil with 0.5% sumac extract varied between 0.868 mg/mL (0th day) and 0.876 mg/mL (28th day). In addition, density values of control mandarin oil changed between 0.876 mg/mL (0th day) and 0.870 mg/mL (28th day) while that of mandarin oil with 0.5% sumac extract were determined between 0.886 mg/mL (0th day) and 0.879 mg/mL (28th day). The viscosity values of control orange oil samples depending on storage times were measured between 0.051 Pa.S (0th day) and 0.675 Pa.S (28th day) while that of orange oils with 0.5% sumac extract were detected between 0.065 Pa.S (0th day) and 0.123 Pa.S (28th day). In addition, the viscosity values of control lemon oil changed between 0.051 Pa.S (0th day) and 0.698 Pa.S (28th day) whereas samples containing 0.5% sumac extract showed a viscosity variation from 0.067 Pa.S (0th day) to 0.257 Pa.S (28th day). The

viscosity values of control mandarin oil changed between 0.044 Pa.S (0th day) and 0.728 Pa.S (28th day) while that of mandarin oil with 0.5% sumac extract were between 0.057 Pa.S (0th day) and 0.215 Pa.S (28th day). Hence, the acidity, peroxide and viscosity values of control citrus oils increased with storage time whereas acidity, peroxide, refractive index, unsaponifiable matter and density values of citrus oils treated with sumac extract at different concentrations decreased with increasing storage time. The most effective extract concentration was found to be 0.5% in terms of these parameters. Other concentrations showed partial effects on physico-chemical properties and storage stability of citrus oils. Differences were noted on physico-chemical properties of citrus oils with sumac extracts added at different concentrations and with changes storage periods. These differences can be probably due to physico-chemical properties of both sumac extracts and citrus oils at different storage times. In addition, these differences might also resulted due to the biochemical reactions of citrus oil and sumac extracts. In general, the partial rise in the viscosity of citrus oils may be due to partial polymerization of the oil in the presence of oxygen. Almost all the concentrations of sumac extracts affected peroxide values and acidity values of citrus oils. Generally, the highest effect on acidity and peroxide values were observed by the 0.5% concentrations of sumac extract. Sumac, which is grown in Mediterranean and Southeastern Anatolian regions of Turkey, was utilized by Özcan and Akgül^{11, 17)} for sunflower oil stability and observed beneficial effects. Bashash *et al.*¹⁸⁾ reported that water extracts of sumac exhibited effective antioxidant and radical scavenging activities as compared extracts prepared in other solvents. The antioxidant capacity values were between 58.802% (Brown

sumac powder) and 82.566% (Brown sumac fruit) for sumac extract ethanol, between 81.243% (Brown sumac powder) and 86.709% (red sumac powder) for sumac distilled water extract⁸⁾. Mazaheri Tehrani *et al.*¹⁸⁾ reported that the antioxidant activity, free radical scavenging and reducing capacity of sumac extract in ethanol were higher than those of the aqueous one. It has been observed that the three types of sumac seed extracts (SSEs) exhibited different antioxidant activities in another study¹⁹⁾ wherein the methanolic SSEs contained larger amounts of phenolic and flavonoid compounds and have higher antioxidant activities than those of aqueous or ethanolic SSEs. Staghorn sumac (*Rhus hirta* L.) is a native tree in Eastern Canada whose fruit has been used by aboriginal peoples to treat various illnesses, and has recently been found to be a good source of antioxidants²⁰⁾. Oxidative stability of black cumin, coriander and niger crude and stripped seed oils was determined and compared. According to results, oxidative stabilities of crude oils were stronger than their stripped counterparts and the order of oxidative stability was as follows: coriander > black cumin > niger seed²¹⁾. The antioxidant properties of potato peels and sugar beet pulp, in comparison with synthetic antioxidant, were investigated. The order of oxidative stability was as follow: TBHQ > potato peels > BHT = sugar beet pulp > BHA²²⁾. Kiralan and Ramadan²³⁾ investigated the effect of heating and microwave treatment on the levels of volatile oxidation products and the stability of safflower (*Carthamus tinctorius* L.), sesame (*Sesamum indicum*) and canola (*Brassica napus* L.) cold-pressed oils. 2-Heptenal and 2,4-heptadienal isomers were determined as key constituents in canola oil, while hexanal and 2-heptenal are found in high levels in safflower and sesame oils in oven conditions²³⁾. Current study also reports an effective utilization of sumac extracts, prepared in methanol, for stabilizing certain physico-chemical properties of citrus oil stored for 28 days at higher than ambient temperatures. Further studies can be carried out on evaluating functional and biological properties of citrus seed oil containing sumac fruit extract.

4 Conclusion

It can be inferred that after addition of sumac flower extract to oil samples from seed of orange, lemon and mandarin different physico-chemical properties were affected. For instance, the peroxide and acidity values increased with storage but they were kept lower in samples containing extracts in comparison to control whereas viscosity was observed to higher in control (without extract) at the end of storage in citrus oil samples. The concentration of extract in the oil samples also showed partial changes in the studied parameters and the most profound effects were observed at highest extract concentration (0.5%)

used in this study.

Acknowledgement

The authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University – Saudi Arabia for its funding this Research Group No (RG-1439-016).

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