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Effects of the powdered fruit of *Rhus coriaria* L. addition on quality attributes based on total polyphenols content of smoothie during storage

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The effects of sumac (5, 15, and 30 g/L) addition on the quality attributes of fruit and vegetable smoothies were investigated over refrigerated storage. A slight decrease in pH was observed in the samples of the sumac-fortified drink, compared to the control smoothie (without the spice). On the third day of the study, the addition of 5, 15, and 30 g/L of sumac reduced the total number of microorganisms by 1.46, 2.07, and 2.95 $\log_{10}$ CFU/ml, respectively, compared to the control. The supplementation of the smoothie with 30 g/L of sumac increased the content of polyphenolic compounds on the first day of storage by 54%, compared to the control sample. This indicates that natural sumac can be used for enrichment of foodstuffs with healthy food ingredients.

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1. Introduction

Fruit and vegetable smoothies, regarded as functional drinks, have been gaining acceptance and rapidly growing popularity among consumers, as they have turned out to be a good source of vitamins, phenolic compounds, carotenoids, and other bioactive substances [1-3]. Unfortunately, these types of products must be consumed soon after preparation or within 24 hours to avoid spoilage during storage. Thermal preservation methods used to control the growth of microorganisms are not a suitable solution for this-type of products, because such treatments may reduce their quality attributes [4-6].

The application of novel natural antimicrobials (especially herbs and spices) to assure the safety of smoothies and prevent quality loss is a promising alternative [7, 8]. Sumac (*Rhus coriaria* L.) represents the cashew family (Anacardiaceae). The shrub grows up to 3 m high and has spirally arranged deciduous leaves. Its greenish-yellow flowers are gathered in a long and dense panicle. The fruits are lenticular drupes, slightly fleshy, surrounded by short glandular hairs, with one seed. The finished spice is a granular, red-burgundy powder. It is distinguished by a characteristic smell and a sour and slightly fruity aftertaste, which gives the dishes a distinct character [9, 10]. Sumac has potential antiviral properties and can be used in complementary therapy to prevent infections and enhance immunity [11-13]. The plant is rich in various classes of phytochemicals (flavonoids, anthocyanins, phenolic and organic acids), vitamins (C, B_6, B_1, B_2) and minerals (Ca, P, Mg). Many scientists have reported that aqueous and alcohol extracts of sumac fruit used in meat and its products as well as fish or oils exhibit strong antioxidant and/or antibacterial activity [14-17]. To the best of our knowledge, sumac has not been used as a smoothie ingredient to date. Therefore, the aim of this study was to assess the effect of powder sumac fruit addition on the quality attributes of fruit and vegetable smoothies.

2. Materials and Methods

2.1. Smoothie Preparation Enriched with Sumac

The smoothie was prepared from freshly pressed juice of good quality carrots cv. Nerac (85%) and bananas cv. Cavendish (15%). Juice was pressed using a slow juicer (Sana EUJ-707, Omega Products, South Korea). The bananas were peeled and cut into small pieces. The products were obtained from a local supermarket. The ingredients were then mixed in a homogenizer (JTC OmniBlend, Guangdong, China) for 60 seconds. Tanner's sumac (*Rhus coriaria* L.) was purchased from a health-food store (Lublin, Poland). The product was ground in a ChemLand laboratory mill, model FW 100 (Stargard, Poland). Powdered sumac fruit with a maximum grain size of 0.5 mm was added to the smoothie in the amount of 5 (sample code S 5), 15 (sample code S 15), and 30 g/L (sample code S 30) and stored refrigerated (6°C) for three days, with daily analyses of the product quality. A smoothie without spices was the control sample (code C).

2.2. Microbiological Analysis

The number of aerobic mesophilic microorganisms was determined in Plate Count Agar (PCA; BioMaxima, Lublin, Poland) after incubation at 30°C for 72 h [18]. Sabouraud Dextrose with Chloramphenicol (BioMaxima, Lublin, Poland) was used to assess the presence of yeast and molds after incubation for 5 days at 25°C [19]. The procedures were performed in sterile conditions provided by a laminar chamber with a CRUMA 670FL UV lamp (El Prat de Llobregat, Barcelona, Spain), and incubation was carried out in a POL-EKO type CLN 115 SMART incubator (Wodzislaw Ślaski, Poland). Typical colonies were counted, and the results were expressed as Log colony forming units per milliliter (Log CFU/mL) of sample.

2.3. Physicochemical Analysis

The pH was measured by direct reading at 25±1°C in a 780 pH Meter Metrohm (Herisau, Switzerland), wchich was calibrated with commercial buffer solutions at pH 7.0 and 4.0. The amount of total polyphenols in the analysed samples was determined with the Folin–Ciocalteu method, reading the results in a UV/Vis Helios Omega 3 spectrophotometer (Massachusetts, MA, USA). The absorbance of the mixture was measured at 765 nm after 90 minutes of storage in the dark at room temperature. The results were expressed as milligrams of gallic acid per 100 mL sample. The color of the samples was measured using a 3Color spectrophotometer SF80 (Marcq-en-Barœul, France) and the D65° illuminant with an angle of observation of 10°. The instrument was calibrated using the black and white tiles provided. The colour was recorded using the CIE colour scale to measure the parameters of L*(lightness/darkness), a*(redness/greenness), and b*(yellowness/blueness).

2.4. Statistical Analysis

Statistica software package, Version 10 was employed for data analysis (StatSoft Inc., Tulsa, OK., U.S.A). Two-way analysis of variance was performed using ANOVA procedures. Comparison of means was carried out by Tukey's test. A p value of 0.05 or less was regarded as significant. Microbiological analysis was performed in three repetitions, and the physicochemical determinations were carried out in four repetitions.

3. Results And Discussion

As shown by the results presented in Figures 1a and b, the average level of contamination of the fresh fruit and vegetable smoothie samples with aerobic mesophilic microorganisms and yeasts after storage day 1 was 6.06 log10 CFU/mL and 2.24 $\log_{10}$ CFU/mL, respectively. On the consecutive days, the total number of microorganisms increased to 6.31 log10 CFU/mL with a further increase to 6.94 log10 CFU/mL. Similarly, the content of yeast colonizing the control products (C) was 2.88 log10 CFU/mL on day 2 and increased to 4.26 log10 CFU/mL on day 3. The addition of the sumac powder to the freshly prepared beverage was effective in reducing microbial growth, but this effect was clearly dependent on the amount of the spice used. Noteworthy, considering the multiplication of microorganisms in the control smoothie samples during storage and the inhibition of their growth in the sumac-supplemented samples, the greatest reduction in the number of microorganisms was recorded after 3 days of storage. The total number of aerobic microorganisms in samples S 5 and S 15 declined by 1.46 and 2.07 $\log_{10}$ CFU/mL, respectively, in comparison with the control (C). The number of yeasts and molds in the smoothie samples supplemented with 5 g/L of sumac decreased to 4.16 $\log_{10}$ CFU/mL. At the supplementation dose of 15 g/L, the average number of the analysed microorganisms was reduced to 2.29 $\log_{10}$ CFU/mL. The addition of 30 g/L of sumac provided the best results and decreased the total number of microorganisms to an average level of 3.66 $\log_{10}$ CFU/mL (43% reduction of their number, compared with the control). Similarly, satisfactory results were obtained in the case of yeasts present in the smoothie, as the sumac supplementation contributed to 48% reduction of their number in samples S 30 on day 3, compared with the control. Our findings and results reported by other scientists [20-22] suggest the potential of *Rhus coriaria* L. fruits to be used as a new source of natural antimicrobial substances for the food industry.

A sumac dose-dependent decrease in the average values of active acidity was found in the analysed fruit and vegetable smoothies (Fig. 2a). During the refrigerated storage period, the value of the parameter in samples C (control), S 5, and S 15 slightly decreased or did not change. In turn, a 6% increase in the pH value of sample S 30 was noted between day 1 and 3. These changes (confirmed by the statistical test) were induced by the presence of acids in the sumac fruit, e.g. malic, citric, fumaric, tartaric, and ascorbic acids [23, 24].

The content of total polyphenolic compounds in the analysed smoothie samples differed statistically significantly ($p < 0.05$) (Fig. 2b). Their highest content was found in the samples supplemented with the highest sumac dose. The differences between C (non-supplemented sample) and S 30 on experimental days 1, 2, and 3 were 54%, 63%, and 65%, respectively. Several scientific studies confirm that sumac is rich in polyphenols and can be used as an innovative ingredient for maintenance and improvement of food quality. In their study, Dziki et al. [25] replaced wheat flour with 1, 2, 3, 4, and 5 g/100 g of sumac flour, which not only helped to reduce the salt content but also enriched the bread with phenolic compounds. Sumac extracts contributed to a statistically significant ($p<0.05$) increase in total phenolics in Cheddar cheese in a dose-dependent manner (doses from 0.5 to 3.0%) [26].

The value of the L* parameter, which indicated the lightness of the smoothie, ranged from 42.09 to 44.96. The highest value, i.e. the lightest colour, was recorded for the control drink (C) on experimental day 1, whereas the lowest value (the darkest colour) was determined in the 30 g/L sumac-supplemented samples (S 30) on day 2. The values of the a* parameter changed depending on the amount of sumac added to the smoothie. At the higher doses of the spice in the beverage, the value of the parameter declined (the level of redness decreased). The values of this parameter on day 1 ranged from 14.20 to 16.21. After three days, the control smoothie had a darker red colour, while the sumac-enriched samples did not show such a change (14.41-17.31). The lower values of the b* parameter in the sumac-enriched products, compared with the non-supplemented smoothie samples, indicated a lower level of yellowness. The highest value of the parameter was determined for the control sample (the most yellow), whereas the product supplemented with 15 g/L of sumac on day 3 had the lowest value (Tab. 1).

6. Summary

Juices are beverages chemically enriched with various additives, such as citric acid or synthetic vitamin C. The use of sumac is a new, natural alternative to products made of perishable or browning fruits and vegetables. Supplementing the smoothie with powdered *Rhus coriaria* L. fruit improves the nutritional value and microbiological safety of the final product. On the first day of storage, the content of polyphenolic compounds increased by 54% in the product containing 30 g/L of sumac compared to the control sample. During three days of storage, the total number of aerobic mesophilic bacteria increased in the control samples, while the growth of these microorganisms was inhibited in the sumac-supplemented smoothie. Future research should cover a larger number of products made from fruit and vegetables, which will be supplemented with sumac fruit *Rhus coriaria* L. in various amounts and forms of fragmentation, which will additionally be subjected to sensory analysis.

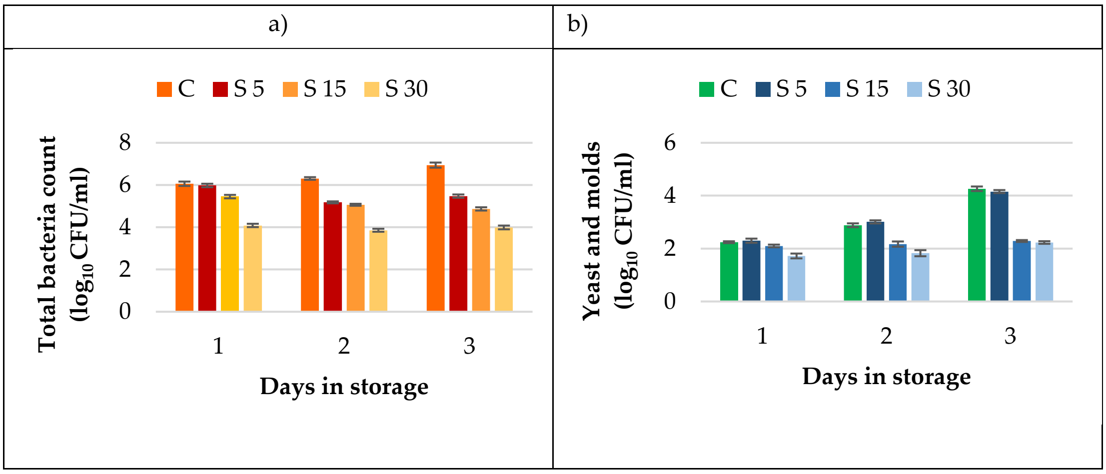

Fig. 1. Effect of powder sumac fruit addition on: a) the total content of microorganisms and b) yeast and mold in smoothie samples stored under refrigerated conditions for 3 days; mean values (n = 4) with standard deviation are given

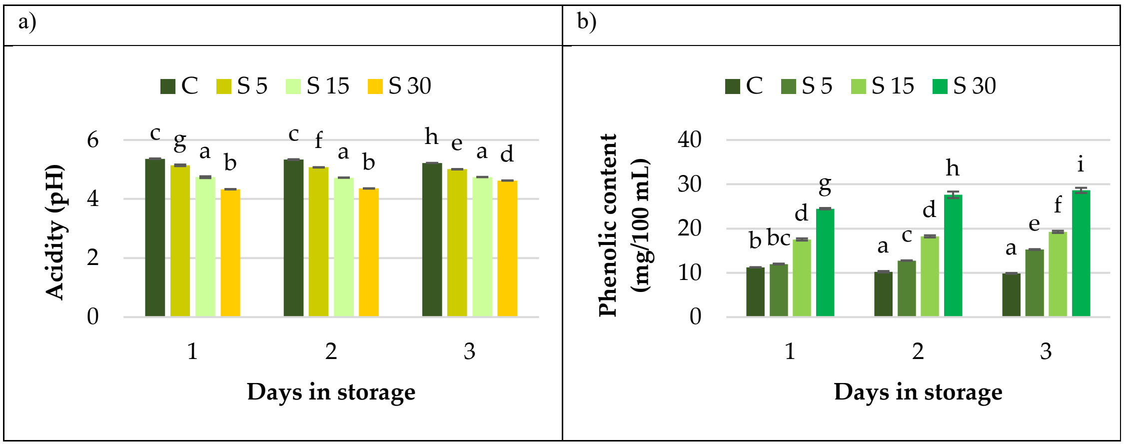

Fig. 2. Effect of powder sumac fruit addition on: a) pH and b) total phenolic content in a smoothie stored under refrigerated conditions for 3 days; the results are expressed as a mean ± standard deviation; different letters next to the mean values in the figures mean statistically significant differences ($p < 0.05$).

Table 1. Effect of the addition of sumac fruit powder on colour parameters of smoothie stored refrigerated for 3 days

Smoothie samples code	Time storage (days)	Color parameters		
		L*	a*	b*
C		44.94 ± 0.02^{h}	16.23 ± 0.02^{gh}	20.63 ± 0.04^{e}
S 5	1	44.80 ± 0.04^{h}	16.12 ± 0.05^{g}	20.58 ± 0.05^{e}
S 15		43.07 ± 0.57^{df}	15.03 ± 0.06^{d}	19.32 ± 0.14^{d}
S 30		43.05 ± 0.06^{df}	14.22 ± 0.03^{b}	18.32 ± 0.05^{c}
C	2	44.80 ± 0.03^{h}	16.42 ± 0.05^{h}	20.91 ± 0.05^{ef}
S 5		44.18 ± 0.03^{g}	15.62 ± 0.18^{f}	20.52 ± 0.02^{e}
S 15		42.18 ± 0.05^{bc}	14.29 ± 0.08^{bc}	17.52 ± 0.44^{b}
S 30		42.11 ± 0.02^{b}	14.38 ± 0.03^{bc}	18.57 ± 0.41^{c}
C	3	44.62 ± 0.04^{hi}	17.26 ± 0.06^{i}	21.22 ± 0.05^{f}
S 5		43.31 ± 0.09^{fg}	15.35 ± 0.07^{e}	19.31 ± 0.03^{d}
S 15		42.83 ± 0.07^{a}	14.18 ± 0.03^{a}	17.68 ± 0.09^{a}
S 30		42.61 ± 0.07^{de}	14.46 ± 0.06^{c}	18.26 ± 0.06^{c}

The results are expressed as a mean ± standard deviation from three independent experiments. Different letters in the same row means statistically significant differences ($p < 0.05$)

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