Antimycotic Activity of Sumac Extract in Composites Based on Epoxidized Natural Rubber for Application in Footwear Soles Production

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Abstract: *Biofilms are attached to different kinds of surfaces or associated with interfaces. The microbial communities are often composed of multiple species, which interact between each other. Attachment is complex process, regulated by diverse characteristics of the growing media, substrates and cell surface. Biofilms have different effects, which can affect changes in surface properties of polymer carriers. Accumulated biomass may provoke negative effects by direct attack, which leads to destruction of polymer matrixes. An option to solve the problem is introduction of bioactive ingredient into the composite.*

The aim of our study was to find and propose bioactive ingredients, derived from renewable sources, particularly such exhibiting of antimycotic influence, which can be included to elastomeric composite materials. These materials can be used for obtaining of winter footwear soles with adhesion, increasing to various types of icy surfaces. The influence of introduced antimycotic additive, extracted from Cotinus coggygria plant, was investigated. Antimycotic activity of obtained plant extracts against two eukaryotic strains was investigated by diffusion method in agar broth. The formation of biofilms from Candida lypolitica and Candida albicans strains onto natural rubber vulcanizates, kinetics and growth of biofilms strains were also observed.

Keywords: *Biofilms, Extract, Antimycotic effect, Elastomeric composite materials.*

Introduction

Biofilms are usually formed onto the surfaces of bio-resistant polymer composites, where microorganisms are colonized. By definition, biofilms are structurally and functionally distinct communities of microorganisms, organized over a variety of natural and artificial surfaces [3]. The composition of a biofilm usually predetermines its interaction with the polymer composite. Unfortunately, structure and functionalization of the latter, i.e., its exploitation properties, as a result of this interaction, can be seriously impaired. These variable effects may range from changes in surface properties of the polymer, caused by the accumulated biomass, therein its negative effects might lead to a direct attack and destruction of the polymer matrix. An option to solve the problem is impregnation of bioactive ingredient into the composite.

According to the definitions, bioactive ingredients, such as bioactive peptides, many vitamins, fatty acids, phytoestrogens, flavonoids and phytosterols, belong to that class [2, 6].

Concerning the up-mentioned, the aim of the study is to find and offer bioactive ingredients, derived from renewable sources, particularly such exhibiting antimycotic influence, which can be included to elastomeric composite materials for obtainment of winter footwear soles with adhesion increasing to various types of icy surfaces. The inclusion of such ingredients is aimed, because of their protection during the harmful soles effects, coming from eukaryotic and prokaryotic microorganisms, ultimately leading to irreversible deterioration of their exploitation. In many cases soles are exploited under humid conditions. In addition, natural rubber matrix contains up to 5% of proteins, fatty acids, resins, etc., which create favorable conditions for the development of various microorganisms. The creation of composite with a maximum content of renewable materials requires searching of antimicrobial additives with natural origin.

According to the literature, concerning the effects of many plant sources onto materials, we used the extract from *Cotinus coggygria* plant (sumac). The role of the same is till that moment not analyzed in case of inclusion to such kind of materials.

The European Smoke tree or ordinary sumac (Fig. 1) grows in the form of shrubs and small trees, reaching a height of up to 10 meters. The leaves are wing-shaped, alternate and the flowers are very small, greenish, creamy white or red with five petals, lying in thick panicles. Fruits are thick and appear as red clusters. Those are dried or ground and used as tea, spice or powder, showing healing on organism effect in cases of many injuries and disorders.

According to [1], sumac has significant antioxidant properties, which are largely due to the presence of polyphenols and other flavonoids.

Fig. 1 *Cotinus coggygria* (European Smoke tree)

The authors [8] investigated the effect of sumac extracts on gram-positive (*Bacillus cereus,* etc.) and gram-negative bacteria (*Escherichia coli, etc*.). The diffusion method of agar broth was applied, where marked inhibition zones were observed against the applied for the investigation bacteria. The results coincided with those of the authors [10], who affirm that Gram-positive bacteria were more sensitive to sumac, compared to Gram-negative bacteria. The authors [9] have chosen to monitor extracts from sumac and eukaryotic microorganisms: *Aspergillus flavus, Candida albicans* and *Penicillium citrinum*. They found that the extract has effect only on *Aspergillus flavus*, at low concentration of the active substance, and the same had insignificant effect on *Penicillium citrinum*, even at high sumac concentration. However, the strong effect of sumac and its antimycotic activity against the three fungal strains was notable.

Materials and methods

Preparation and characterization of the sumac extract

In medical practice, according to the literature, active flavonoids in sumac composition are widely used as antiseptics [11], successfully extracted when the plant source is fully dried.

The plant extracts were prepared as follows: 100 g of a mixture of different parts of *Cotinus coggygria* were mixed with 100 ml of 70% ethanol for 8 hours on a Soxhlet apparatus, and then filtered through a flame filter at a room temperature. The filtrate was evaporated to dryness on a rotary evaporator. The extracts were characterized by the method of atomic absorption assay (ICP-OES), concerning their heavy metals content. The obtained extracts were also tested for antioxidant activity properties.

Antioxidant activity determination

Sumac extract in aqueous phase was treated to permanganate oxidation in presence of indigo carmine indicator. The indicator reacted with potassium permanganate only after complete oxidation of rutin (vitamin P), changing the color of the reaction mixture.

Hot distilled water (50 ml) was added to 100 mg of pre-prepared sumac extract and re-extracted for 5 minutes. Then 10 ml of the extract were transfer with a pipette into titration flask. After that the flask was loaded with 10 ml of distilled water and 5 drops of indigo carmine, which changed the phase color to blue one. The solution in the flask was titrated with 0.025 n of $KMnO_4$ till appearance of steady yellow colorization.

It is experimentally proved that, 1 ml 0.1 n solution of $KMnO_4$ oxidizes completely 6.4 μg of rutin. The percent of rutin content was determined by the following formula:

$$x = \frac{3.2AV_1}{V_2P1000}100,$$

where x is the content of vitamin P rutin in formulation, [%]; 3.2 – standard recalculation coefficient; A – volume of the used 0.05 n of $KMnO_4$ solution [ml]; V_1 – volume of water, used to dilute the vitamin; V_2 – volume of titration solution [ml]; P – quantity of sumac, subjected to extraction [mg]; 1000 – conversion from μg into mg vitamin.

It was found that antioxidant activity of the used sumac extract was x = 0.063%.

Quantitative determination of metal content in the extract, by the ICP-OES method, showed the following results (Table 1). Table 1 shows that there is relatively high iron and zinc content in the extract.

Table 1. Metal content in sumac extract by ICP-OES method

Element	Quantity (SD), μg/g	Content, %
Al	5.18 (0.06)	0.0005
Fe	12.32(0.03)	0.0011
Cu	1.57 (0.03)	0.0002
Zn	6.76 (0.03)	0.0007

Antimycotic activity of the sumac extract

Monitoring of antimycotic activity of sumac extract in presence of eukaryotic microorganisms: *Candida lipolityca* and *Candida albicans*, was obtained in the current study.

Cultivation of the used microorganism strains

Cell strains were provided by the National Bank for Industrial Microorganisms and Cell Cultures. The used reagents were: meat, yeast and malt extracts, peptone, agar and anhydrous glucose provided by Merck, Sigma-Aldrich (Germany) and Valerus (Bulgaria). All of the reagents were pure for analysis.

The strains were originally grown on a solid agar broth containing:

- Yeats extract 3 g
- Malt extract 3 g
- Peptone 5 g
- Glucose 10 g
- Agar 15 g
- Distilled water 1000 ml

Following the incubation of cells growth in thermostat for 24 hours at 28 °C, some of them were suspended in liquid culture medium, containing:

- Yeats extract 3 g
- Malt extract 3 g
- Peptone 5 g
- Distilled water 1000 ml

To prepare pre-cultures, nutrient medium was used, containing:

- Aqueous nutrient medium for respective strain 90 ml
- 10% of sterile glucose 10 ml

The inoculum was sampled by sterile needle and the same was added to the obtained solution. The pre-cultures were incubated into shaker for 24 hours at optimum for the respective strain temperature. Working cultures were prepared, containing:

- Liquid nutrient medium for respective strain 80 ml
- Pre-culture of respective strain 10 ml
- 10% sterile glucose 10 ml

After 24 hours on the shaker at optimal for each strain temperature, the working cultures were ready to be used for preparation of experimental and control flasks.

Antimycotic activity of the obtained extracts

The antimycotic activity was investigated, applying diffusion method in agar broth. The method is based on the ability of antimicrobial agent to diffuse into agar broth and form inhibition zone, wherein retaining growth or bactericidal activity. Antimicrobial activity of the extracts on the reported size of inhibitory zones was monitored.

Agar broth of the respective strain was melted and poured into petri dishes to obtain 4 mm thick layer. The prepared plates were cultured in thermostat for 24 hours and microbe test was observed. Two cm^3 of pipette was sampled from the culture and added to each glass. So that to wet the entire surface, the dishes were shaken and the latter was pipetted. The plates were evacuated to dry state into thermostat for 20 minutes.

Sterile filter disks with 6 mm diameter were loaded with 50 µl of each extract, added in drops and left at room temperature for 24 hours. Antimycotic filter disks, impregnated with antimycotic drug Fluconazole and supplied by Ridacom, were used as controls.

By sterile tweezers pre-immersed in alcohol and flamed on a spirit lamp. The filter disks were placed onto the agar surface. The prepared plates were left at room temperature for 30 minutes, then cultured in thermostat at 28 °C for 24 hours.

Measurements of diameter of the diffusion zones with a millimeter line, were recorded.

Preparation and vulcanization of elastomeric composites containing sumac extracts used for production of soles with enhanced adhesion to icy surfaces

The sumac extract was incorporated as ingredient to rubber compound with the following composition (Table 2). Prior to obtainment of elastomeric composites, sumac extract was mixed with rapeseed oil. Rubber compound was vulcanized into shoe soles at temperature of 170 °C for 25 minutes.

Table 2. Rubber compounds for running experiments with sumac extracts

Ingredients, parts per hundred of rubber (phr)	**Control sample**	**Extract containing sample**
1. Epoxidized natural rubber	100	100
2. Silica	45	45
3. Short glass fibers	15	15
4. Carbon black N 550	5	5
5. Bis(triethoxysilylpropyl)tetrasulfide (Si 69®)-silane – compatibilizer	6	6
6. Rapeseed oil	15	15
7. Zinc oxide	3	3
8. Stearic acid	2	2
9. Polymerized 2,2,4-tri methyl-1,2dihydroquinoline (TMQ) – anti-aging agent	1.5	1.5
10. *Dimethylbutyl-phenyl*-p-phenylenediamine (6PPD) – anti-aging agent	1.5	1.5
11. N-tert-butyl-2-benzothiazyl sulfenamide (TBBS) – accelerator	1.5	1.5
12. *Diphenylguanidine* – accelerator	0.5	0.5
13 N-Phenyl-N-(trichloromethylthio)-benzenesulfonamide (Vulkalent E/C) – retardant	0.3	0.3
14. Sulfur – vulzanization agent	1.6	1.6
15. Sumac extract	2	2

Investigation of antimycotic activity of sumac extract in elastomeric composites

Samples from soles (6.0×6.0 mm) were tested to determine their antimicrobial activity against strains of microorganisms under examination – *Candida lipolityca* and *Candida albicans.* Sample bodies were cut from the vulcanized soles from rubber composition, containing or free of the plant extract, were added to erlenmeyer flasks with the respective strain.

Kinetics of growth of biofilms from cells of *Candida lipolytica* and *Candida albicans* strains were examined in control and sample bodies from vulcanized soles in presence of sumac extract. The test was performed by the modified Lowry method [7], based on samples protein content.

An extraction of extracellular polymeric substance (EPS) from biofilms with 1N NaOH, was previously performed. The samples were suspended in 4 ml of 1 N NaOH and heated in water bath at 80 °C for 30 minutes. Samples were filtered, and the filtrate was stored at 4 °C for further study of protein content.

Cell samples were added to the cell suspension so that to immobilize microbial cells by adhesion and biofilm formation, after culture development and biomass accumulation was performed. The kinetics of production of extracellular proteins from biofilms over the samples for 120 hours was followed, starting at the 24th hour since incubation.

Samples of adherent cells on rubber samples with and without plant extract presence were treated on a magnetic stirrer for 150 minutes at 25 °C, so that the amount of protein produced by the biofilm to be determined, according to the modified Lowry method [7].

Characterization of the composites comprising sumac extract

- Vulcanization characteristics of the composites were determined, according to ISO 3417:2002;
- Physicomechanical properties (Modulus at 100% and 300% elongation, tensile strength, relative elongation, residual elongation) were obtained, according to ISO 37:2002 and EN 12 803;
- Shore A hardness was determined, according to ISO 7619:2001;
- Coefficients of static and dynamic friction to different types of icy surfaces “dry” ice, “wet” ice and “melting” ice were determined tribologically, according to a methodology, especially developed for the purpose [4, 5].

Results and discussion

Antimycotic activity of the extracts against Candida lipolityca

Fig. 2 shows the inhibitory zones, formed by the influence of plant extracts against tested strains, following cultivation for 24 hours.

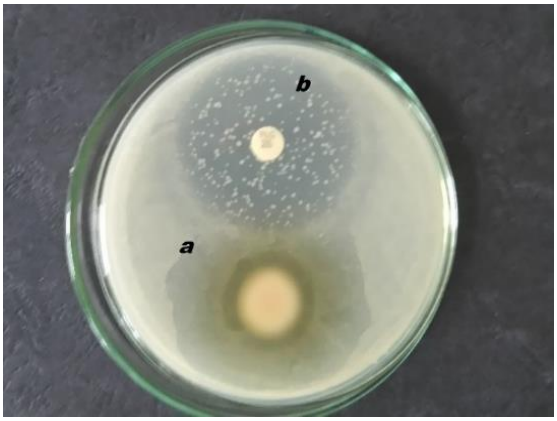

Fig. 2 Inhibitory zones, monitoring cultivation of *Candida lipolityca* in presence of sumac for 24 hours: a) effect of sumac extract; b) control with antifungal formulation fluconazole.

A strong antimycotic effect against *Candida lypolitica* in presence of sumac extract was observed. The measured inhibitory area is larger than 26 mm, i.e., higher than recorded area, under the impact of the manufactured impregnated with an antifungal preparation of fluconazole (23 mm) disc. Under influence of standard antifungal preparation, individual colonies of fungal strain in inhibitory zone may be distinguished, whereas no microbial growth under the influence of the plant extract was observed. There is also formation of two concentric circles in presence of sumac extract, centered on the sample. Even though they were empty of microbial growth areas, the same differ in color (Fig. 2). The appearance of two zones could be explained by the fact that the diffusion of antimicrobial agent is stronger in inner zone, and the concentration of diffused plant extract is the highest, whereas in the outer zone it gradually decreases. These results are prerequisite for future studies on determining the extent, to which the two areas will retain after cultivation period, longer than the applied one, according to the standard procedure for antimicrobial diffusion in agar broth.

Antimycotic activity of the extracts against Candida albicans
Fig. 3 shows the inhibitory zones, formed by influence of plant extracts against the tested strains, following cultivation for 24 hours.

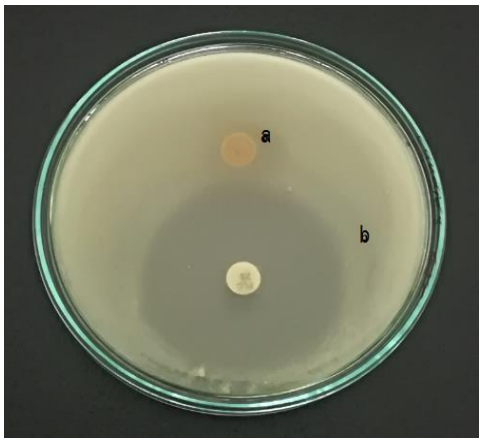

Fig. 3 Inhibitory zones, following cultivation of *Candida albicans* in sumac presence for 24 hours: a) effect of sumac extract; b) control with antifungal formula fluconazole.

There is slight antimycotic effect against *Candida albicans* in presence of sumac extract. The measured inhibitory area is 15 mm smaller than the area, recorded under the influence of impregnated with antifungal formulation of fluconazole disks, where the area is 23 mm. Although there is no larger inhibitory zone versus the fluconazole flanked impregnated disk, we can conclude that sumac extract provokes certain antimycotic effect, enhancing strong mycotic and pathogenic activity to *Candida albicans*.

As a result of the obtained by diffusion method in agar broth experiments, we can conclude that: depending on the formed against the two strains under consideration size of sumac extract inhibitory zone, the extract shows antimycotic effect against *Candida lypolitica*.

Comparative studies of the contribution of sumac extract to the generative development time of two microbial strains, under consideration.
According to the method, fungal strains were sequentially grown on solid agar medium and liquid broth. The influence of sumac antimicrobial activity extract on the generative development time of the two strains was studied.

Relations, using free *Candida lypolitica* and *Candida albicans* cells, were followed. Fig. 4 and Fig. 5 clearly show main phases of cell growth. Lag phase is up to 4 hours and the exponential phase for the cells of fungal strains in absence of extract is from 4 to 15 hours. There is rapid development of biomass in presence of extract from the 4th hour to 10-12 hours for the strains. Regarding the growth of *Candida lypolitica*, in presence of extract after the exponential phase, the process slows down as the strain enters stationary phase, after the eighth hour of incubation. As Fig. 4 shows, cells enter lethal phase of development after 12 hours.

Candida albicans strains show growth retention and inhibition of strain development after 10 hours of incubation. Cells enter stationary phase of development.

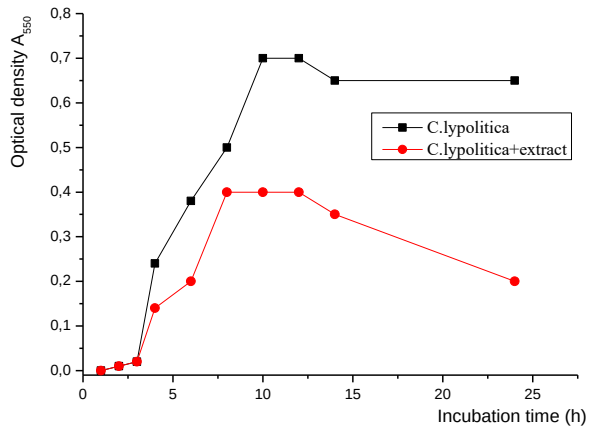

Fig. 4 Generation time of free *Candida lypolitica* cells in presence and absence of sumac extract

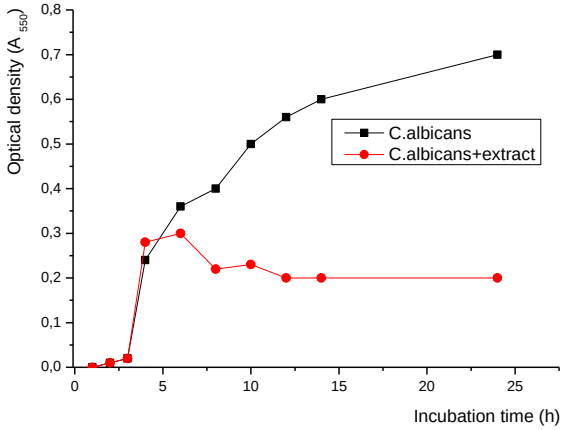

Fig. 5 Generation time of free *Candida albicans* cells in the presence and absence of sumac extract

The experiments of growing cells from fungal strains in the presence of sumac extract led to the following conclusions: after the rapid exponential phase, *Candida lypolitica* strains slow down their development and entered the lethal phase after the 12th hour. *Candida albicans* strains exhibit some resistance at onset of their development, when the extract is present in culture medium. Strain enters stationary phase, where the number of dead cells is equal to the one of living cells. Cells of *Candida lypolitica* strain are sensitive to the influence of plant extract that has an inhibitory effect, whereas in the case of *Candida albicans*, cells growth is suppressed by the extract.

Assay of antimycotic activity of sumac extract in vulcanizates

The amount of protein content of the formed biofilms over the samples were studied by UV spectra taken on Shimadzu Spectrophotometer UV-1280 spectrophotometer at absorbance λ = 750 nm, against control sample. Calibration curve of protein amount in mg/ml was used as reference. To plot standard curve, protein bovine serum albumin (Fig. 6) was used as reference protein.

The quantitative impact of synthesized extracellular biofilm proteins, formed by the examined microorganisms upon control vulcanizates and upon those, containing sumac extract within the incubation period, is shown in Figs. 7 and 8.

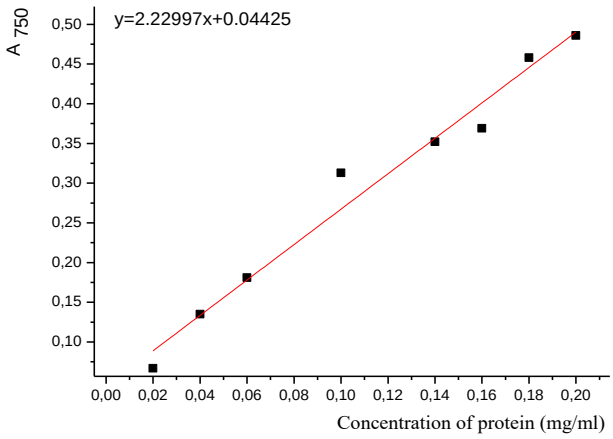

Fig. 6. Standard curve for determination of protein according to modified Lowry proteins assay

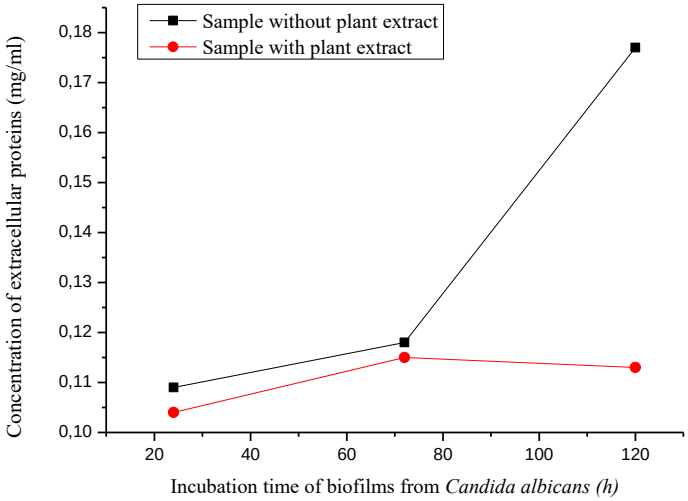

Fig. 7 Kinetics of protein production by *Candida albicans* strain biofilm formed on samples in presence and absence of sumac extract

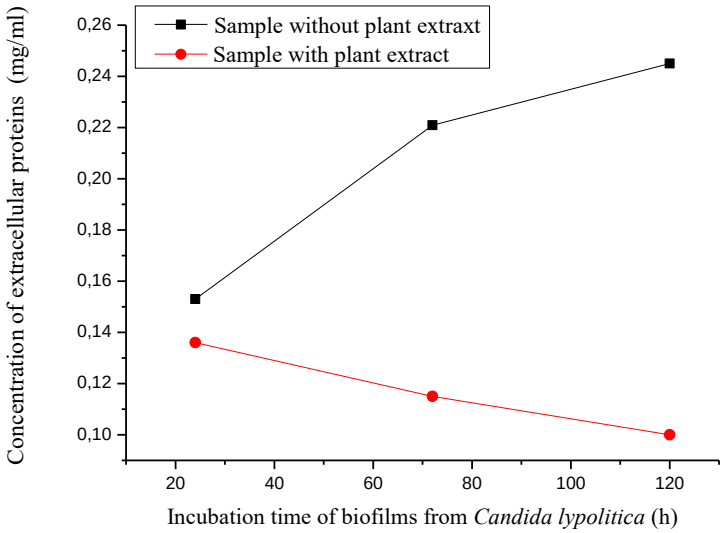

Fig. 8 Kinetics of protein production by *Candida lypotica* strain biofilm, formed on to samples in presence and absence of sumac extract

As the experimental data presented in Figs. 7 and 8 shows, biofilms are unstable in presence of plant extract and cells enter lethal phase of their generative development time, three days after incubation. The free extract control samples show continuous increase in amount of the produces protein. Such growth has also been observed in samples, impregnated with plant extract, incubated in medium, containing *Candida albicans*, but to lower extent. After 72 hours the amount of produced protein began to decrease. The amount of produced from cells of *Candida lypolitica* strain in the biofilm protein decreases immediately in the case of testing antimycotic activity of samples, impregnated with plant extract. The amount of protein, produced by biofilms in presence of plant extract decreases, till the end of 120 hours investigation period. It is clear from the presented graphically experimental data, that at the beginning of incubation period the amount of adherent cells on samples, containing the plant extract, is smaller compared to the free extract control samples. A significant effect of antimicrobial activity reveals the results of testing rubber samples with plant extract against biofilms of *Candida lypolitica* strain cells. The amount of produced protein is relatively low at the considered incubation time, which proves antimycotic effect of the sumac extract.

In conclusion, monitoring of cells kinetics growth, which form biofilms, demonstrates convincingly the antimycotic resistance of soles, containing sumac extract. That guarantees preservation of their good exploitation properties over a long period of time, even under atmospheric conditions and favoring biofilm formation. Inhibitory effect of the extract against *Candida lypolitica* cells is stronger and more significant, compared to the effect against *Candida albicans* strains. Effect of the extract against this fungal strain may be summarized as the one suppressing the strain development.

Characterization of the compounds and vulcanizates, containing sumac extract
Effect of sumac extract on vulcanization characteristics
The vulcanization characteristics of rubber compounds, containing sumac extract are summarized in Table 3.

Table 3. Vulcanization characteristics of rubber compounds, based on epoxidized natural rubber (vulcanization temperature – 150 °C)

	Control sample without extract	**Sample with extract**
ML, dNm	0.86	0.80
MH, dNm	21.44	19.47
ΔM = MH – ML	20.58	18.67
Ts_1, min:sec	6:10	6:14
Ts_2, min:sec	6:20	6:30
T_{50}, min:sec	8:46	8:54
T_{90}, min:sec	13:32	13:45

Legend: ML – minimum torque, correlating with effective viscosity of compounds; MH – maximum torque, correlating with hardness of compounds; ΔM = MH – ML, correlating with density of cure network; Ts_1 – scorch, till one torque unit rise above the minimum, correlates with the resistance to premature vulcanization, Ts_2 – time till the beginning of vulcanization process (increase of the torque by 2 units), correlates with the resistance to premature vulcanization, T_{50} – time to run 50% of vulcanization process; T_{90} – time to run 90% of vulcanization process (optimum vulcanization time).

According to the presented in Table 3 data, sumac extract has not such noticeable influence on vulcanization characteristics of extract-containing composites. There is slight decrease of the minimum and maximum torque, which correlates with the effective viscosity and hardness of compounds. That can be explained by certain plasticizing action of the extract, which comes from plant's oily liquid origin, such as rapeseed oil. Its addition to the composition increases substantially the total amount of technological additives.

Influence of sumac extract on physicomechanical characteristics of composites

The influence of sumac extract on physicomechanical properties of composites is shown in Table 4. The results in Table 4 confirm those in Table 3, revealing certain plasticizing effect of sumac extract, resulting in slight reduction in values for modulus at 100% and 300% elongation, for tensile strength and Shore hardness. Values of the relative elongation and abrasion resistance are improved, i.e., the wearability decreases, which is particularly positive effect with regard to the usage of composites for production of footwear.

Table 4. Physicomechanical indicators of vulcanizates, based on epoxidized natural rubber

	Control sample	**Extract containing sample**
Modulus at 100% elongation, M_{100}, MPa	3.6	3.4
Modulus at 300% elongation, M_{300}, MPa	8.0	7.7
Tensile strength, σ, MPa	13.8	13.5
Relative elongation, ε_1, %	500	550
Residual elongation, ε_2, %	45	45
Shore A hardness, relative units	72	70
Wear resistance, mm^3	210	195
Tear resistance, N/mm	5.1	5.5
Fatigue resistance, number of cycles	> 60000	> 60000

Effect of sumac extract upon the static and dynamic friction coefficients

The effects of sumac extract are summarized in Tables 5-7.

Table 5. Static and kinetic coefficient of friction of studied composites from 0 to 1 °C (melting ice)

Composite	**Coefficient of friction**		**Jump**
	μ_o	μ	$\mu_o - \mu$
Control sample	0.30	0.27	0.03
Extract, containing sample	0.32	0.28	0.04

Table 6. Static and kinetic coefficient of friction of studied composites from –4 to –5 °C (wet ice)

Composite	**Coefficient of friction**		**Jump**
	μ_o	μ	$\mu_o - \mu$
Control sample	0.30	0.25	0.05
Extract, containing sample	0.34	0.27	0.07

Table 7. Static and kinetic coefficient of friction of studied composites from –10 to –12 °C (dry ice)

Composite	Coefficient of friction		Jump
	μ_o	μ	$\mu_o - \mu$
Control sample	0.48	0.43	0.05
Extract, containing sample	0.50	0.45	0.05

As tables show, inclusion of sumac extract into composite material results in slight improvement of kinetic coefficient of friction to various types of icy surfaces. That may be associated with the fact that, in presence of extract Shore A hardness of composite, from which sole is made of (4/4), is softer and leads to decrease of kinetic coefficients of friction to different types of icy surfaces.

Our study is dedicated of development of rubber compound for the production of ECO-soles, which should be as environmentally friendly as possible, with the maximum number of renewable ingredients. Therefore, epoxidized natural rubber, cole oil, sumac extract, etc. are included in the composition of the mixture. Since natural rubber is generally easy to age (aging means a gradual and irreversible decrease in performance, mainly due to climatic factors, but also to operating conditions), to slow down this aging, usually in the composition of rubber. The mixture includes an antioxidant component or one that is thought to have such an effect. Our desire is to be a component of plant origin, i.e. from renewable sources and it is the reason to study the antioxidant activity of the sumac. The antimycotic effect of sumac is due to the fact that the sumac is very rich of phenols mainly and tannins as well as flavonoids. We chose *Candida* as the famous fungal strain among the natural microflora and also, because of the easy formation of biofilms.

Conclusion

In our study we investigated the introduction of sumac extract into composites, based on epoxidized natural rubber to make winter footwear soles with improved kinetic coefficients of friction to various types of icy surfaces, possessing antimycotic activity. The kinetics of growth of biofilms strains of *Candida lypolitica* and *Candida albicans* by modified Lowry method, convincingly demonstrate antifungal activity of soles, containing sumac extract of 2 phr, which guarantees to preserve good performance properties for extended period of time. 2 phr is a measure used to determine what amount of certain ingredients are needed especially in the case of pre-vulcanization, shown as parts of the ingredients and calculated in percentages. Sumac extract, included into composite material has no negative impact on its vulcanization and physicomechanical properties. A slight improvement in kinetic coefficient of friction to various types of icy surfaces was observed. That is due to the fact that as technological additive, sumac extract contributes to some plasticizing effect, which leads to softer vulcanizates, hence improvement of friction coefficients. All that reveals the possibility of using sumac extract in elastomeric compositions to produce soles with improved coefficients of kinetic friction to various types of icy surfaces. That also corresponds to the aim of maximum percentage of components from renewable sources. No data have been found for such studies and applications in the literature, so the experimental setup may be considered as pioneer.

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