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USE OF A WAX-CONTAINING PRODUCT FROM SUNFLOWER OIL PRODUCTION WASTE IN ELASTOMERIC COMPOSITIONS

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To expand the range of ingredients based on renewable biological raw materials and enhance environmental protection, the effectiveness of the OS Wax product in elastomeric compositions was investigated. This product is derived from the waste generated during the winterization stage of sunflower oil production and, according to differential thermal analysis and IR spectroscopy, is a thermostable, non-volatile, long-chain saturated ester. It was found that incorporating 1.0–2.0 phr of OS Wax as a processing additive in elastomeric compositions for tire manufacturing initiates and enhances the sulfur vulcanization process, reduces heat generation, and positively influences the Payne effect due to its structure and the reduction of the effective activation energy of sulfur vulcanization. At the same time, the dynamic and physical-mechanical properties of the rubber remain comparable to those prepared with petrochemical microwaxes of the SVOZ-75 U grade.

Keywords: elastomeric composition, wax-containing ingredients, sunflower oil production waste, properties of rubber compound and rubber, renewable biomaterials, environmental safety.

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Introduction

The greening of the rubber industry is characterized by a comprehensive approach based on technological innovations, the use of environmentally friendly ingredients, and compliance with environmental standards. The development of elastomeric compositions using bio-ingredients is one of the ways to diversify the sources of raw materials for their production using resource-saving technologies. This will make it possible to abandon environmentally harmful and at the same time toxic materials and reduce dependence on carcinogenic petroleum products by using renewable raw materials of natural origin [1].

In particular, during the processing of oilseeds, especially sunflower, waste is generated at the stages of crushing and wax freezing during oil refining. This waste, which does not have any further effective use, can be utilized in elastomeric compositions as target ingredients, such as antioxidants, physical stabilizers, etc. Study [2] showed the possibility of extracting waxes from sunflower husks and using them in rubber compounds as stabilizers to replace traditional petrochemical products. Another promising source for preparing technical waxes (as an ingredient in elastomeric compositions) may be the waste from the winterization stage of oil production, namely, the used oily adsorbent, which, in addition to the mineral component, contains about 28% of the wax-containing product.

Taking into account the volume of domestic sunflower oil production [3] and the corresponding environmental protection problems, it is relevant for Ukraine to develop a technology for obtaining a wax-containing product from the waste of the winterization stage of sunflower oil production. The purpose of this work is to obtain a wax-containing product (without fat fraction) from sunflower oil production waste as an alternative to industrially used waxes of petrochemical origin and to study its effect on the formation of the properties of elastomeric compositions.

Experimental

Materials

Earlier [4–6], we carried out several studies of the fat- and wax-containing component of the hydrophobized adsorbent after the winterization stage of sunflower oil production in elastomeric compositions based on diene rubbers.

The subject of this study is a wax-containing product obtained from the used adsorbent of the winterization stage of refined sunflower oil at Oleina PJSC (Dnipro, Ukraine) using a two-stage technology. At the first stage, according to the procedure described elsewhere [5], a fat- and wax-containing fraction was isolated from the used filter powder by washing with dichloroethane. At the second stage, a wax-containing product was isolated from the filter powder by washing with petroleum ether and studied. The resulting product is a pale beige opaque viscous mass with a melting point of about 70^{0}C.

According to the data of differential thermal analysis (Fig. 1), obtained on the derivatograph of the Paulik system manufactured by IOM (Hungary) at a heating rate of 10^{0}C/min, the product under study (hereinafter referred to as OS Wax) is characterized by an endothermic peak in the temperature range up to 100^{0}C (DTA curve), i.e., a reaction with heat absorption, namely the transition of a substance from a solid to a liquid state, occurs. The determined melting point is 68^{0}C, which correlates with the literature data [7,8]. Within the temperature range of processing the rubber compounds (max 90^{0}C), OS Wax loses only 0.5% of its mass, indicating the absence of water and solvent residues in the sample. In the temperature range of vulcanization (max 200^{0}C), the mass loss of the sample reaches 3.4%. A sharp mass loss starts from 289^{0}C. The maximum mass loss rate was recorded at 345^{0}C, which is also reflected by the peak on the DTG curve. The completion of the thermal oxidation degradation process is observed at a temperature of 400^{0}C. That is, the product OS Wax proved to be thermostable and non-volatile in the temperature range of elastomeric composition processing and vulcanization, as well as in the operating temperature range of products made from them.

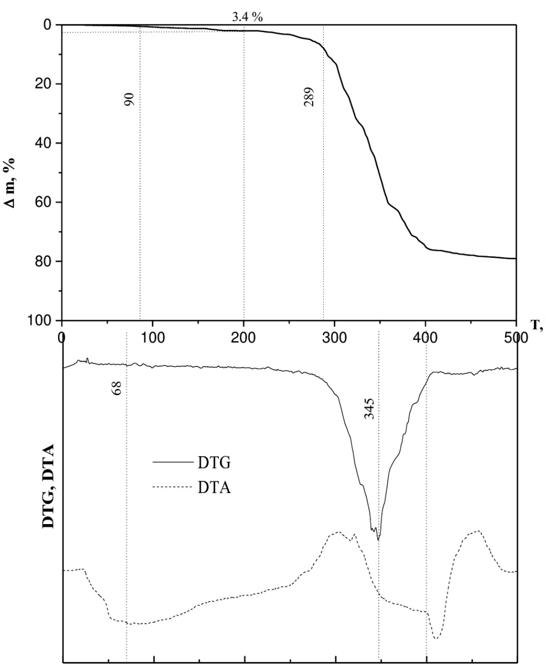

Fig. 1. Curves of differential thermal analysis of OS Wax (air as a medium; heating rate of 10 deg/min)

According to the results of infrared spectral analysis using a Perkin Elmer BXII device (film based on AgCl), the investigated OS Wax showed the bands in the stretching vibration region of 1164 cm^{-1} (C–O bond of the ester group), 1746 cm^{-1} (C=O bond of the ester group), 3008 cm^{-1}, 2918 cm^{-1}, 2850 cm^{-1} (deformation and stretching vibrations of the C–H bond in CH_3-, CH_2-, CH-groups), and 3449.5 cm^{-1} (–OH bond of alcohol and carboxyl groups) (Fig. 2). Thus, the product under study is a long-chain saturated ester (wax), which probably contains 40 to 60 carbon atoms [7] with the distribution of fatty alcohol and fatty acid in the range of 18–34 and 14–34 carbon atoms, respectively [9].

A comparative analysis of the IR spectra (Fig. 2) of industrial petrochemical protective wax for rubber of the SVOZ-75 U brand (according to the Ukrainian technical regulations TU U 73.1-13.831091-022-2001, domestically produced) with the IR spectra of the investigated bioproduct OS Wax showed the absence of stretching vibrations of the C=O group (band at 1746 cm^{-1}) in the industrial wax. Obviously, this industrial ingredient of petrochemical origin differs significantly from the studied product and belongs to the class of saturated hydrocarbons with a straight carbon chain, with the number of carbon atoms from C_{18} to C_{36}, which is typical for paraffins [10].

The acid number was determined by standard methods following Ukrainian State Standard DSTU ISO 660:2009. The sample of OS Wax has an acid number of 2.8 mg KOH/g, and the acid number of SVOZ-75 U is 0.72 mg KOH/g.

The effect of the investigated OS Wax on the

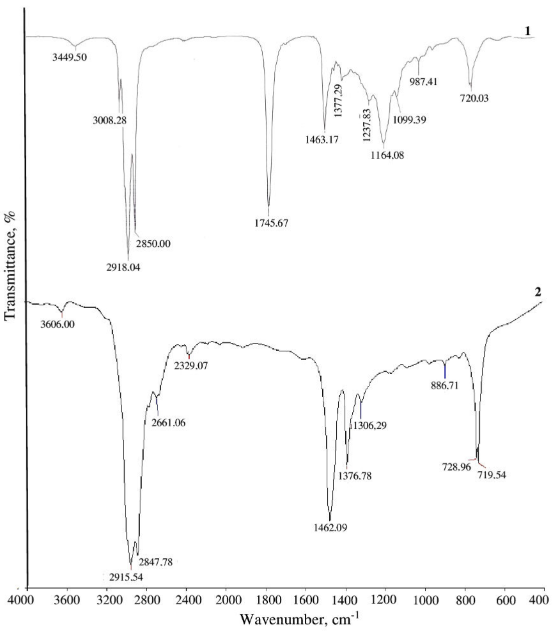

Fig. 2. Infrared spectra of the studied products: 1 – OS Wax; 2 – SVOZ-75 U

formation of a set of properties of elastomeric compositions for the manufacture of truck tire sidewalls based on a combination of natural and polybutadiene rubbers of the BR Synteca 44 brand was evaluated under the following conditions: 1) equal replacement (2.0 phr) of industrial wax of SVOZ-75 U brand with OS Wax; 2) joint introduction of 1.0 phr of SVOZ-75 U and 1.0 phr of OS Wax. The production of rubber compounds was carried out in a laboratory rubber mixer with a mixing chamber volume of 2 dm^3 according to the following a two-stage scheme. The first stage was carried out at a rotational speed of 40 rpm at a temperature of 145^0C for 2.0 min; the second stage was carried out at a rotational speed of 30 rpm at a temperature of 108^0C for 2.5 min. At the first stage, all the ingredients (including waxes) were introduced into the rubber mixers, except for sulfur and a sulfenamide vulcanization accelerator, which were introduced at the second stage. Vulcanization of rubber samples for physico-mechanical and dynamic tests was carried out at the optimum of vulcanization in a hydraulic press at a temperature of 155^0C.

Research methods

The technological characteristics of rubber compounds and the properties of rubbers were evaluated according to current international standards and relevant methods [11]. In particular, the rheological, vulcanization, dynamic, and relaxation properties of elastomeric compositions were determined following international standards DIN 53529, ASTM D 6204, ASTM D 6601, and ISO 13145 using a Mon Tech MDR 3000 Professional rotorless rheometer with Mon Control software. The device allows the study of the properties of rubbers and ingredients, as well as the processing and vulcanization characteristics of elastomeric compositions.

Considering that the investigated additive OS Wax is a high-molecular ester with 40–60 carbon atoms in the main chain, it can hypothetically act not only as a stabilizer of rubbers of physical action, but also as a technological additive with a possible effect on the kinetics of sulfur vulcanization of elastomeric compositions, the formation of a set of rubber properties, and their stabilization. The objective of the experimental studies of this work and the methods used was to test the above hypotheses.

Results and discussion

Technological and rheokinetic characteristics

Analysis of the technological properties of rubber compounds based on a combination of diene rubbers at a temperature of 70^0C (Table 1) shows insignificant differences in the effect of the bioingredient OS Wax in comparison with the petrochemical microsurfactant SVOZ-75 U on the plasticity, elastic recovery and cohesive strength of elastomeric compositions (at equal mass concentrations). OS Wax is somewhat inferior in terms of its positive effect on plasticity and elastic recovery to the rubber compound with SVOZ-75 U, but unlike it, it increases the cohesive strength. When OS Wax and SVOZ-75 U are used together, the effect of bio-wax on the level of controlled technological characteristics of the rubber compound can be observed.

The results of determining the plasticity of rubber

Table 1

Technological properties of rubber compounds in the presence of studied products of petrochemical and biological origin

Index	Value		
	type and content (phr) of additive		
	SVOZ-75 U (2.0) industrial	SVOZ-75 U (1.0)+OS Wax (1.0)	OS Wax (2.0)
Karrer plasticity, conv. unit	0.40	0.38	0.37
Elastic recovery, mm	0.8	1.0	0.9
Cohesive strength, MPa	0.17	0.18	0.19

compounds are correlated with the rheometry parameters at test temperatures of 155^0C and 165^0C (Table 2). Based on the fact that the rheometric parameter, namely minimum torque (S'min), characterizes the viscosity (plasticity) of rubber compounds (the higher the value of S'min, the lower the level of plasticity), it is quite logical to have a higher (up to 7%) level of the S'min parameter in the presence of 2.0 phr of OS Wax in comparison with the composition containing 2.0 phr of the industrial product SVOZ-75 U. This dependence is, in most cases, also inherent in the indicators characterizing the maximum torque (S'max) and the relative degree of crosslinking (S'max−S'min) of rubbers (Table 2), but to a lesser extent. The simultaneous introduction of 1.0 phr of SVOZ-75 U and 1.0 wt.% of OS Wax into the elastomeric composition is accompanied by the maximum level of the proposed rheometric parameters.

Under the condition of equal replacement, the rubber compound with the bioadditive OS Wax is slightly inferior to the industrial microwax SVOZ-75 U as a technological additive (in terms of plasticity and minimum torque). Still, it increases the cohesive strength and relative degree of crosslinking of elastomeric compositions. The more acidic nature of OS Wax, in contrast to SVOZ-75 U, indicates an increased concentration of polar groups that can affect the interfacial interaction in the elastomeric composition, which leads to an increase in cohesive strength [12].

The rheokinetics of sulfuric vulcanization of elastomeric compositions in the presence of the studied products of petrochemical and biological origin is represented by S-shaped curves (Fig. 3,a), indicating the identity of the chemistry of the polydiene vulcanization process.

According to the kinetic curves of the vulcanization process of elastomeric compositions, for example, at a temperature of 155^0C, we observe a certain negative effect of the industrial microwax SVOZ-75 U (compared to OS Wax) on the equilibrium torque at the vulcanization plateau (Fig. 3,a) and the crosslinking rate (Fig. 3,b). The maximum vulcanization rate (Peak Rate) of the rubber compound in the presence of an equal mass (2.0 phr) of the SVOZ-75 U ingredient was only 1.21 dN·m/min, compared to 1.3 dN·m/min for the composition with OS Wax. However, the initiation of the vulcanization process of the rubber compound in the presence of the OS Wax product (Fig. 3), the reduction in the time to reach a certain stage of the crosslinking process (TS1, TS50, and TS90 indicators in Table 3) and the time to start reversal (T@Rev98 in Table 3) relative to the industrial elastomeric composition with SVOZ-75 U microwax is not critical

Table 2

Rheometric parameters of elastomer compositions in the presence of studied products of petrochemical and biological origin

Index	Values at the temperatures of 155^0C/165^0C		
	type and content (phr) of additive		
	SVOZ-75 U (2.0) industrial	SVOZ-75U (1.0)+OS Wax (1.0)	OS Wax (2.0)
S'min, dN·m	2.86/2.72	3.01/2.84	3.07/2.91
S'max, dN·m	15.38/14.73	15.89/15.10	15.66/14.88
S'max–S'min, dN·m	12.52/12.01	12.88/12.26	12.59/11.97

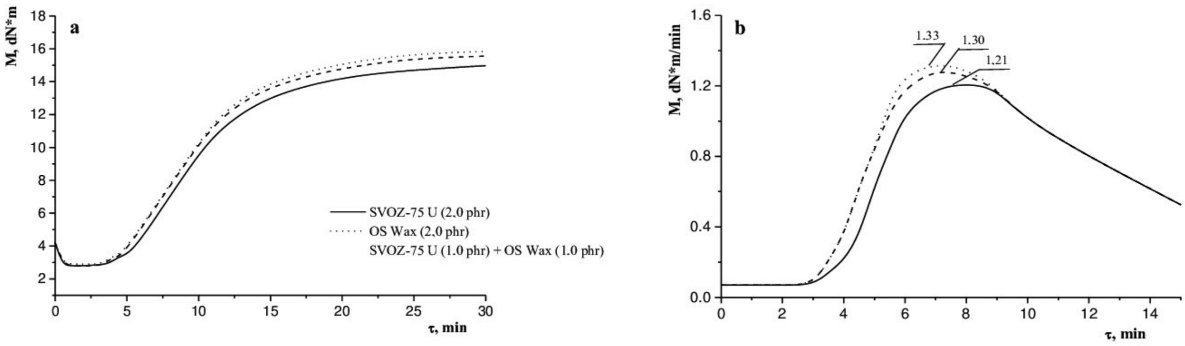

Fig. 3. Kinetic curves (a) and rate change (b) of sulfur vulcanization (T=155^0C) of elastomeric compositions based on diene rubbers for the manufacture of truck tire sidewalls in the presence of the studied products of petrochemical and biological origin

but requires a deeper analysis.

As shown in ref. [13], more objective characteristics of the vulcanization rate than the maximum vulcanization rate (Peak Rate) are the vulcanization rate (Rv), which is widely used in production, determined according to the state standard GOST R 54547-2011, and the vulcanization rate (Vc), which takes into account the increase in torque at all stages of the formation of vulcanization bonds. Table 4 shows the values of not only the listed characteristics, but also the conditional constant of the vulcanization rate during the main vulcanization period (k_2) determined by the two methods, the effective activation energy at the stage of the induction period of vulcanization (Et_i), at the stage of full use of the vulcanization accelerator (E_{dis}), and at the stage of reaching the optimum vulcanization (Et_{C90}). It was found that the k_2 index, determined by the formula k_2=1.608/TC90−TC50, is more sensitive to the formulation factors we studied. The analysis of Rv, Vc, and k_2 values at vulcanization temperatures of 155^{0}C and 165^{0}C indicates a positive effect of OS Wax on the rate and conditional rate constant of vulcanization, especially at a temperature of 155^{0}C. The use of 2.0 phr of the petrochemical product SVOZ-75 U, compared to the use of 2.0 phr of the bioproduct OS Wax, leads to a significant increase in the level of the vulcanization effective energy of the rubber compound at all vulcanization stages. For example, the energy is increased by 1.2 times, 1.6 times, and 1.1 times at the stages of the induction period, the full use of the accelerator, and reaching the optimum vulcanization, respectively (Table 4). The joint use of SVOZ-75 U (1.0 phr) and OS Wax (1.0 phr) has less effect on the effective activation energy (E_{act}) of the studied stages of sulfur vulcanization relative to the indicators of the industrial elastomeric composition.

Thus, it is obvious that the initiation and deepening of the vulcanization process of a polydiene-based rubber compound in the presence of the bioproduct OS Wax compared to a composition with a petrochemical product of SVOZ-75 U brand is accompanied by a non-critical change in vulcanization characteristics due to a decrease in the activation energy of the sulfur vulcanization process stages, a different chemical structure of the bioadditive, and its higher acid number [14].

Dynamic and physical-mechanical characteristics

The dynamic properties of elastomeric compositions were determined using the MDR 3000 rheometer following the requirements of the international standard ASTM D 6601, which allows obtaining the following characteristics: modulus of elasticity in shear (G'), kPa; shear loss modulus (G''), kPa; complex shear modulus (G*), kPa; loss coefficient TanDelta (tangent of the dynamic loss angle as the ratio of the loss modulus to the elastic

Table 3

Kinetic characteristics of the sulfur vulcanization process of elastomer compositions in the presence of the studied products of petrochemical and biological origin

Index	Values at the temperatures of 155^{0}C/165^{0}C type and content (phr) of additive		
	SVOZ-75 U (2.0) industrial	SVOZ-75 U (1.0)+OS Wax (1.0)	OS Wax (2.0)
TS1, min	5.40/2.74	5.19/2.76	5.17/2.81
TC50, min	9.78/5.11	9.41/5.10	9.41/5.17
TC90, min	18.85/9.68	18.03/9.48	18.08/9.59
T@Rev98, min	58.44/28.21	55.62/27.19	56.63/27.33

Table 4

Parameters of the sulfur vulcanization process of elastomer compositions in the presence of the studied products of petrochemical and biological origin

Index	Values at the temperatures of 155^{0}C/165^{0}C type and content (phr) of additive		
	SVOZ-75 U (2.0) industrial	SVOZ-75 U (1.0)+OS Wax (1.0)	OS Wax (2.0)
$R_v=100/t_{90}-t_s$, min^{-1}	7.44/14.41	7.79/14.88	7.46/14.75
$V_c=M_{90}-Mt_s/t_{90}-t_s$, dN·m/min	0.76/1.41	1.09/1.49	1.13/1.44
$k_2=1.608/t_{90}-t_{50}$, min^{-1}	0.18/0.35	0.31/0.37	0.32/0.36
$k_2=1.1/t_{75}-t_{25}$, min^{-1}	0.17/0.33	0.18/0.34	0.18/0.33
Et_i, kJ/mol	100.55	92.81	85.65
Et_{dis}, kJ/mol	102.36	83.38	63.23
Et_{C90}, kJ/mol	103.63	99.36	98.60

modulus: tgδ=G''/G') (Table 5). Samples of elastomeric compositions were tested on the vulcanization plateau (20 min/1.67 Hz/7% strain) to determine the above indicators at a strain ranging from 1% to 100% and the difference in elastic modulus at small strain amplitudes (1%); elastic modulus at large strain amplitudes (100%) – the complex dynamic modulus DeltaStrain, which quantitatively characterizes the Payne effect [5,15]. The tests were performed for 3 and 5 minutes at a temperature of 60^{0}C and a strain frequency of 1 Hz (Table 5).

Table 5 shows that the formulation factors and test conditions (strain level) studied in this work affect the dynamic properties of the elastomeric composition. The presence of 2.0 phr of the bioingredient OS Wax in the rubber causes an increase in the values of G', G'', and G* parameters compared to those of the industrial composition with 2.0 phr of SVOZ-75 U microwax. With an increase in the deformation level of the rubber samples from 1% to 100%, a decrease in the elastic modulus (G'), losses (G''), and complex elastic modulus (G*) is observed. The value of the dynamic loss tangent (TanDelta) increases with the level of rubber deformation. Since the TanDelta characterizes the fraction of energy dissipated by the rubber sample, and the larger (higher) its value, the more the elastomeric composition sample heats up under sinusoidal oscillations, the obtained dependences are quite logical.

In terms of dissipative energy loss, vulcanizers (test conditions: 10% strain, temperature 60^{0}C, strain frequency 1 Hz, time 5 minutes) in the presence of 2.0 phr of the industrial wax-containing product SVOZ-75 U or 2.0 phr of the experimental OS Wax are characterized by similar values of the TanDelta heat generation parameter (Fig. 4). The joint use of OS Wax and SVOZ-75 U allows ensuring minimal heat generation according to the TanDelta parameter.

Determining the Payne effect (ΔG') allows evaluating the interaction between vulcanizates filler particles [5,15]. Its quantitative value was determined by a decrease in the elastic modulus (G') with an increase in strain during dynamic tests. An increase in the strain amplitude causes changes in the microstructure of rubbers, which in turn leads to partial destruction of weak physical bonds in the grid created by the filler.

It was found that the presence of 2.0 phr of the bioingredient in the elastomeric composition led to an increase in the value of the Payne effect recorded during dynamic rheometer tests, the results of which are shown in Fig. 4. This correlates with a change in the dynamic loss tangent (TanDelta) at all controlled points. An increase in the value of ΔG' means an

Table 5

Dynamic characteristics of rubber according to test data using the MDR 3000 rheometer (test time 3 minutes/5 minutes)

Type and content (phr) of additive	Index and its value				
	Strain, %	G', kPa	G", kPa	G*, kPa	TanDelta
SVOZ-75 U (2.0) industrial	1	1597.43/1057.06	217.46/170.67	1612.17/1070.76	0.136/0.162
	2	1450.37/980.69	200.58/163.40	1464.18/994.21	0.138/0.167
	5	1176.15/878.49	188.95/139.66	1191.23/889.52	0.161/0.159
	10	1006.23/808.04	159.48/122.69	1018.79/817.30	0.159/0.152
	20	848.72/736.21	129.64/107.46	858.46/744.02	0.153/0.146
	50	639.76/583.13	101.88/125.75	647.83/596.54	0.159/0.216
	100	472.43/450.76	102.89/120.62	483.58/466.62	0.218/0.268
SVOZ-75 U (1.0)+OS Wax (1.0)	1	1698.90/1064.18	188.75/167.12	1709.36/1077.23	0.111/0.157
	2	1487.04/989.39	188.69/158.86	1498.97/1002.06	0.127/0.161
	5	1201.21/892.94	182.66/134.93	1215.02/903.09	0.152/0.151
	10	1025.94/827.14	155.63/119.37	1037.67/835.71	0.152/0.144
	20	872.41/757.43	127.00/106.90	881.61/764.94	0.146/0.141
	50	658.65/595.18	102.89/132.11	666.64/609.67	0.156/0.222
	100	481.11/459.42	110.65/127.83	493.76/476.88	0.230/0.278
OS Wax (2.0)	1	1695.29/1062.24	205.12/173.09	1707.65/1076.26	0.121/0.163
	2	14199.04/985.90	198.72/164.57	1512.40/999.54	0.133/0.167
	5	1201.13/888.61	188.20/139.45	1220.73/899.49	0.156/0.157
	10	1024.30/821.10	158.73/123.47	1036.52/830.33	0.155/0.150
	20	864.17/751.95	128.39/110.62	872.66/760.04	0.149/0.147
	50	647.69/586.10	104.90/138.38	666.64/602.21	0.162/0.236
	100	468.73/443.96	118.78/135.02	483.66/464.03	0.253/0.304

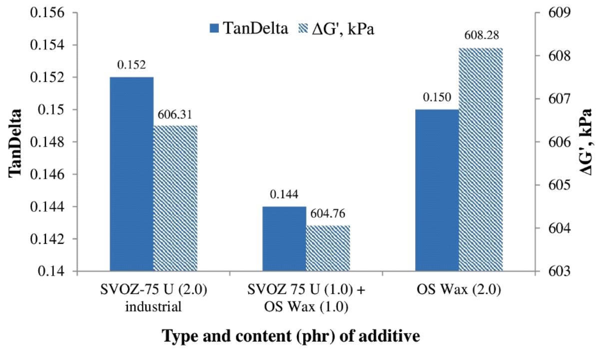

Fig. 4. Influence of the type and content of the studied additives on the characteristics of elastomeric compositions: dynamic loss tangent (TanDelta) and Payne effect (ΔG')

increase in the number of filler-filler bonds and may indicate a tendency for the appearance of filler clusters (aggregates) in the structure of the elastomeric composition.

However, the combined use of SVOZ-75 U and OS Wax additives is close to a synergistic system in terms of their positive influence on reducing the Payne effect. They obviously positively affect the dispersion of carbon black in the rubber matrix of the elastomeric composition and the additional formation of rubber-filler bonds. That is, the joint use of petrochemical wax and bio-wax additives in rubber compounds is effective for high-quality filler distribution.

Evaluation of the dynamic properties of rubbers for the manufacture of truck tire sidewalls based on natural rubber and synthetic polybutadiene indicates a certain negative effect of the bio-wax additive OS Wax on the value of fatigue endurance of rubbers under repeated tension and repeated longitudinal bending compared to the petrochemical additive SVOZ-75 U (Table 6). In the presence of 2.0 phr of bio-wax OS Wax, the rubber is almost as good as rubber with 2.0 phr of the known additive SVOZ-75 U in terms of fatigue endurance at repeated longitudinal bending but has a 14% lower fatigue endurance of rubber at repeated tensile testing under normal conditions. It is also inferior to industrial rubber in terms of this indicator after aging. The use of OS Wax (1.0 phr) and SVOZ-75 U (1.0 phr) additives in the system leads to a 33% decrease in the value of fatigue endurance under repeated tensile stress under normal conditions compared to the industrial rubber with 2.0 phr of SVOZ-75 U and insignificantly affects the endurance of rubber under longitudinal bending (Table 6). The latter is important for truck tire sidewall rubbers.

According to the effect on the physical-mechanical properties of rubbers (Table 7) at the optimum of vulcanization at a temperature of 155^{0}C, the equal-mass replacement of 2.0 phr of the petrochemical additive SVOZ-75 U with the bioadditive OS Wax almost does not cause changes in the parameters f_{200}, f_{300}, f_p, and ε under normal test conditions and at 100^{0}C. The values of heat resistance coefficients in terms of f_p and ε (Fig. 5) of the rubbers

Table 6

Dynamic properties of rubber for truck tire sidewalls in the presence of investigated products of petrochemical and biological origin

Index	Value		
	type and content (phr) of additive		
	SVOZ-75 U (2.0) industrial	SVOZ-75 U (1.0)+OS Wax (1.0)	OS Wax (2.0)
Fatigue endurance of rubber under repeated stretching at 200% elongation (250 cycles/min), thousand cycles:			
– under normal conditions	109.8	74.0	94.8
– after aging 120^{0}C×12 h	45.8	38.0	42.6
Fatigue endurance of rubber under repeated longitudinal bending, thousand cycles:			
– under normal conditions:			
visible	444	418	438
to 12 mm	864	864	864
– after aging 120^{0}C×12 h:			
visible	375	356	367
to 12 mm	864	864	864

with the tested product OS Wax are somewhat lower compared to the industrial rubber. The joint use of the petrochemical product SVOZ-75 U (1.0 phr) and the product of biological origin OS Wax (1.0 phr) provides a minimal improvement in the values of the main physico-mechanical characteristics of rubbers under normal conditions but is inferior to individual ingredients in terms of temperature and heat resistance (Table 7, Fig. 5).

Conclusions

Taking into account the established fact that the wax-containing product OS Wax, obtained from the waste of the winterization stage of sunflower oil production, is a high-molecular long-chain saturated ester that is thermostable and non-volatile in the temperature range of processing elastomeric compositions and operating products made of them, the paper investigates its effect as a technologically active additive on the formation of a set of properties of an elastomeric composition for the manufacture of truck tire sidewalls.

It has been shown that the investigated product of biological origin, when equally weighted to replace the petrochemical microwax SVOZ-75 U, provides rubber compounds with a satisfactory level of technological properties as a technological additive, increases the cohesive strength of elastomeric compositions and their relative degree of crosslinking. The initiation and deepening of vulcanization of polydiene-based rubber compounds in the presence of OS Wax is accompanied by a change in rheokinetic characteristics as a result of a decrease in the effective activation energy of sulfur vulcanization, which is likely due to the excellent chemical structure of the bioadditive and its higher acid number.

Determining the dynamic characteristics of the elastomeric composition on the MDR 3000 rheometer, we recorded an increase in the level of the Payne effect and preservation of the level of the heat generation

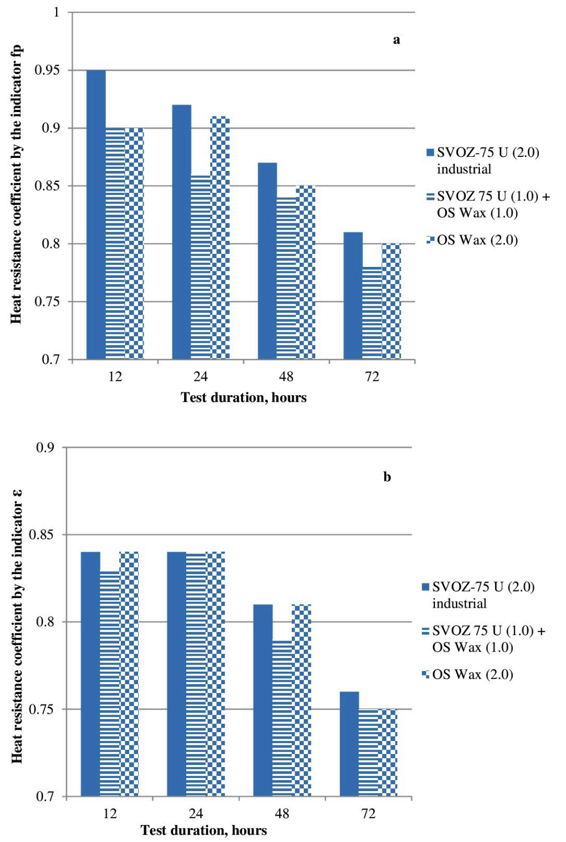

Fig. 5. Influence of the type and content of the studied additives on the heat resistance coefficients by the indicator of conditional tensile strength (a) and relative elongation at break (b) at a temperature of 100^0C and different test duration

parameter when introducing 2.0 phr of the bioingredient OS Wax compared to the composition with an equal mass content of the petrochemical product SVOZ-75 U. The joint introduction of petrochemical wax and bio-wax has a positive effect

Table 7

Physical-mechanical properties of rubber in the presence of the studied products of petrochemical and biological origin

Index	Value		
	type and content (phr) of additive		
	SVOZ-75 U (2.0) industrial	SVOZ-75 U (1.0)+OS Wax (1.0)	OS Wax (2.0)
under normal conditions/at a temperature of 100^0C*			
Conditional stress at 200% elongation, f_{200}, MPa	3.6	4.0	3.5
Conditional stress at 300 % elongation, f_{300}, MPa	6.2	6.8	6.2
Conditional tensile strength, f_p, MPa	17.2/11.5*	18.1/10.7*	17.1/11.6*
Relative elongation at break, ε, %	630/870*	630/820*	630/860*
at a temperature of 120^0C for 12/24 hours			
f_p, MPa	12.7/8.4	12.0/8.4	12.4/8.6
ε, %	480/330	415/360	495/380

on certain properties of rubbers, as demonstrated by a decrease in the Payne effect and the level of the TanDelta heat generation parameter. It was shown that the content of the additive OS Wax does not significantly affect the fatigue endurance, physical and mechanical properties of rubber under normal conditions, and their stabilization.

The OS Wax product can be considered as a promising ingredient based on renewable plant materials to expand the range of multipurpose technological additives and an alternative to petrochemical rubber ingredients.

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ВИКОРИСТАННЯ ВОСКОВМІСНОГО ПРОДУКТУ З ВІДХОДІВ ВИРОБНИЦТВА СОНЯШНИКОВОЇ ОЛІЇ У СКЛАДІ ЕЛАСТОМЕРНИХ КОМПОЗИЦІЙ

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З метою розширення асортименту інгредієнтів на основі відновлюваної біологічної сировини та захисту навколишнього середовища було досліджено ефективність продукту Віск ОС в еластомерних композиціях. Продукт отримують з відходів стадії вінтеризації виробництва соняшникової олії, і за даними диференційно-термічного аналізу та ІЧ-спектроскопії він є термостабільним нелетким довголанцюговим насиченим естером. Встановлено, що при використанні 1,0–2,0 мас.ч. Воску ОС як технологічної добавки в еластомерних композиціях для виготовлення елементів шин, продукт ініціює та поглиблює процес сірчаної вулканізації, зменшує теплоутворення, позитивно впливає на показники ефекту Пейна завдяки своїй будові та зниженню ефективної енергії активації сірчаної вулканізації. При цьому рівень динамічних і фізико-механічних властивостей гум залишається таким же, як і з нафтохімічним мікровоском марки СВОЗ-75 У.

Ключові слова: еластомерна композиція; восковмісні інгредієнти; відходи виробництва соняшникової олії; властивості гумових сумішей та гум; поновлювана біосировина; екологічна безпека.

USE OF A WAX-CONTAINING PRODUCT FROM SUNFLOWER OIL PRODUCTION WASTE IN ELASTOMERIC COMPOSITIONS

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To expand the range of ingredients based on renewable biological raw materials and enhance environmental protection, the effectiveness of the OS Wax product in elastomeric compositions was investigated. This product is derived from the waste generated during the winterization stage of sunflower oil production and, according to differential thermal analysis and IR spectroscopy, is a thermostable, non-volatile, long-chain saturated ester. It was found that incorporating 1.0–2.0 phr of OS Wax as a processing additive in elastomeric compositions for tire manufacturing initiates and enhances the sulfur vulcanization process, reduces heat generation, and positively influences the Payne effect due to its structure and the reduction of the effective activation energy of sulfur vulcanization. At the same time, the dynamic and physical-mechanical properties of the rubber remain comparable to those prepared with petrochemical microwaxes of the SVOZ-75 U grade.

Keywords: elastomeric composition; wax-containing ingredients; sunflower oil production waste; properties of rubber compound and rubber; renewable biomaterials; environmental safety.

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