

Catalytic Conversions of Linalool on Micro- and Micro-Mesoporous BEA-Type Zeolites under Microwaves Irradiation

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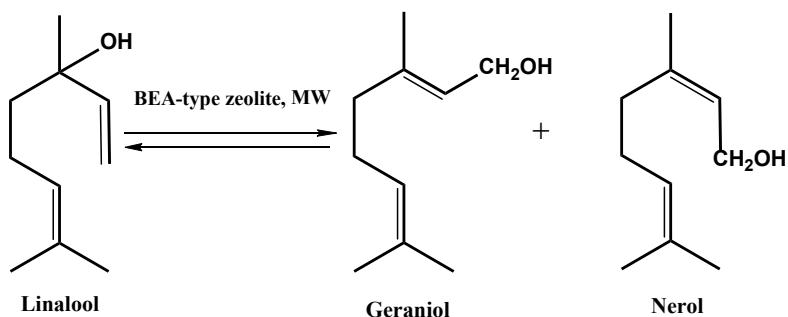
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ABSTRACT. The microwave assisted conversion of tertiary terpene alcohols – racemic linalool (97-98%) and D-linalool (57.6%) contained in coriander seed oil was investigated on samples of microporous BEA-type zeolite (BEA-25 and BEA-150 with molar ratio $\text{SiO}_2/\text{Al}_2\text{O}_3$ of 25 and 150, respectively) and on modified micro-mesoporous forms (RBEA-25 and RBEA-150 with $\text{SiO}_2/\text{Al}_2\text{O}_3$ of 23.8 and 176.4). The experiments were carried out at 40-100 °C in the atmosphere of argon or air, in the solvent-free conditions either using alcoholic solvents methanol, ethanol, and n-propanol. It has been shown that racemic linalool, by microwave irradiation (100-650 W) in argon atmosphere in solvent-free condition or dissolved in methanol had a low degree of conversion, up to 2-3% at 40-100°C. Reactions of dehydration and cyclization of racemic linalool with the formation of monoterpenic compounds $\text{C}_{10}\text{H}_{16}$ proceed more intensively on the micro-mesoporous RBEA zeolites under the microwave irradiation (200- 650 W). On the corresponding microporous samples (BEA-150, BEA-25), the racemic linalool isomerization reaction is significantly inhibited under MW irradiation. In solutions of alcohols, irradiation of racemic linalool with microwaves in the presence of BEA-type zeolite catalysts initiates also methoxylation reactions forming the methyl ethers of linalool, nerol, geraniol and α -terpineol; selectivity for the products of linalool isomerization to geraniol and α -terpineol was only about 5%. D-Linalool of coriander oil dissolved in methanol in argon atmosphere or in solvent-free state in air is predominantly transformed regioselectively into geraniol on catalysts RBEA-25 and BEA-150 under MW-irradiation (200 W, run time 1 h); at 40 and 70°C conversion of D-linalool is 29.7 and 27.7%, trans-geraniol yield and selectivity is 27.5/92.5 and 24.7/87.7, respectively. © 2019 Bull. Georg. Natl. Acad. Sci.

Key words: linalool, micro-mesoporous BEA-type zeolite, microwave assisted reaction

Linalool (3,7-Dimethyl-1,6-octadien-3-ol) is monoterpene allyl tertiary alcohol. Due to the presence of a chiral carbon atom (C3) in linalool, it has two enantiomers: licareol is (R)-(-)-linalool (L-linalool) and coriandrol is (S)-(+)-linalool (D-linalool), which are contained, for example, in lavender flowers and coriander oil, respectively. Synthetic linalool is a racemic mixture of both stereoisomers, (\pm)-linalool. Linalool is used for the synthesis of geraniol (*trans*-3,7-Dimethyl-2,6-octadien-1-ol) and nerol (*cis*-3,7-Dimethyl-2,6-octadien-1-ol), by catalytic isomerization, the allyl rearrangement including 1,3-migration of the OH-group and appropriate shift of the double bond (Scheme 1).

The chemical synthesis by using microwaves (MWs) irradiation is considered as one of the relatively new “green”, environment-friendly and progressive direction of chemistry similar to the use of high-effective catalytic systems – micro-mesoporous composite zeolite materials. In contradistinction from zeolites, developed mesoporous system enables selective transformation of large (>1 nm) molecules used in pharmacy and perfumery. The MW activation method allows to conduct processes faster and even catalyst- and solvent-free. Today several thousand chemical reactions accelerated by MWs are known [9, 10]. “Microwave-assisted organic synthesis (MAOS) is based on the efficient heat transfer



Scheme 1. Linalool isomerizaion reaction to geraniol and nerol.

Geraniol and nerol are important substances used in perfumes, cosmetics, flavoring agents. Also they are strategic materials – “building units” in syntheses of A, E and K vitamins, carotenoids, ionones and methyl-ionones. Catalysts for isomerization of linalool described in the literature are homogeneous acidic complex compounds of vanadium and other transition metals that are harmful to the environment [1-5]. In the case of heterogeneous “green” zeolite catalysts such as MOR, OFF, BEA, mesoporous MCM-41 and micro-mesoporous BEA, the yields of the isomers were low [6, 7]. Today there are no regioselective catalysts of linalool isomerization to geraniol or nerol; only the possibility of its receipt via microbial transformation is known [8].

achieved by dielectric heating, which, in turn, is mainly dependent on the ability of the solvent or reagent to absorb microwave energy” [11].

The aim of our work was to study the effect of MWs on the conversion of linalool in order to identify opportunities of obtaining the products of its isomerization, geraniol and nerol.

Materials and Methods

Chemicals. Linalool (97-98%, racemic GC), geraniol ($\geq 97\%$, FG), nerol (97%), methanol (for HPLC, $\geq 99.9\%$) were purchased from Sigma-Aldrich, and ethanol (for HPLC, 99.9%) from Roth; 1-propanol (for chromatography, Reachim). Linalool containing up to 1.2% of 1,2-dihydrolinalool was used without further

purification. Coriander (*Coriandrum sativum* L.) seeds essential oil was derived by steam distillation from coriander seeds cultivated in Georgia, "AgroAroma Group", Georgia. The main component of coriander seeds essential oil was D-linalool, its content was 70-71% as a relative percentage of the total peak area on the GC/MS chromatogram, which is 57.6 wt. %, according to the calibration. Argon (99.999% purity, Metihbect, Ukraine) was used as an inert medium during reactions.

Preparation and characterization of catalysts.

The micro-mesoporous materials, denoted as RBEA-25 and RBEA-150, have been prepared [12, 13] from microporous zeolites NH₄-BEA (molar ratio SiO₂/Al₂O₃ = 25) and H-BEA (SiO₂/Al₂O₃ = 150, both from Zeolyst International, USA), respectively. Before the experiments, the H-form was calcined for 2 hours at 550°C in a stream of purified air, and the NH₄-form – under the same conditions, but 6 hours in the program mode. Physical and chemical characterization of catalysts was described earlier [7, 14].

Reaction procedures. The conversion of racemic linalool or coriander oil was carried out under microwave irradiation in Ultrasonic-Microwave (hybrid) Reactor UMR-300B (Shinka, Japan). The microwave-assisted and conventional catalytic experiments were conducted in an atmosphere of argon. The conversion of linalool was carried out at 40-80°C in a 50 ml round bottom Bomex glass flask with a reflux condenser [14].

Analysis of the reaction products. The reaction products were analyzed by GC/MS method (Agilent Technologies GC/MS, 7890B/5977A, USA) [14].

Results and Discussion

Characterization of BEA-type zeolite catalysts.

The molar ratio SiO₂/Al₂O₃ and the acid properties

change slightly during recrystallization from BEA zeolites with microporous structure to RBEA zeolites with the combined micro-mesoporous structure, the RBEA samples have a larger total pore volume and a larger proportion of mesopores with an average pore diameter of 3.5 and 3.9 nm for RBEA-25 and RBEA-150, respectively [14].

Linalool conversion in inert atmosphere under the MW irradiation and the simultaneous application of zeolite catalysts. Linalool conversion under the MW irradiation (100-650 W) in argon atmosphere without catalysts is rather low (up to 2-3% at 40-100°C); the linalool conversion practically does not change when it is dissolved in methanol characterized by high dielectric losses (tan δ = 0.659). Previously [7] it was shown that on micro mesoporous BEA- type zeolites by the conventional thermocatalytic conversion of linalool the dehydration and cyclization reactions mainly occur and the selectivity of the formation of nerol and geraniol as products of linalool isomerization is low – up to 5% at conversion of 40%.

Under the MW irradiation (200-650 W), the reactions of dehydration and cyclization of linalool on the BEA-type zeolites proceed more intensively with the formation of monoterpene compounds C₁₀H₁₆. Conversion of linalool on the micro-mesoporous catalysts in the MW irradiation mode is higher; on the most active catalyst RBEA-25 the degree of conversion is up to 35%, the yield and the selectivity for terpene hydrocarbons (C₁₀H₁₆) in the temperature range of 40-80°C are significant, 32 and 91.2%, respectively. However, the yield of isomerization reaction products geraniol and nerol is also low, up to 4%, as during the thermocatalytic conversion of linalool. On the microporous samples (BEA-150, BEA-25), the linalool isomerization is significantly inhibited under MW irradiation.

Linalool conversion under simultaneous influence of MW and zeolite catalysts in inert atmosphere in the presence of solvents. MW-

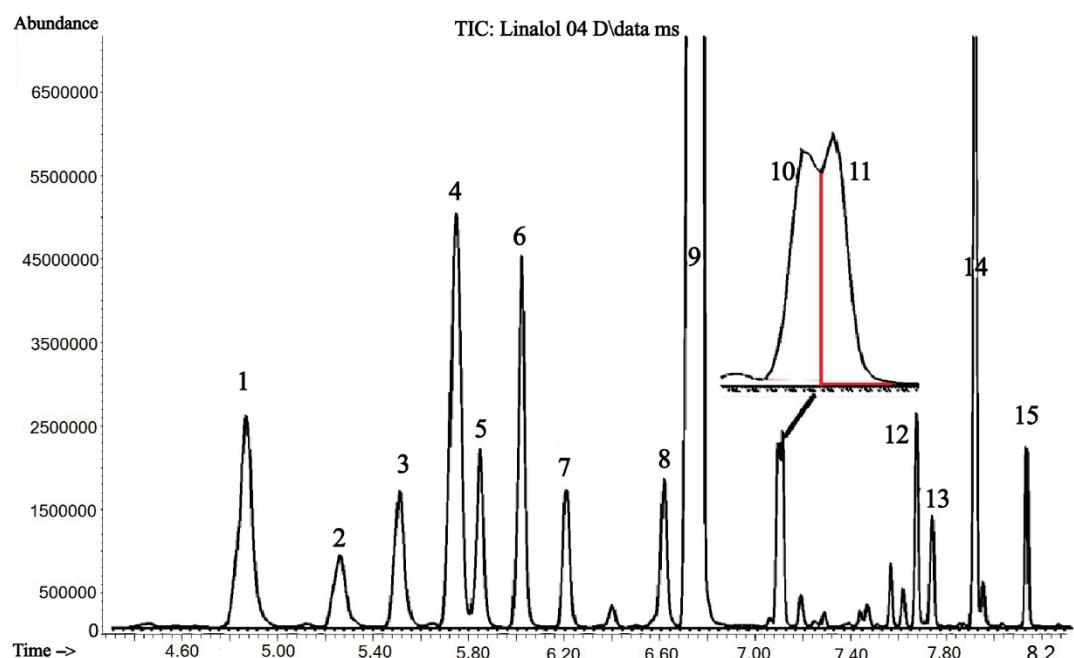


Fig. 1. GC/MS Chromatogram of catalytic conversion products of linalool under MW irradiation (200 W, 1 h) on micro-mesoporous zeolite RBEA-25 ($m_{\text{cat}}/m_{\text{linalool}} = 1/35$, reaction carried out in methanol, molar ratio of methanol/linalool = 2.2 /1) in an argon atmosphere at 40 °C: 1 – β -Mircene $C_{10}H_{16}$, 2 – α -Phellandrene $C_{10}H_{16}$, 3 – α -Terpinolene $C_{10}H_{16}$, 4 – D- limonene $C_{10}H_{16}$, 5 – trans- β -Ocymene $C_{10}H_{16}$, 6 – β -Ocymene $C_{10}H_{16}$, 7 – γ -Terpinene $C_{10}H_{16}$, 8 –Isoterpinolene $C_{10}H_{16}$, 9 – β -Linalool $C_{10}H_{18}O$, 10 – 1,2-Dihydrolinalool $C_{10}H_{20}O$, impurity substance of initial linalool, 11–Linalyl methyl ether, $C_{11}H_{20}O$, 12 – α -Terpineol $C_{10}H_{18}O$, 13 – Neryl methyl ether $C_{11}H_{20}O$, 14 – Geranyl methyl ether $C_{11}H_{20}O$, 15 – trans-Geraniol $C_{10}H_{18}O$.

assisted conversion of linalool in a solution of methanol in the presence of zeolite catalyst mainly results in dehydration, cyclization, isomerization, and etherification (methoxilation) reactions; for example, the full transformation spectrum on RBEA-25 is shown in Fig. 1 including products of dehydration and cyclization (terpene hydrocarbons $C_{10}H_{16}$, chromatogram peaks (CP) 1-8), products of isomerization (terpene alcohols $C_{10}H_{18}O$, CP 12, 15 and traces of nerol), products of methoxylation of linalool and terpene alcohols $C_{10}H_{18}O$ obtained from linalool through isomerization ($C_{11}H_{20}O$, CP 11, 13, 14).

With a twofold increase in the molar ratio of methanol to linalool, the conversion of linalool increases mainly due to strengthening of the processes of dehydration, cyclization and etherification; at the same time, the selectivity for the products of these reactions is almost unaffected, while it decreases in isomerization into geraniol and

α - terpineol. In a more polar, n-propanol with loss tangent 0.757 [15], the conversion and selectivity to isomerization products – geraniol, nerol and α -terpineol grow with increasing of temperature to 70°C; however, the yields and selectivity for them are low. The dependencies of linalool conversion, reaction products yields, selectivity and distribution on microwave power are displayed in the Table 1.

In a methanol solution by influence of microwaves and a catalyst – a BEA-type zeolites, linalool is converted into a multitude of products, Fig. 1, Table 1. These are terpene acyclic and cyclic hydrocarbons $C_{10}H_{16}$ (β -mircene, D-limonene, trans- β -ocimene, cis- β -ocimene, γ -terpinene, α -phellandrene, α -terpinolene), isomeric to linalool monoterpene alcohols ($C_{10}H_{18}O$) geraniol, nerol, α -terpineol, as well as methoxylation products – linalyl, neryl, geranyl and terpinyl methyl ethers. The latter are probably formed as a result of consecutive reactions of linalool isomerization into

Table 1. Effect of BEA-type zeolite catalysts on linalool conversion under microwaves irradiation (650 W) in argon atmosphere at 40°C

Catalysts	RBEA-25		BEA-25			RBEA-150	BEA-150
Entry	1	2	3	4	5	6	7
m _{cat} /m _{Lin}							
vMethanol /vLin, vLinalool/g cat,	1/26 113.4/1 0.17	1/26 113.4/1 0.17	1/69.4 40.5/1 0.45	1/69.4 40.5/1 0.45	1/69.4 40.5/1 0.45	1/26 113.4/1 0.17	1/69.4 40.5/1 0.45
Conversion of Linalool, % /Run time, h/MW power, W	13.9/1.5h /550	28.0/1.5h /650	16.6/1.5h /650	20.1 /1.5+2h /650	23.0/1 h /800	3.3-7.3 /2-4 h /650	10.3/1.5h /650
Yields, % / Selectivity, %							
Terpene HC	3.0/21.6 Acycl terp	10.3/36.7 Acycl+cycl monoterp	7.7/46.3 Acycl terp	7.5/37.3	8.3/36.1 Acycl terp	0.3/9.0- 1.1/15.1 Acycl+cycl monoterp	7.5/72.8
Products of linalool isomerization reaction, %	0.5/3.6 G	1.3/4.6 G, α- Terpineol	1.1/6.6 G, α- Terpineol	1.3/6.5 G, α- Terpineol	1.6/7.0 G, α- Terpineol	0.6/18.2- 0.9/12.3 G Little: N, α-Terpineol	trace
Ethers, %	10.3/74.1	16.4/58.4	8.0/48.1	11.3/56.2	12.4/55.0	2.4/72.0- 5.3/72.6	2.7/26.2
Linalyl methyl ether	1.0/7.2	0.5/1.8	Little	1.0/5.0	1.1/5.8	0.0/0.0- 0.8/11	1.0/9.7
Neryl methyl ether	0.7/5.0	1.3/4.6	0.7/4.2	0.9/4.5	1.0/4.3	0.0/0.0- 0.6/8.2	-
Geranyl methyl ether	-	-	-	-	-	-	1.7/16.5
Terpinyl methyl ether	8.6/61.9	14.3/51.1	7.3/43.9	9.4/46.7	10.3/44.8	2.4/72.0- 3.9/53.4	-

the corresponding terpene alcohols, and then their further methylation reaction.

Under comparable conditions Table 1 (Entries 1 and 2; 3 and 5), the increase in microwave power from 550 to 650 W or from 650 to 800 W, respectively, contributes to a noticeable increase in linalool conversion, yield of terpene hydrocarbons, esterification products and, accordingly, isomerization. The process of formation of the latter is also similarly affected by an increase in the exposure time from 1.5 to 3.5 hours Table 1 (Entries 3 and 4); isomerization activity is greatly reduced for catalyst BEA-150 when it is irradiated with microwaves. According to the value of the total linalool conversion at its MW irradiation in the presence of BEA-type zeolite catalysts, there is the

following relative activity range: RBEA-25>BEA-25> RBEA-150 >> BEA-150, Table 1. As in the case of thermal catalytic conversion of linalool on the same catalysts [7], a large conversion of linalool on micro-mesoporous samples (RBEA-25 and RBEA-150) in comparison with microporous (BEA-25 and BEA-150) correlates with the highest total acidity the first (1179 μmol / g and 1200 μmol/g) and with the larger share of mesopores in them, Table 1 (Entries 2, 6 and 3, 7), [14].

MW-assisted conversion of linalool contained in coriander seeds essential oil. The studied coriander seed essential oil (hereinafter “coriander oil”) is a multicomponent mixture of terpenes and

terpenoids with the predominance of D-linalool, Table 2; its amount in the used oil according to GC/MS calibration data is 57.6%. Essential oils contain small amounts of polar molecules, their dielectric constant ϵ at room temperature is low (2–8) [16], and irradiation of coriander oil with microwaves of different power (200–650 W) did not lead to noticeable chemical changes. To increase its ability to absorb microwaves, coriander oil was dissolved in ethanol, n-propanol and methanol having high dielectric loss with $\tan \delta = 0.941$, 0.799, and 0.659, respectively [9]. Alcohol solutions of the coriander oil were irradiated with microwaves of different power in an atmosphere of argon and air. Composition of coriander oil tested and partially the results of its MW-assisted conversion are presented as the GC-MS chromatogram in Fig. 2 and Table 2.

terpenoids in it, Table 2 (Entries 1,5). And in the presence of catalyst RBEA-25 in an atmosphere of argon in methanol solution there is a significant transformation contained in coriander oil linalool into trans-geraniol, Table 2 (Entry 2); in the reaction products, the content of trans-geraniol reaches 30.5%. In ethanol solution, under conditions similar to that of Table 2 (Entry 2), the content of trans-geraniol (2.1%) is low with a linalool conversion of 49.6%. Significant was the effect of the nature of the solvent and the medium; in a solution of 1-propanol in an Ar atmosphere, the conversion of linalool increased to 63.6% at 70°C and the content of esters, especially δ -terpinyl acetate $C_{12}H_{20}O_2$, to 14.6, and the yield and selectivity for trans-geraniol decreased to 7.6 and 12%, respectively, Table 2 (Entry 4). It is noteworthy that in the atmosphere of air when

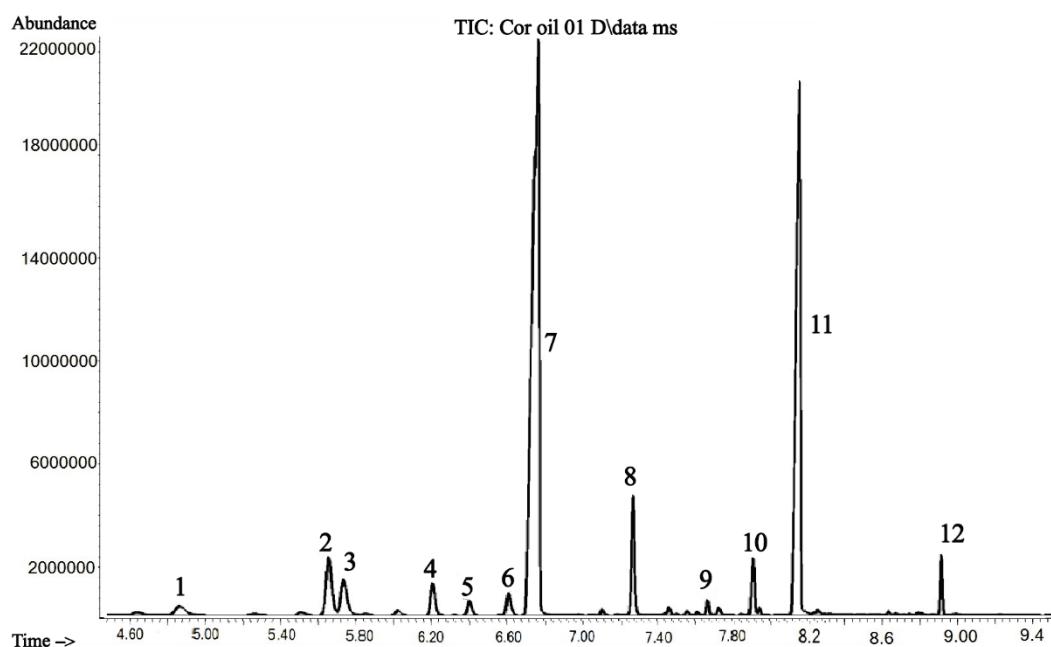


Fig. 2. GC/MS chromatogram of catalytic conversion products of coriander oil conversion under MW irradiation (200 W, 1 h) on micro-mesoporous zeolite RBEA-25 ($m_{cat}/m_{coriander\ oil} = 1/70$, methanol – 0.049 mol, $m_{cat}=0.05$ g) in an argon atmosphere at 40 °C: 1 – β -Mircene $C_{10}H_{16}$, 2 – m-Cymene $C_{10}H_{16}$, 3 – D-limonene $C_{10}H_{16}$, 4 – γ -Terpinene $C_{10}H_{16}$, 5 – cis-Linalool oxide $C_{10}H_{18}O_2$, 6 – Isoterpinolene $C_{10}H_{16}$, 7 – β -Linalool $C_{10}H_{18}O$, 8 – D-Camphor $C_{10}H_{16}O$, 9 – α -Terpineol $C_{10}H_{18}O$, 10 – Geranyl methyl ether $C_{11}H_{20}O$, 11 – trans-Geraniol $C_{10}H_{18}O$, 12 – Geranyl acetate $C_{12}H_{20}O_2$.

It can be seen that the irradiation with MWs (200 W) of solutions of coriander oil in methanol slightly changes the content of terpenes and

irradiated by MWs of coriander oil without solvent in the presence of a catalyst BEA-150 at 70°C, the content of trans-geraniol reaches 24.8%.

Table 2. Chemical composition of coriander oil and products of its microwave-assisted (200 W, run time 1 h) and catalytic conversion under BEA-type zeolites (0.05 g) according to GC-MS

Entry/Catalysts	Products composition, %				5
	1 Without catalyst	2 RBEA-25	3 BEA-150	4 RBEA-25*	
Temperature, °C, Medium	40 Ar	40 Ar	70 Air	70 Ar	
m _{cat} /m _{coriander oil}	- 2.0	1/69.4 2.0	1/26.4	1/34.7	Composition of coriander seeds essential oil, %
V _{methanol} , mL	4.0	4.0	-	-	
V _{coriander oil} , mL	-	-	1.5	2.0	
V _{n-propanol} , mL	-	-	-	2.0	
Conversion of Linalool, %	-	29.7	27.7	63.6	
**Trans-geraniol Yield, %	-	27.5/92.5	24.7/87.7	7.6/12.0	
/ Selectivity, %	-				
Sum of terpenes, C ₁₀ H ₁₆ %	12.8	9.9	14.2	24.6	
Sum of terpenoids, %	86.2	89.2	85.9	75.4	
Products composition, %					
cis-Linalool oxide C ₁₀ H ₁₈ O ₂	0.9	0.8	1.1	3.1 cis- (0.8)+ trans- (2.3)	1.0
Linalool C ₁₀ H ₁₈ O	74.6	49.7	51.1	25.7	70.7
D-Camphor C ₁₀ H ₁₆ O	6.8	4.3	5.0	4.2	7.6
Terpineols C ₁₀ H ₁₈ O		0.5 α-terpineol	α-terpineol (1.4) + terpinen-4-ol (0.5)	7.5 α-terpineol (5.8) + terpinen-4-ol (1.7)	
Trans-Geraniol	1.7	30.5	24.8	7.8	1.1
Nerol C ₁₀ H ₁₈ O				0.7	
Terpinyl methyl ether C ₁₁ H ₂₀ O		1.9		0.6	
δ-Terpinyll acetate C ₁₂ H ₂₀ O ₂				14.6	
Neryl acetate C ₁₂ H ₂₀ O ₂				7	
Geranylacetate C ₁₂ H ₂₀ O ₂	2.2	1.5	2.0	2.4	3.0

*Also, there were (%): p-menthane-0.3, ethanone-0.3, trans-piperitol-0.4, cytronellal hydrate-0.8.

**Calculated relative to linalool.

Conclusion

- Racemic Linalool under the MW irradiation (100–650 W) in argon atmosphere, in solvent-free state or dissolved in methanol has a low degree of conversion, up to 2–3% at 40–100°C. The reactions of dehydration and cyclization of linalool proceed more intensively with the formation of monoterpenic compounds C₁₀H₁₆ on micro-mesoporous RBEA zeolites under the MW irradiation (200–650 W). MW-assisted conversion

of linalool on the micro-mesoporous catalysts is higher than its thermocatalytic conversion. Yields of isomerization products (geraniol and nerol) are low, up to 4%, as well as during the thermocatalytic conversion of linalool. On the corresponding microporous samples (BEA-150, BEA-25), the linalool isomerization is significantly inhibited under MW irradiation.

- MW-assisted conversion of linalool in solutions of methanol or n-propanol in the presence

of BEA-type zeolite catalysts mainly results in dehydration, cyclization, etherification (methoxilation) and isomerization reactions producing terpene acyclic and cyclic hydrocarbons $C_{10}H_{16}$, (β -mircene, D-limonene, trans- β -ocimene, cis- β -ocimene, γ -terpinene, α -phellandrene, α -terpinolene), isomeric to linalool monoterpene alcohols ($C_{10}H_{18}O$) geraniol, nerol, α -terpineol, as well as methoxylation products – linalyl-, neryl-, geranyl- and terpinyl methyl ethers. The prevailing reactions are methoxylation (with the formation of ethers of linalool, nerol, geraniol and α -terpineol) and dehydration-cyclization (with the formation of terpene hydrocarbons); in the case of active RBEA-25, the selectivity for the methoxylation and dehydration products is 58 and 37%, respectively, and for the products of isomerization to geraniol and α -terpineol it is only about 5%.

3. The influence of the MW on the conversion of coriander oil containing 57.6% of D-linalool was

investigated. Irradiation (200-650 W) of coriander oil or its solution in methanol in an atmosphere of argon and air did not lead to noticeable chemical changes. D-linalool of coriander oil dissolved in methanol in argon atmosphere or in solvent-free state in air is predominantly regioselectively converted into geraniol without formation of nerol on catalysts RBEA-25 and BEA-150 under MW-irradiation (200 W, run time 1 h), only a very small amount of α -terpineol is formed; at 40 and 70°C conversion of linalool is 29.7 and 27.7%, geraniol yield (%) and selectivity (%) is 27.5/92.5 and 24.7/87.7, respectively.

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სან დივებოს სახელმწიფო უნივერსიტეტი საქართველოში, თბილისი, საქართველო

§ ივანე ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტი, ფიზიკური და ანალიზური ქიმიის დეპარტამენტი, თბილისი, საქართველო

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გამოკვლეულია მესამეული ტერპენული სპირტის - რაცემული ლინალოოლის (97-98%) და ქინძის (*Coriandrum sativum* L.) თესლის ეთერზეთის შემადგენელი D-ლინალოოლის (57,6%) გარდაქმნები მიკროფორმოვან BEA-ტიპის (BEA-25 და BEA-150, მოლური $\text{SiO}_2/\text{Al}_2\text{O}_3$, თანაფარდობით 25 და 150, შესაბამისად) და მათ მოდიფიცირებულ მიკრო-მეზოფორმოვან ფორმებზე (RBEA-25 და RBEA-150, $\text{SiO}_2/\text{Al}_2\text{O}_3$ 23,8 და 176,4, შესაბამისად) მიკროტალღების ზემოქმედებისას. ქინძის მარცვლების ეთერზეთის შემადგენელ D-ლინალოოლზე კატალიზატორების RBEA-25 ან BEA-150 და მიკროტალღების მოქმედებისას (200 W, დასხივების დრო - 1 სთ) გამხსნელად მეთანოლის გამოყენებისას არგონის ატმოსფეროში ან გამხსნელის გარეშე რეაქციის ჰაერზე წარმართვისას ხდება D-ლინალოოლის მნიშვნელოვანი გარდაქმნა ტრანს-გერანიოლში ნეროლის წარმოქმნის გარეშე; აღნიშნულ კატალიზატორებზე შესაბამისად, ტრანს-გერანიოლის გამოსავლიანობა ს/ელექტრიულია ტოლია 27,5/92,5 და 24,7/87,7, D-ლინალოოლის გარდაქმნის ხარისხი კი 29,7 და 27,7% ტოლია 40 და 70°C ტემპერატურებზე.

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