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RESEARCH PAPER

Development of a New Silicon-Based Transdermal System. I. Study of Silicone Elastomers and Effect of Liquid Ingredients

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ABSTRACT

The polarities of four elastomers made of silicon oligomers of different viscosities were investigated by measuring the uptake of swelled solvent in different polarity solvents after 24, 48, and 72 hr of treatment. The solvent uptake provides a good characterization for the polarity of the inside of the matrix. On the basis of the results the oligomers were divided into two groups. The same method has been used for the investigation of the change of the inner polarity of samples containing various amounts of polar and apolar liquid ingredients. It was shown that the polarity of the inside of the matrix is related to the swelling properties. The ingredients used changed the matrix framework, which was also influenced by the type of oligomers. The solvent uptake shows large dependence on the timing of the measurement. Measurements carried out after 48 hr of polymer production showed constant solvent uptakes, indicating that the final structure of the polimer was formed.

MATERIALS AND METHODS

The four oligomers R-1 R-5, R-18, R-38 (the number used in the product code indicates the viscosity of the oligomer in terms of Pa · s) and the poly(dimethylsiloxane) oil/M 350 (Szilor Kft., Budapest, Hungary) were selected for the tests. The catalyst T-47 (Wacker Chemie GmbH, München, Germany) was used as networking agent. It contains poly(alkoxy-silane) as the crosslinking compound and organic tin compound as the crosslinking initiator. The T-47 was mixed in a quantity of 5% into the oligomer and/or oligomer-additive mixtures, then the mixtures were crosslinked at 25°C by spreading them on poly(tetrafluoroethylene) (PTFE) plates at a thickness of 1 mm. The dry glycerine and propylene glycol used were Ph Hg VII degree, the eth-

ylene glycol was analytical purity (Reanal Finechemical Factory, Budapest, Hungary) and the polyethylene glycol/PEG 400 was PLURIOL E 400 (BASF, Ludwigshafen, Germany). The silicone oil/M 350 used has 350 mPa · sec viscosity. For the test, films with 1 mm thickness were prepared and after an aging period of 7 days, disks with a diameter of 2 cm and a surface area of 3.14 mm^2 were cut out. Each test was made with five parallel samples. Following a mass measurement with a four decimal point accuracy using an analytical balance, the samples were placed into solvents with different polarity–toluene, ethyl-acetate, *n*-butanol, ethanol, (Reanal Finechemical Factory) and distilled water—and their mass was measured after 24, 48, and 72 hr. The volume of the absorbed solvent was calculated using Eq. (1):

$$V = \frac{m_{sw} - m_d}{V_d \cdot \delta_s} \cdot 100 \quad (1)$$

where V is the relative volume of the solvent uptake (that is, the percentage increase in volume of the sample compared to that of the initial sample), m_{sw} is the mass of the sample in a given solvent after soaking, m_d is the mass of the dry sample, δ_s is the density of a given solvent, and V_d is the volume of the dry sample.

The data of the parallel samples were averaged. Deviation of the parallel samples never exceeded 3%. To the thermoanalytical tests the silicone elastomer membranes were cut into pieces of about 1 × 1 mm. From these samples, 100 mg was tested in a type MOM OD2 derivatograph using a simultaneous method of thermogravimetric analysis, differential thermogravimetry, or differential thermal analysis (TGA, DTG, DTA, respectively). As reference material α-aluminum oxide was used in the same quantity as the sample. Recordings were made by means of platinum sample holders in static atmosphere with a heating rate of 5°C/min. The same test method was used to make the derivatograms of the base polymers (1).

RESULTS AND DISCUSSION

As a result of pharmaceutical technology research, a new drug type, the transdermal therapeutic system (TTS), emerged in pharmaceutical technology in the early 1970s. This new drug type releases its active ingredient through the patient's skin providing a uniform blood level. In addition, since the active ingredient moves with the blood stream directly into the targeted organ, the effective dose can be lower than that in the traditional drug types (2–4). Several forms of TTSs have been developed during the recent years (5–7), which can be divided into two major groups. In the first group the optimal degree of release of the active ingredient is provided by the plaster base and the plaster structure together, and in the second group by a special microporous or nonporous membrane. In the present work the objective was to select silicon rubber base materials that would allow the development of a new TTS with the optimal characteristics. Several publications have dealt with the characteristics of silicon membranes or with the testing of material diffusion through membranes (8–16), however, commercially available silicon rubber films or factory kits used for manufacturing silicon rubber were used in these studies and unfortunately it is very difficult to establish what additives they really contain. Since the additives used fundamentally change the characteristics of the base materials, general conclusions from these results can only be drawn with difficulty and with reservations. Therefore, first we carried out the testing of poly(dimethyl-siloxane-α,ω-diols).

Study of Silicone Oligomers

As shown in Table 1, the oligomers can be divided into two main groups, one containing the elastomers made from oligomers R-1 and R-5, and the other containing those made from oligomers R-18 and R-38. The uptake of solvents by the samples within a group is very similar. The results of our tests correlate well with those published in our previous study (1). A plot of the solvent uptake against the polarity of the solvent (Fig. 1) shows clearly the different behavior of the elastomer groups. Figure 1 shows the data of the samples measured after 72 hr, and the polarity of the solvents is characterized by their values calculated on the basis of their solvatochromic effect (17). Polarity values ($E^{N/T}$) characteristic for the solvents are shown in Table 2.

The comparison of the data shows that the extent of swelling in apolar solvents of elastomers made from the individual oligomers greatly depends on the viscosity of the initial oligomer, i.e., the length of the polymer chain. By increasing the chain length of oligomers, the network to be formed has a looser, more flexible structure, and because of the longer chains there is more space for the solvent. Conversely, it can be assumed that not all of the silanolic groups that are evidently present in greater numbers in oligomers with a smaller

Table 1

Solvent Uptake of Silicone Elastomers in Several Solvents with Different Polarities

Sample	Time (hr)	Average Solvent Uptake of Elastomer (%)				
		Toluene	Ethyl acetate	*n*-Butanol	Ethanol	Distilled Water
R-1	24	149.2	103.4	1	3	0
	48	174.3	102.7	1	1.8	0
	72	179.4	101	1	1	0
R-5	24	191.7	109	8	2	0
	48	195.2	112	8.6	2	0
	72	197.5	113.3	9.3	1.8	0
R-18	24	221	127.6	8.9	2.9	0
	48	227	129	8.6	2.6	0
	72	234	129.7	9.2	2	0
R-38	24	269	148.6	1	2	0
	48	295.5	153	1	2.3	0
	72	302	153.7	1	1.6	0

siloxane chain will have a condensation reaction with the crosslinking agent. Thus the nonreacting silanolic groups reduce the apolar character of the inner part of the matrix.

To affirm this assumption further tests were carried out. Oligomers R-5 and R-18 were selected for the tests and used in the experiments.

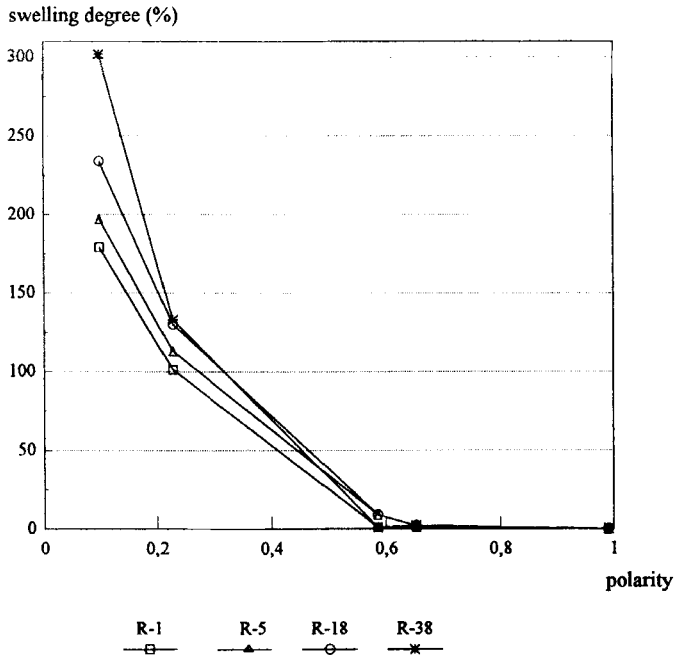

Figure 1. Solvent uptake of base elastomers.

Study of the Time Elapsed from Preparation

The relationships between the time elapsed from the preparation to the tests and the volume of the solvent uptake by the elastomer were examined.

The samples aged for 0–5 days according to the procedure described above were immersed into the solvents having different polarity immediately following preparation and left. The volume of solvent uptake was measured after 24, 48, and 72 hr. The results are shown in Tables 3 and 4.

As the data from the tables show, after the third day following the preparation the quantity of solvent uptake by the samples changed only to a very small extent. During the first 24 hr additional bonds are still formed within the matrix and the structure of the polymer becomes more and more rigid, but this process terminates in about 72 hr and the matrix structure is fully developed. This test has provided us with very important information since the basic condition of reproducible measurements is that no changes should take place in the matrix structure during the course of the measurements. This is also very important from the point of view of the transdermal product to be produced since in the course of the dissolving test of the product the emergence of the active ingredient from a matrix with a looser structure can evidently be much more extensive. Therefore, the tests on the samples used in the experiment were always made at least 5 days after the preparation of the sample.

Table 2

Polarity of Solvents Used

Solvent	Toluene	Ethyl Acetate	*n*-Butanol	Ethanol	Distilled Water
$E^{N/T}$	0.099	0.228	0.586	0.654	0.991

Following the polarity testing of basic elastomers, we wanted to test the effect of various additives on the characteristics of basic elastomers. The active ingredients that might be suitable for transdermal application have a very diverse chemical structure and many among them are polar molecules. Since they dissolve poorly in a polymer matrix, the diffusion of the active ingredient within the matrix must be facilitated by a polar phase formed inside the matrix. This polar phase can be accomplished chemically (by changing the chemical structure of the elastomer) or physically (by introducing a mobile polar phase). Of course this differentiation is artificial and not explicit since the mobile phase must be linked also with chemical bonds to the polymer matrix frame. If this was not accomplished the silicone matrix would "squeeze out from itself" the liquid that is "foreign" to it which has a different polarity. First, the effect of glycerine with a polar structure on silicone elastomers made from oligomers R-5 and R-18 was tested.

Study of the Effect of Glycerine

The effect of glycerine on silicone elastomers has also been studied by other research teams (18–20). The solvent uptake by the samples was tested the same way as for the basic elastomers. Test results are given in Table 5. Data from the table shows that the use of glycerine significantly changes the characteristics of silicone matrixes for both base materials. As it could be expected, with the use of as little as 3% of glycerine the polymers can take up distilled water and this capacity increases with the increase of glycerine content. The use of glycerine at 3 or 5% increases water uptake nearly to the same extent for both polymers. The presence of

Table 3

Solvent Uptake of Elastomers Made from R-5 in Several Solvents with Different Polarities After Several Days

Age of Sample (days)	Time of Swelling (hr)	Average Solvent Uptake of Elastomers (%)				
		Toluene	Ethyl Acetate	*n*-Butanol	Ethanol	Distilled water
0	24	219	122	7.8	2	0
1	24	195	116.7	7.9	2	0
2	24	193.4	114.6	7.9	2.2	0
3	24	191.7	114.6	7.9	2.4	0
4	24	190.5	114.8	9.3	2.6	0
5	24	187.9	114.5	9.2	3	0
0	48	230.5	122	7.8	2	0
1	48	200	119	7.9	2	0
2	48	196.8	117.4	8.2	2.2	0
3	48	194	117	8.6	2.4	0
4	48	193.8	116.5	8.7	2.6	0
5	48	193	116	8.7	2.6	0
0	72	237.6	122.6	8.1	2	0
1	72	205	122.3	8.4	2.2	0
2	72	200.4	121.3	8.7	2.6	0
3	72	200	120	8.6	2.4	0
4	72	198.7	119.8	8.7	2.8	0
5	72	198.4	115.6	8.7	2.9	0

Table 4

Solvent Uptake of Elastomers Made from R-18 in Several Solvents with Different Polarities After Several Days

Age of Sample (days)	Time of Swelling (hr)	Average Solvent Uptake of Elastomers (%)				
		Toluene	Ethyl Acetate	*n*-Butanol	Ethanol	Distilled Water
0	24	252	148.8	8	1	0
1	24	223.8	129.8	7.9	2.5	0
2	24	222.6	127	9.7	2.4	0
3	24	221.7	127	9.5	2.3	0
4	24	223.9	127	9.7	2.7	0
5	24	221.7	127	8.7	2.7	0
0	48	268	146	7.3	1	0
1	48	231.6	131.5	8.4	2.4	0
2	48	230.4	131	8.8	2.3	0
3	48	227.7	128.3	8.7	2.2	0
4	48	227	128	8.4	2.4	0
5	48	224	129	8.6	2.2	0
0	72	277.4	149.5	7.2	1	0
1	72	239.6	143.6	9	2.8	0
2	72	238.4	145.2	9.7	2.7	0
3	72	237	138.2	9.8	2.3	0
4	72	237.5	129.6	9.9	2.6	0
5	72	237.7	127.6	9.6	2.9	0

glycerine at 10% results in a water uptake 1.5-times larger for polymer R-18 than for R-5. The behavior of silicone elastomers also changes in apolar solvents. For elastomer R-5 the presence of glycerine had no effect on the behavior of the elastomer in toluene or in ethyl acetate.

Significant solvent uptake was observed in *n*-butanol and in ethanol. In these two solvents the swelling of the elastomer starts at the same time as the degradation of the polymer network. By the end of 72 hr, a significant reduction in mass can be observed. The glycerine content causes a decreasing tendency of swelling for elastomer R-18 in toluene and ethyl acetate. Compared to the base elastomer R-18, the glycerine content of 3, 5, and 10% reduces the toluene uptake by 37, 47, and 56%, respectively. In ethyl acetate this reduction

Table 5

Solvent Uptake of R-5 and R-18 Elastomers with Different Glycerine Quantities in Solvents with Different Polarities

Glycerine Content	Time (hr)	Solvent Uptake of Elastomers (%)				
		Toluene	Ethyl Acetate	*n*-Butanol	Distilled Ethanol	Water
R-5						
3%	72	208	103	6.4	1.7	8.8
5%	72	206	104.2	10	11.5	16.5
10%	72	192.6	96.8	25	17.7	30
R-18						
3%	72	226.7	108	5.7	1.3	10
5%	72	217	107.5	6	28.4	15.3
10%	72	208	100	25	37	46.4

amounts to about 35%. A process similar to that of R-5 can be observed in *n*-butanol and ethyl acetate, and the elastomer degradation is also quite significant. These processes show that with the use of glycerine the apolar character of the inside of the matrix is reduced. In the presence of glycerine the degree of crosslinking of an oligomer is smaller, poly(dimethy-siloxane) chains containing free Si-OH groups remain in the internal regions of the network. These chains, in the polar and easily moving liquid phase, fill in the inside of the small channels of the matrix and can be easily detached from the matrix framework. This explains the reduction in mass shown in alcohol. The increase in polarity caused by the larger siloxane chains and the glycerine content results for R-18 in a more flexible, looser structure, and this is manifested to a larger extent in polar solvents because the two elastomers swell in toluene and ethyl acetate nearly to the same degree, but distilled water and ethyl alcohol is taken up by R-18 in a much greater quantity than in R-5. Presumably a part of glycerine also diffuses from the inside of the matrix; however, its extent is far from the amount of mass reduction in alcohol. This is also indicated by the fact that in distilled water only mass increase was observed, although glycerine also mixes perfectly with this solvent, so it could even fully dissolve from the matrix. The poly(dimethylsiloxane) chains are, conversely, so apolar that even the free-moving silanol-ended chain fragments cannot solvate in water; therefore, the chain scission following solvation cannot even take place. This is why only mass increase was observed for this solvent. However, we thought it would be interesting to determine to what extent can the glycerine, located in the polymer matrix, move freely. Furthermore, it could also be envisaged that a part of glycerine was linked by chemical bonds to the siloxane structure. For this reason some thermoanalytical tests were also performed.

Thermoanalytical Study

As has been mentioned above, the R-1 and R-5 samples have two exothermic stages. The mass reduction of 2–2.5% observed until the first decomposition stage is due to the exit of the small amount of volatile components absorbed on the surface and/or contained by the matrix. At 295°C a significant mass reduction of 8% (partial process II) was observed and this was followed at 350°C by the thermal degradation of the matrix. The recordings of samples made from R-18 and R-38 did not show the first thermal stage observed in the previous samples, only the continuous mass reduction due to the exit of volatile components (5.75 and 4.25%) and then the exothermic mass reduction due to the degradation of the structure at 364°C and 360°C. When glycerine was added at 3, 5, and 10% to the base elastomers the appearance of a new stage was observed between 80 and 220°C (partial process I). The size of mass reduction increased when the additives were added in larger amounts, but each particular mass reduction was always below the actual concentration value. The measurement results are shown in Table 6. At the same time the mass reduction observed for base elastomers increased by about 1.5–2%. The sum of partial processes I and II amounted approximately to the sum of the concentration of the additives used and that of the mass reduction observed during the testing of base elastomers. On the basis of these results it can be concluded that glycerine at 1.5–2% can be incorporated into the matrix structure and quantities greater than this are linked only with weak interactions.

These tests eventually supported our original assumption that not only the viscosity of the oligomers, but the time elapsed between preparation and testing (i.e., the final development of the matrix structure) and the additive used also influence the polarity characteristics of

Table 6

Thermogravimetric Analysis Data of Glycerine with Silicone Elastomers

	R-5		R-18	
Sample	I Δm (%)	II Δm (%)	I Δm (%)	II Δm (%)
3% Glycerine	1.0	10	2.5	8.5
5% Glycerine	4.0	9	3.0	10.0
10% Glycerine	8.5	9.5	7.0	11.0

a silicone elastomer matrix. The glycerine used in the tests was bonded both chemically and physically in the inside of the matrix structure, significantly modifying its characteristics.

Effect of Propylene Glycols

Propylene glycol was added to the oligomer T-47 mixture in quantities of 3, 5, and 10%, and the solvent uptake of these matrixes was measured. The results of this study are shown in Table 7. The data show that the use of propylene glycol did not result in an increase of the water uptake. However, a larger difference was observed by using alcohols. The toluene uptake is independent of the propylene glycol content. This behavior is in contrast to that observed for the samples prepared with glycerine.

As can be seen in the table, the propylene glycol is built into the matrix structure to a small extent only. It builds up a liquid phase in the tubes of the matrix structure. This polar liquid phase increases the toluene uptake of the R-5 matrix by an insignificant degree only, but in the case of the R-18 elastomer the toluene uptake is considerable (30%). This is because the propylene glycol is settled around the silanol groups, remaining inside of the matrix structure after the networking, in physically bonded form. In the case of R-5 the swelling in toluene is independent from the liquid ingredient content. The propylene glycol associated to the free silanol groups inside of the matrix does not prevent the penetration of toluene into the external layers of the matrix, but makes the penetration into the inside of matrix more difficult. The elastomer can take up the toluene in a quantity of 4–6% after the first 24 hr.

In the R-18 elastomer fewer free silanol groups remain than in R-5, thus the propylene glycol can move in the matrix more freely, increasing the polarity of the elastomer and making the toluene uptake more difficult. The 3% propylene glycol with elastomer can take up toluene to a degree of 23% after the first 24 hr but the 10% ingredient having samples in a degree of 6.6% toluene only. The high (5% and 10%) propylene glycol content increased the alcohol uptake insignificantly, however, this alcohol uptake causes the degradation of polymers. This can be due to two parallel process; the first volume-increasing process is the mixing of the alcohol and the polar liquid phase, and the other volume-decreasing process is the dissolution of the polar ingredient and the breaking of the silanol group with side-chains.

Effect of Ethylene Glycol

This liquid ingredient is not usable in pharmaceutical practice because it is a harmful and toxic compound. Nevertheless, we have examined the effect of this compound too, to understand, apart from the effect of the apolar methyl group and two polar OH-groups, with propylene glycol, the effect of the only two polar OH-groups with glycol. This compound was added to the oligomer/T-47 mixture in quantities of 3, 5, and 10%. The solvent uptake of these matrixes was measured. The results are shown in the Table 8.

As the data show, the ethylene glycol modified the

Table 7

Solvent Uptake of 3, 5, and 10% 1,2-Propylene Glycol Containing R-5 Elastomers in Solvent with Different Polarities After 72 hr

Propylene Glycol Content	Swelling Time (hr)	Increase of Sample Volume (%) in Toluene	in Ethyl Acetate	in *n*-Butanol	in Ethanol	in Distilled Water
R-5						
3%	72	194.5	105.5	4.5	2.6	7.8
5%	72	194	93	22.7	39.5	8.3
10%	72	194	96	12	40	8.4
R-18						
3%	72	252	126	6.6	2.7	2
5%	72	229	113	22	62	7.4
10%	72	206.6	102	13	41	7.8

Table 8

Solvent Uptake of 3, 5, and 10% Ethylene Glycol Containing R-5 and R-18 Elastomers in Solvents with Different Polarities After 72 hr

Ethylen Glycol Content	Swelling Time (hr)	Increase of Sample Volume (%) in Toluene	in Ethyl Acetate	in *n*-Butanol	in Ethanol	in Distilled Water
R-5						
3%	72	264	103	5.3	4.5	1.4
5%	72	244	95.4	7.6	7.4	8
10%	72	184	74	11	46	20
R-18						
3%	72	350	103	8	12	4
5%	72	379	95	13	25	10
10%	72	193	100	39	49	216

solvent uptake of the silicone matrixes in a different way than the glycerine or propylene glycol with elastomers. Both of the 3% ethylene glycols with elastomer types have an increased swelling in toluene compared to the base elastomers. The ingredient content of 5% slightly increased the solvent uptake. The ingredient content of 10% decreased the toluene uptake. The 10% ethylene glycol content increases the swelling in alcohols too, but it can be seen in the degradation of the matrix and the dissolving of polar liquid phase. The liquid ingredient increased the water uptake more than the propylene glycol, but not more than for glycerine.

The ethylene glycol in a content of 3% can build into the matrix structure, thus, this elastomer can swell in toluene to a higher degree than the base elastomer. The liquid ingredient in a larger amount cannot build into the siloxane structure and make a liquid phase in the matrix. This liquid phase can move easily, because the matrix has no more free silanol groups. The 10% ethylene glycol with elastomer cannot swell to a high degree like the elastomers with a different polar ingredient. This polar liquid phase can bind the water in a larger amount than the propylene glycol, but to a smaller extent than in glycerine.

Effect of PEG 400

The study of this polar ingredient is very important from two points of view. On one hand PEG 400 is a commonly used pharmaceutical ingredient and we supposed that this large molecule close into the framework of the matrix forms an undissoluble, and for the moving drug molecules, a usable polar liquid phase. Conversely, this ingredient is commonly used in the study of transdermal devices in amounts of up to 20%. If PEG 400 can penetrate into the matrix, it can change the properties of the device and it can cause false results. Therefore, we have made the same samples as with the other ingredients. The results are shown in the Table 9.

On the basis of the study we could state, that the use of PEG 400 by R-5 increased the toluene uptake to a small degree only. The polar macromolecule has a different polarity than the matrix, thus, the repulsion between the PEG 400 and the silicone matrix makes the diameter of the tubes larger, and both the polar and the apolar solvent can penetrate into the matrix more easily. This concept is supported by the fact that the PEG 400 containing R-5 (which has a relatively rigid structure) expands in toluene to a higher degree than the base polymer because of the presence of the liquid ingredient in the tubular structure. This effect, however, can be observed in the samples containing 3 and 5% PEG 400 only. The swelling of the 10% PEG 400-containing substance is nearly the same as that of the base elastomer, since the increased amount of the polar liquid counteracts the effect of the strain in the structure. Such a behavior, however, could not be observed in case of the R-18 matrixes, which have a more elastic structure. In this case the presence of the polar liquid ingredient in the matrix makes the diffusion of toluene into the elastomer difficult, thus the swelling of these samples is much less than in the case of the base elastomer. Since PEG 400 is relatively fixed in the matrix structure, the depolymerization phenomenon (noted for the previously described samples) was not observed when this ingredient was used. The networking process is similar to the

Table 9

Solvent Uptake of 3, 5, and 10% PEG 400 Containing R-5 and R-18 Elastomers in Solvents with Different Polarities After 72 hr

PEG 400 Content	Swelling Time (hr)	Increase of Sample Volume (%) in Toluene	in Ethyl Acetate	in *n*-Butanol	in Ethanol	in Distilled Water
R-5						
3%	72	203.5	92.8	13.5	23.7	10.7
5%	72	212.5	104	11	22.6	17
10%	72	195	92	41.6	61	34
R-18						
3%	72	246	96.5	22	19.5	7.3
5%	72	278	104.3	12.7	21	7.5
10%	72	218.9	95	54.6	69	2,6

case of the basic elastomers. Because of the presence of the polar liquid phase, the swelling increases in polar solvents.

The increase of weight and volume is continuous, since there is no subsequent degradation after the solvent uptake. Elastomer made from R-5 swells considerably better in distilled water than the elastomer made from R-18. This behavior may be due to the fixed ingredient, which is fixed inside the matrix. From the loose structure of R-18 the ingredient can dissolve, thus water cannot reach the inside of the matrix.

Effect of Poly(dimethyl-siloxane) Oil

The 350 mPa · s viscosity of poly(dimethyl-siloxane) (M 350) oil makes it a commonly used apolar liquid ingredient. This oil has the same chemical structure as the silicone elastomer, thus, this ingredient forms a liquid phase within the matrix. This apolar liquid phase can help the diffusion of apolar drugs. The presence of silicone oil did not change the properties of silicone elastomers. In the case of R-5 elastomer with 10% M 350, we can observe an increased toluene uptake, because the diffusion across the liquid phase takes place more easily. Thus, we have obtained a liquid phase containing elastomer with similar polarity to the base elastomer. The results of this study are shown in Table 10.

CONCLUSIONS

On the basis of the solvent uptake measurements the viscosity and the chain length of the starting oligomer

Table 10

Solvent Uptake of 3, 5, and 10% M 350 Containing R-5 and R-18 Elastomers in Solvents with Different Polarities After 72 hr

M 350 Content	Swelling Time (hr)	Increase of Sample Volume (%) in Toluene	in Ethyl Acetate	in *n*-Butanol	in Ethanol	in Distilled Water
R-5						
3%	72	192	100	5.5	5.5	0
5%	72	195	95	4.6	2	0
10%	72	221	111	5	1	0
R-18						
3%	72	266	112	5	2.1	0
5%	72	264	118	3.5	1.2	0
10%	72	269	110	5	1.2	0

influenced the swelling properties of the silicone elastomer produced. The differences observed were attributed to two factors (i) the rigidity of the matrix structure, (ii) and the number of the unreacted Si-OH groups. The solvent uptake shows large dependence on the timing of the measurement. Measurements carried out after 48 hr of the production of the polymer showed constant solvent uptakes, indicating that the final structure of the polymer was formed. According to our investigations the liquid ingredient used for the production of the elastomer has considerable influence on the properties of the products. It has been shown that 3% glycerine and ethylene glycol are built into the structure of the matrix, while propylene glycol and PEG 400 are present as a liquid phase, even if they are in small concentrations. If the amount of the ingredient is between 5 and 10%, it forms a liquid phase in the tubes of the matrix, increasing its polarity. The silicone oil is not built into the elastomer, but forms a liquid phase inside of the matrix, with a polarity similar to that of the base elastomer.

These results show that the ingredients influence the properties of the silicone matrices considerably, thus the characteristics of the drug release of pharmaceuticals forms can be varied too.

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