INVESTIGATION OF THE REACTION BETWEEN POLYMERS AND AQUEOUS INSULIN SOLUTIONS

A. I. Ivanov, S. I. Ponomarenko, Ž. I. Semenenko, A. A. Seid-Guseinov, and V. I. Shumakov

The use of polymer materials for the prosthesis of various human organs has grown considerably in the last decade. Polymers are widely used for the production of artificial arteries and heart valves, in plastic and restorative surgery, and for the production of wholly implantable artificial organs [1].

Dimethylsiloxane rubber and compositions based on it occupy a special place amongst these polymers [2]. Dimethylsiloxane rubbers and compositions prepared from it are chemically, biologically and physiologically inert, are compatible with the tissues of the organism [3-6], do not cause local visible irritation, do not give rise to swellings or inflammatory foreign-body reactions [2], do not have toxic, allergic or carcinogenic effects on the organism, are resistant to aging and to low and high temperatures, are similar to living tissue in their density and elasticity, and are resistant to microorganisms.

Implants made of dimethylsiloxane rubber compositions have been located in the subcutaneous cellular tissue of rabbits for several years without appreciable deterioration of the properties of the material [7].

When dimethylsiloxane balls have been used as artificial heart valves, it has been noted that they undergo a slight decrease in strength and an increase in expansion, as well as discoloration, swelling and cracking in the case of some balls after being in the heart of a person for several years [8]. It has been suggested [9] that the reason for these changes is the absorption of blood lipids by the silicone balls.

Dimethylsiloxane rubber and compositions based on it are universal materials for use as coatings and component parts in various types of implantable units and devices, including artificial organs. Over the past few years, we have developed an implantable artificial pancreas for the treatment of diabetics. Analogous parallel investigations have been carried out in the USA [10]. For example, under order from NASA, the firm Whiteacre (Houston, Texas) is involved in developing an implantable device for the treatment of diabetics. The pancreas being developed by the American researchers consists of a polymer reservoir in which the reserve of insulin is replenished by puncturing the wall with a syringe. There are no data in the literature about the reaction of polymers, including organosilicon polymers, with insulin or its solutions.

The present work is devoted to investigating the reaction of dimethylsiloxane and natural rubbers (SR and NR), cured compositions based on them (SC and NC), and a butadiene-styrene block copolymer (DST-30) with aqueous insulin solutions and also to studying the aging of these polymers.

Natural rubber and the butadiene-styrene block copolymer were selected for investigation because siloxane polymers do not meet some of the requirements demanded for implantable devices. In particular, the airtightness of chambers made of silicone materials is not always satisfactory when various punctures are made, although the punctures themselves can be made quite easily. If the chambers of the implantable devices are made of natural rubber or butadiene-styrene block copolymer, the physicochemical properties and airtightness of the chambers are satisfactory.

Curves showing the weight gain of NR, SC and DST-30 on contact with an aqueous insulin solution are given in Fig. 1. It can be seen from Fig. 1 that the weight gain of DST-30 at 37° is considerable; when the...
temperature is increased to 60°, the weight gain over 50 days increases from 7 to 50%. In the case of SR and SC, the weight hardly increases at all, even over 2 months. It should be noted that the weight of NR increases for 30 days, after which saturation sets in, whereas the weight gain curve for DST-30 does not reach saturation even after 60 days.

Examination of the IR reflectance spectra (Fig. 2) shows that new bands appear in the 1520, 1610, and 3300 cm\(^{-1}\) regions in the spectra when the polymers are contacted with the insulin solution. These are the absorption bands corresponding to NH group bending (amide II), CO group stretching (amide I) and bonded NH stretching respectively [11]. In other words, the absorption bands of insulin appear in the spectra of the polymers. This is probably connected with the sorption of insulin on the surface of the samples. It can be seen from Fig. 3 that the curves representing sorption at 37° reach a saturation point, the curve for silicon rubber reaching saturation in 20 days. This indicates that the insulin concentration decreases only for the first 20 days, after which the dimethylsiloxane rubber becomes insulin resistant and the insulin concentration undergoes no further change.

It is interesting to note that in spite of the sorption of insulin, the weight of the SR and SC hardly increases. This may be explained by the fact that parallel with the sorption of insulin, slight elution of low-