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Study the Mechanical Properties of Starch-Silicone Rubber Composites Using in Prosthetic Liners

Mohamed Hamza Al-Maamori[1], NehadAbdull-AmeerSaleh[2], Noor Hadi Aysa[3]

[1]College of material engineering/University of Babylon, Iraq
[2]College of Science/University of Babylon /Iraq-Babylon, Iraq
[3]College of pharmacy/University of Babylon /Iraq- Babylon, Iraq

Abstract : Composites materials works to improve the physical properties of materials used in the manufacture of prosthetic liners, therefore the aim of this project is to enhance the mechanical properties of starch-silicone rubber composites that makes it prosthetic liners, so we have to add the different percents of the starch to the silicone rubber to determine the right addition for manufacturing high-performance to it. The optimum result shows 5 % of starch because it gives the highest mechanical properties.As detailed, the presence of filler tended to increase the hardness of the samples whilst reduce the tensile and tear strength. Starch is extremely hydrophilic, this leads to absorbing the accumulated sweat between the liner and stump besides that its used to reduce the cost.
Keywords : Silicone rubber; Composites; Starch.

Introduction:

Because of the security situation in Iraq as well as due to diabetes , traffic accidents ,cancer , and other infection note increase preparing amputees each year ,for that all of these victims need prosthetic liners.[1] The use of prostheses makes soft tissue in the residual limb bears by the body weight. The inner surface (lining) which is the part that separated between the residual limb and artificial part[2]. One of the most important complications use of synthetic liners is skin problems in the amputee stump(in inner surface) because exposed to many non-normal conditions during weight-bearing skin by shear stress forces, which may lead to edema of the stump and blisters due to shear forces and stress that occurs.[3]

In addition, it cannot evaporate sweat freely from the skin area , increase moisture , inflammation and bacterial infection in addition to abscesses, cellulitis, pyoderma, and inflammation of the sweat glands[4].

Silicone rubber-starch composites are used in many applications such as ligament replacements, heart valve prostheses, vascular graft prostheses, breast prosthesis, catheter and canola, etc. because its good biocompatibility, high resistance against hydrolysis and body fluids, excellent mechanical properties (high tensile strength, highly elastomeric) and low degree of degradation. Therefore a medical grade silicone elastomeric filled with starch it opens new horizons for use in medical fields[5]

Experimental (Material and method) and results:

Silicone rubber (type RTV-2 addition cure liquid silicone/skin safe (HY-Y810)),imported from Shenzhen Hong Ye Jie Technology Co., LTD, it has many characteristics such as good medical performance, chemical stability with features of waterproof, physiologically inert, non-baneful, flavorlessness, aging-resistance, easy pouring, easy operation, and completely vulcanization. It can meet requirement of the mechanical strength even under a very low hardness. Another material that be used as a filler is a commercial corn starch also has many characteristics' such as dysfunction filler to reduce cost ,ease of preparation from the food and used to produce a water absorbent composite. The properties of silicone rubber used is shown table 1.

Table 1: The properties of silicone rubber[6]

Property	Value
Appearance	Translucent
Hardness shore A	8-12
Mix ratio%	1:1
Viscosity(mPa.s)	5000-7000
Tensile strength(MPa)	4
Tear strength(MPa)	1
Elongation %	400

To prepare the samples we use different ratios of starch (1%, 2%, 3%, 4% , and 5%) and mixed withliquid silicone rubber.The second step involves pouring into specified models (tensile and tear molds have the dimension of (150×150) mm) according to the ASTMs (tensile strength and elongation ASTM412[7], tear resistance ASTM624.[8]hardness ASTM2240[9], resilience ASTM1054[10],and compression ASTM D395[11]. Final step the samples will be left at room temperature for 24 hours before the tests are be done. The figures 1, 2 and 3 shows the samples for each test.

Figure 1:The sample used to prepare tensile, tear,elongation, modulus and water absorption specimens

Figure 2: Hardness, Impact, Specific gravity and Compression set mold and Specimens.

Results:

Tensile strength shows a decrease with the increase of starch ratio which indicate the starch particles clumps together within the matrix causing poor adhesion between starch and matrix when using high ratio of it as shown in the figure (3A), this result is a good agreement with[13], while homogenous distribution occurs when we use a small amount of starch figure (3B). So the 5% ratio depended as a standard when one can add another filler which gave better mechanical as shown in figure (4).

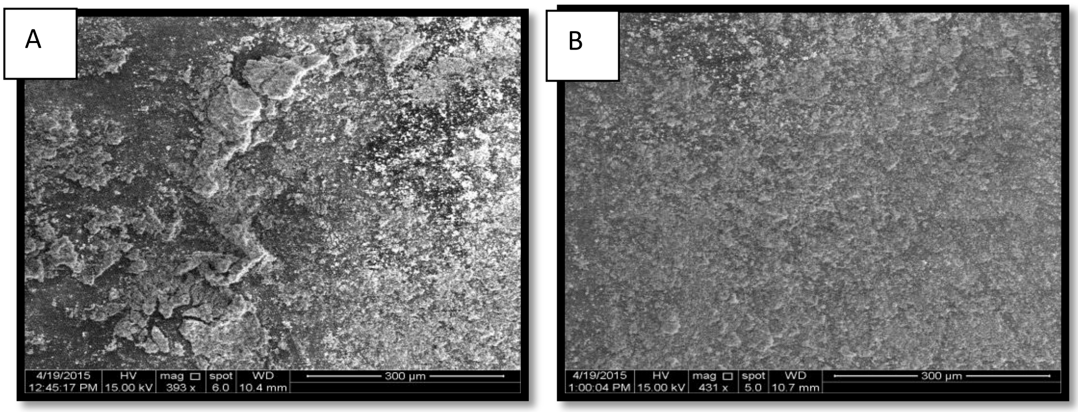

Figure 3: A: The SEM images clearly show poor adhesion, B: the homogeneity mixing for 5% content of a starchpowder

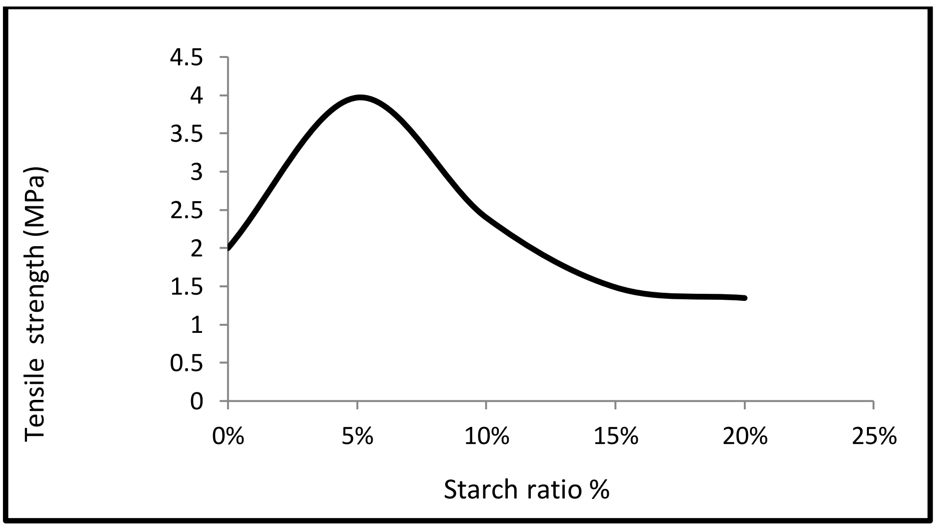

Figure (4) Effect of starch on the tensile strength of silicone matrix

Tears resistance is primarily affected by the arrangement of starch particles to polymer chains and the amount of starch used. It is also well-known that the tear properties of the silicone rubber are dictated by the level and type of filler used so the small amount of starch enhance tear resistance due to homogeneous distribution through the matrix while high content lead to poor homogeneity lowering the tear resistance as illustrated in figure (5)

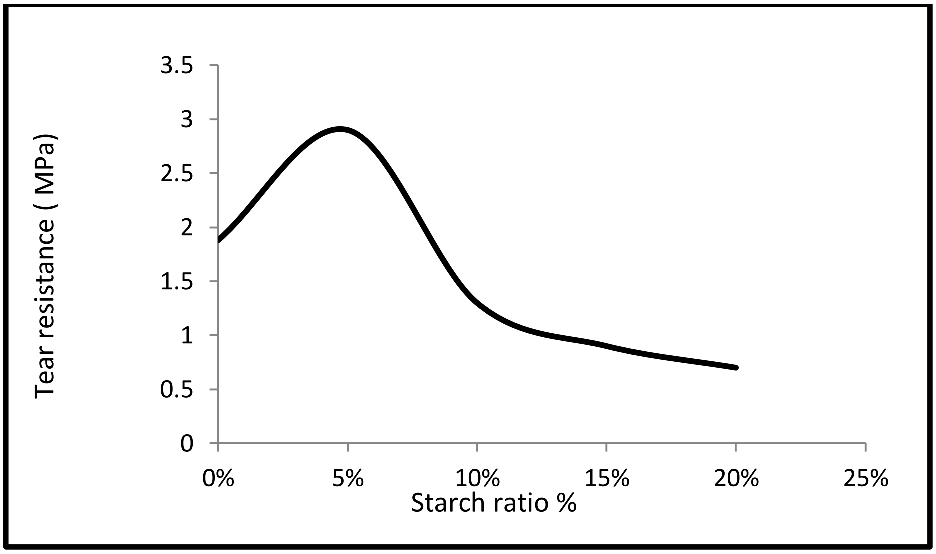

Figure (5) Effect of starch on the tear resistance of the silicone matrix

Young modulus at 300% for each recipe, decrease with the increment of starch content because the high concentration of starch produced poor crosslinks density as shown in figure (6) andit's a good agreement with [14].

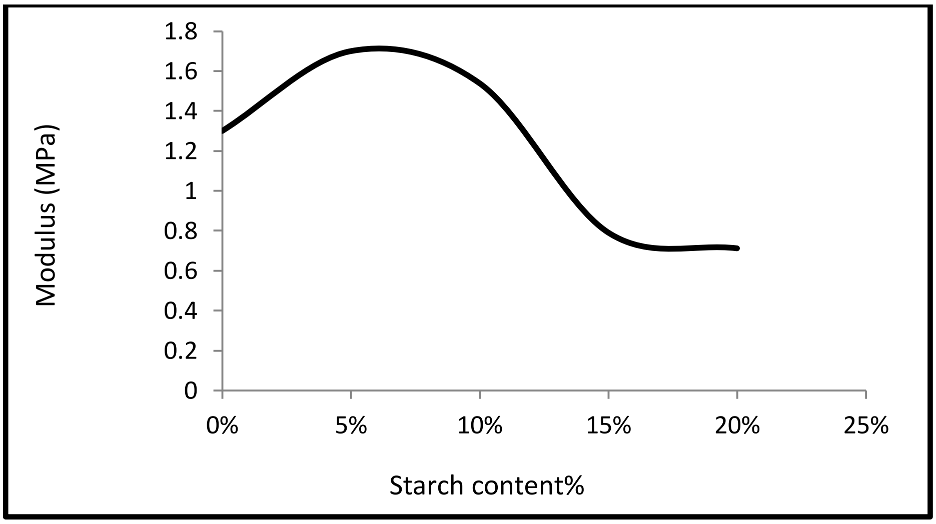

Figure (6) Effect of starch on elastic modulus of the silicone rubber matrix

There was a significant decrease in rebound resilience with the incorporation of starch into a silicone matrix as shown in figure (7) makes it to absorb the impact energy, thus reducing resilience with the high content of starch contributed to the reduction in strain energy due to the decrease in molecules mobility. That has produced an increase in the amputee stability when walking and running.

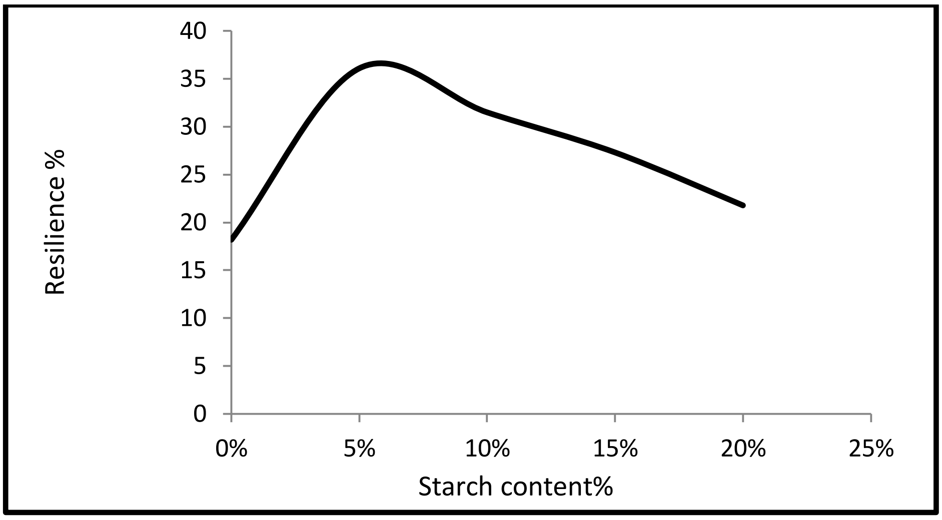

Figure (7) Effect of starch on the resilience of the silicone matrix

When thestarch ratio increase they density and viscosity increasebecause silicone matrix stiff spreading deformation in wide areas of composite which reduce elongation as in figure (8) so, such low percent of the starch acts as a fine powder and diffuse easily between the recipe component causes increases in the link between the component and increase the rubber elasticity results in an increase in the elongation.

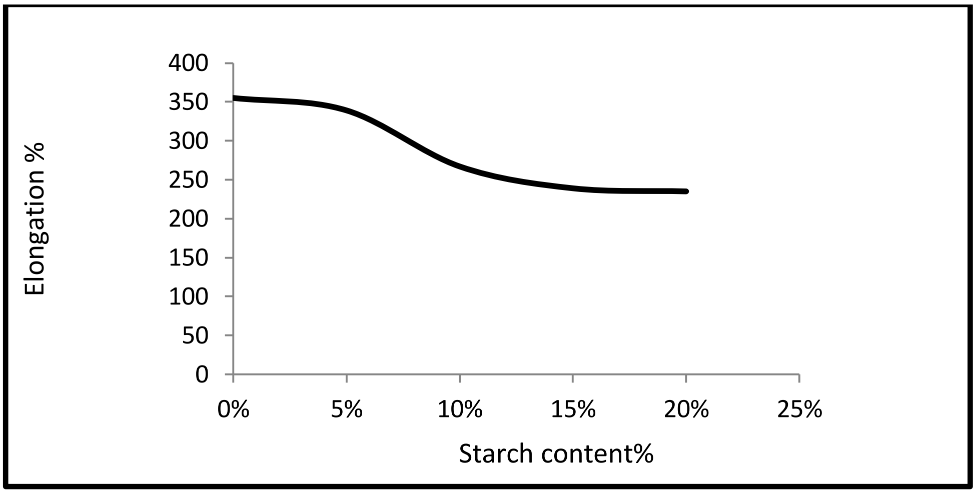

Figure (8) Effect of starch on the elongation of the SR matrix

The hardness directly increases when the starch ratio increase as shown in figure (9).This is due to the diffusion of starch and fill the spaces in rubber recipe results in an increasing density and hardness getting dimensional stability.

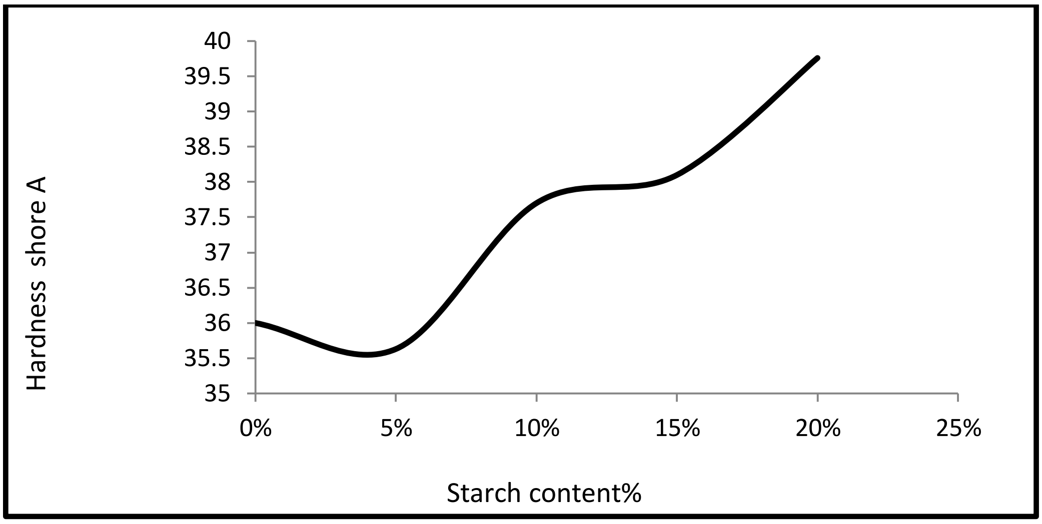

Figure (9) Effect of starch on the hardness of the silicone matrix

The recipe thickness gradually decreases when starch ratio increase as shown in figure (10), because the deformation in the sample decreases due to the increase of hardness this results agree with[15].

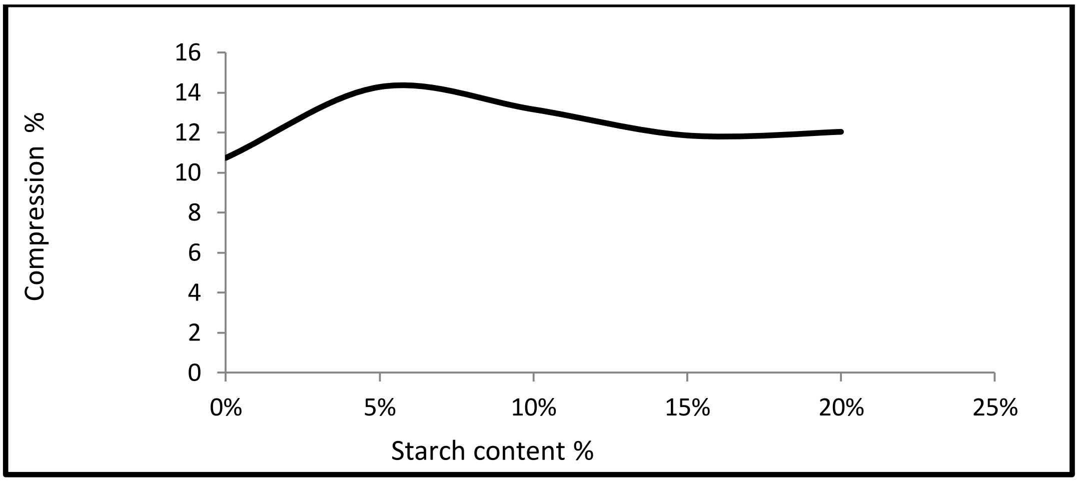

Figure (10) Effect of starch on the compression set of the SR matrix

Figure (11) shows the relation between specific gravity and the starch ratio in which specific gravity increases as starch ratio increases because the decrease in voids between rubber chains explains starch acts as plasticizer this results compatible with[16].

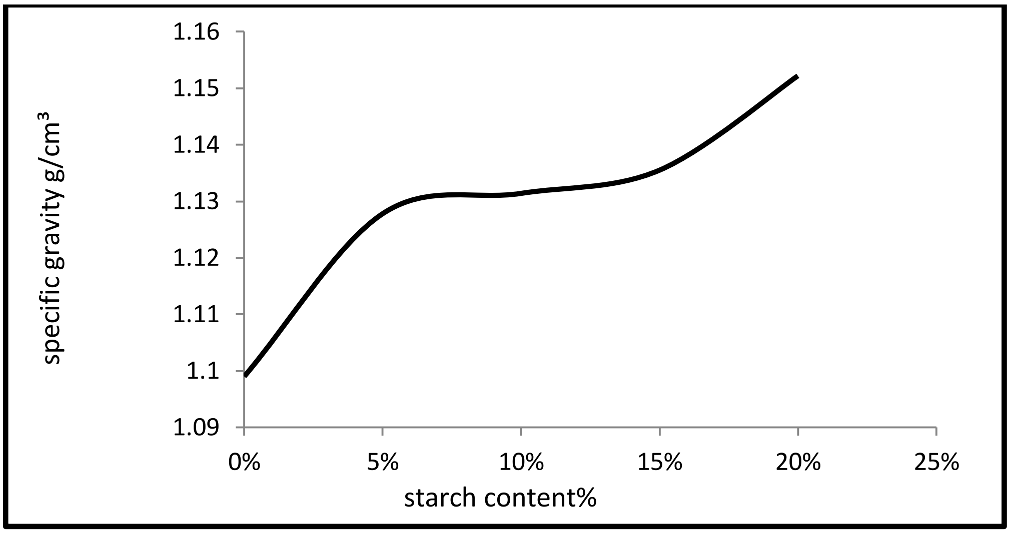

Figure (11) Effect of starch on the specific gravityof silicone matrix

After immersion the samples for different periods of time in water at room temperature the water absorption appears very little this is a good recipe for the liner because the weight is not be increase so the sweat will transmit through the outer shell and the absorption enhanced, when we used hot water (100˚ C). Hot water breaks the chemical bonding and produce large amount the hydroxyl groups of silicone which tend to absorb plenty of water molecules inside silicone structure, the molecular chains could easily expand and retained large volumes of water, agreed with [17, 18] as shown in the Figure (12) so we advise not using hot water in cleaning the liner and just put it under the sun rays in order to evaporate the least amount of sweat in the outer shell.

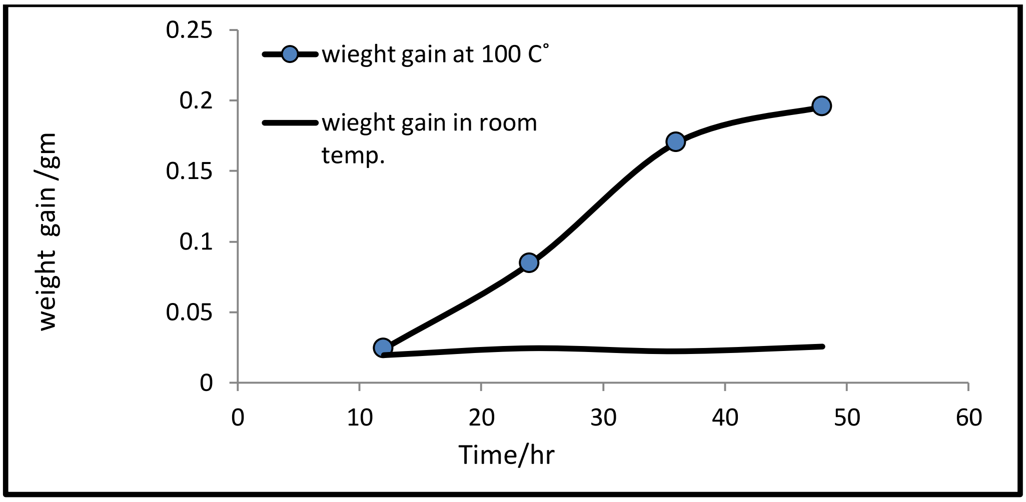

Figure (12) Water absorption of silicone composites during different time

Table 2: Shows the increase in (silicone rubber-starch composite) weight when it absorbs water

Time/hr	Weight gain at room temperature g	Weight gain at 100˚ C g
12	0.019608	0.024
24	0.02451	0.0845
36	0.022353	0.17
48	0.025686	0.1954

Conclusion:

1. Add corn starch to the silicone rubber prosthetic liner warking to reducing costs and absorbing moisture.

2. When the starch ratio increase the mechanical properties decrease and the best amount is(5%)allowing sweat to transmit through the outer shell without interaction with the silicone matrix.
3. Increase absorbency composite of prosthetic liners to the water by increase the temperature above 50 C° leading to the accumulate of the sweat in it and became heavy, also will be a nutrient medium for bacteria growth that cause skin infections.

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