MECHANICAL PROPERTIES OF PHYSICALLY MODIFIED BACTERIAL NANO CELLULOSE

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Introduction

Bacterial nanocellulose (BNC) is a material which has application in medicine. BNC has very good biological properties like non-toxicity, biocompatibility, bio-functionality, hypoallergenicity and well adsorbed so most often it is used for wound dressing materials [1]. BNC after synthesis process has high water content which is associated with low tensile strength. The higher tensile strength of BNC would allow it to be used as a material for artificial heart valves and blood vessels. Physical or chemical modification can improve the mechanical properties of the BNC. The aim of the work was to create a physical modification of BNC and check its mechanical properties.

Materials and Methods

Bacterial nanocellulose produced by BoWil Biotech Company according to the procedure described in the PL 171952 B1 was used. Modification consisted of convective drying in 25ºC and then re-soaking in distilled water for 2 hours. After modification tensile strength test according to ASTM modified method D882-00, using 5543 Universal Testing Machine (Instron C., Canton, MA, USA) was carried. Initial grip separation was 50 ± 5 mm, and cross-head speed was 10 mm/min. BNC samples were strips whose dimensions were 15 by 100 mm. Measurements of the tensile strength (TS) and elongation at break (A) for all of the other samples were carried out immediately after the removing of the samples from water.

The nanoindentation test was carried out using a nanointender (Micro Materials, United Kingdom). Loading and unloading nanoindentation test using a Berkovich indenter was performed. The maximum load was constant and it was 5 mN and test applied load rate 0.01 mN/sec. The study provided information about the hardness of the material (H) and its reduced Young's modulus (E).

Tear test was carried out according to PN-EN ISO 9073-4:2002 for 10 samples using an INSTRON model 1112 testing machine.

A cavitation test was carried out in Ringer solution. The distance between the grips was 75 mm and the feed rate was 100 mm/min. The tip of the sonificator vibrated at 24 kHz. Cavitation tests were performed at the maximum vibration amplitude. The BNC sample was placed 0.5 mm from the vibrating tip of the sonificator.

Results and Discussion

Tensile strength of native BNC was about 2 MPa and after modification it increased to 18.3 MPa, which similar corresponds to Ul-Islam *et al.* [2]. This could be caused by a change in the degree of crystallinity index, the appearance of compressive stresses and a change in the spatial arrangement of the polysaccharide chains in the material. This has also been confirmed by physicochemical tests. Obtained TS values are also several times higher than the tensile strength of pig tissues of the circulatory system [3]. The hardness of BNC determined during the nanoindentation test is 0,26 MPa and reduced Young's Modulus about 4 GPa.

Below we can see the table with the obtained results of mechanical properties.

	Test	
	Tensile strength	Nanoindentation
Physical modyfied BNC	TS= 18.3 MPa	H= 0.26±0,01MPa
	A= 9.5 %	E= 4.13±0,31 GPa
	Tear	Cavitation
	R_{rd} =858 N/mm	Weight loss=0,04%

After physical modification, BNC has a higher tensile strength than natural pig tissues, so this material was additionally subjected to a tear test and cavitation resistance test. The tear strength (Rrd) was calculated in newtons per mm of thickness of the torn sample in accordance with of the formula: Rrd = P/g, where P is the maximum force which the sample was torn and g is the arithmetic mean of the sample thickness from three measurements. The average tear strength of the modified BNC was 858 N/mm. The standard deviation was 184.5 N/mm. The tear test result of the physically modified BNC was compared with the tear strength of the human aorta reported by Carson and Roach [3]. According to them, the tear strength of the human aorta is 15.9 ± 0.9 J/cm^2. Since 1 J/cm^2 corresponds to 10 N/mm, the tear strength of the human aorta is 159 N/mm. Comparing the tear strength of the human aorta and the physically modified BNC, it can be concluded that BNC has over five times greater tear resistance than the tissue which the human aorta is made from.

As it is considered that BNC could be a material for coatings of artificial heart valves, a cavitation resistance test of this material was also performed. Cavitation was carried out for 1.5 h. During this time, the BNC sample was taken out of the cavitation station every 30 minutes, dried in compressed air and weighed. The first weight loss of the sample, caused by cavitation loads, was recorded after 90 minutes of the cavitation test. After 90 min of the cavitation test, the measured weight loss was 0.04%, what is good result for overload conditions.

Conclusions

BNC after physical modification consisting in convection drying at 25°C and re-soaking in water, has good mechanical properties which could meeting the requirements for biomaterial for applications in cardiac and vascular surgery.

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