# The properties of hair covered by conditioners containing collagen, chitosan and hyaluronic acid

Sylwia Grabska, Alina Sionkowska

Nicolaus Copernicus University in Torun, Faculty of Chemistry, Department of Chemistry of Biomaterials and Cosmetics, Poland

***European Journal of Medical Technologies***
*2019; 3(24): 11-17*

www. medical-technologies.eu
Published online 29.09.2019

**Corresponding address:**
Nicolaus Copernicus University in Torun, Faculty of Chemistry, Department of Chemistry of Biomaterials and Cosmetics, Gagarin 7, 87-100 Torun, Poland
sylwiagrabska91@gmail.com
tel. +48 56 611 48 33

## Abstract

The aim of this work was to observe impact of hair conditioners with addition of biopolymers on hair structure. In this work hair conditioners with addition of collagen, hyaluronic acid and their mixtures with addition of chitosan were obtained.
The hair protection possibility was studied using mechanical testing and scanning electron microscopy of hair coated by the conditioners with addition of biopolymers (collagen, hyaluronic acid, chitosan) and their blends.
It was found that the conditioner with three-component biopolymer mixture (collagen, hyaluronic acid, chitosan) improves the mechanical properties of individual hair the most between others. Such conditioner gives the greatest increase in the Young's Modulus value and the greatest increase of elongation during the break. The results of SEM imaging have shown that the thickness of a hair shaft with the polymer covering is bigger than without it. SEM images showed that scales of hair are more detached in a shaft without the polymer covering.

## Key words:

hair, hair conditioner, mechanical tests, film-forming properties

## Introduction

Beautiful and healthy hair is desired by most of population. For most people, maintenance and grooming of hair and skin is a daily process [1]. Weather conditions, chemical dyeing, combing and permanent wave treatment contribute a large amount of mechanical and chemical damage to the fibers. It leads to degradation of mechanical properties and structure of hair. It is undesirable for healthy hair [2]. Everybody wants to have beautiful and healthy hair, so several laboratories try to find new way for perfect hair conditioning.

Hair conditioners are cosmetic products for hair treatment. In general, hair conditioners have no effect on growth and cannot affect cellular repair, however, they can temporarily improve the cosmetic appearance of damaged hair [3]. Conditioner is used to coat

the hair with a thin film in order to protect it and provide desirable look and feel. Conditioners repair hair damage and make the hair easier to comb, prevent flyaway, add feel, shine, and softness. They can increase shine, decrease static electricity, improve hair strength and protect against ultraviolet radiation. Conditioners, which typically repair the hair surface, respectively, have a distinct effect on its mechanical properties as well. They improve the general appearance of hair on the outside [4,5]. To meet the needs of consumers, many ingredients, such as synthetic and natural polymers are added to conditioners [2,6].

Today, there is a broad array of hair conditioning products available on the market [7]. In order to meet the consumer's expectations toward the effectiveness of such products, the cosmetics industry brings modern recipes out to the market. The laboratories testing the impact of raw materials on the hair structure and proving their effectiveness play a crucial role in the process of care preparation production. Biopolymers are widely used in cosmetic industry, particularly in hair care products [8-11]. Biopolymers are particularly attractive as raw materials in conditioners due to their film-forming properties [1,5]. From the point of view of the cosmetics industry, biopolymers are significantly compelling. Biopolymers belong to the group of raw materials exhibiting a positive impact on the hair structure, mainly due to film-forming properties.

Biopolymers are present in many cosmetic formulas, although the research concerning their effectiveness is still not well developed [8-11]. In order to develop an effective cosmetic preparation, the mixtures of biopolymers is proposed. The conditioning properties of preparations containing such mixtures depend on the proper proportion rates of the particular biopolymers [5]. Thanks to their biocompatibility and nontoxicity, biopolymers are good cosmetic ingredients [5,7].

Biopolymers are compounds which occur naturally in living organisms or are produced by living organisms [12]. Ingredients in preparations for cosmetic applications should be non-toxic, because these materials are brought into contact with the skin or body. Natural polymers are biodegradable, bioresorbable, biocompatible, bioactive and non-toxic.

Collagen (Coll) is the most abundant protein in mammals constituting over 30% of the total proteins in animal body. It is the foremost constituent of the extracellular matrix which is abundant fibrous structural protein. Collagen is mostly found in skin, ligament and tendon, cornea, blood vessels, bone, cartilage, intervertebral disc and the gut [13].

Chitosan (CTS) is an amino polysaccharide. It is extracted as deacetylated derivative of chitin. The deacetylation mechanism involves elimination of acetyl group via treatment of chitin with concentrated sodium hydroxide for a long period leaving behind only amine group. Chitin is available in exoskeleton of crustaceans, insects and several fungi [14].

Hyaluronic acid (HA) is a natural linear polysaccharide. It plays a role in several biological processes, including cell growth, differentation and migration. This biomacromolecule is one of the major constituents of the skin and can be found in extracellular tissues of various parts of the body [15].

Collagen, chitosan and hyaluronic acid are the biopolymers, which show interesting properties for application in the cosmetic field; specifically they have film-forming and fiber-forming properties and they are biocompatible, biodegradable, nontoxic and non-immunogenic polymers.

The aim of this work was to obtain hair conditioning products containing biopolymers such as: collagen, chitosan, hyaluronic acid and their mixtures and to observe impact on structure of hair covered by prepared hair conditioners. The hair was subjected to endurance tests and microscopic evaluation.

# Experimental

## Formulation and preparation of conditioners

Five conditioners with collagen, hyaluronic acid, 50/50 (w/w) mixture of collagen and hyaluronic acid, and 50/50 (w/w) mixture of collagen and hyaluronic acid with 30% addition of chitosan were prepared (Tables 1-5). Collagen was prepared in our laboratory from rat tail tendons according to a known procedure [16]. Chitosan and hyaluronic

**Table 1.**
Ingredients of conditioner without biopolymers

| Component (INCI[1]) | Precentage [%] |
|---|---|
| Oil phase | |
| Stearic acid | 20.0 |
| Cera alba | 9.00 |
| Ceteareth – 20 | 4.00 |
| Argan oil | 1.00 |
| Water phase | |
| Glycerol | 2.00 |
| Aqua | 64.0 |

[1]INCI: International Nomenclature of Cosmetic Ingredients

**Table 2.**
Ingredients of conditioner containing 1% of collagen

| Component (INCI[1]) | Procentage [%] |
|---|---|
| Oil phase | |
| Stearic acid | 20 |
| Cera alba | 9 |
| Ceteareth – 20 | 4 |
| Agran oil | 1 |
| Water phase | |
| Glycerol | 2 |
| Collagen | 1 |
| Aqua | 63 |

**Table 3.**
Ingredients of conditioner containing 1% of hyaluronic acid

| Component (INCI) | Precentage [%] |
|---|---|
| Oil phase | |
| Stearic acid | 20.0 |
| Cera alba | 9.00 |
| Ceteareth – 20 | 4.00 |
| Argan oil | 1.00 |
| Water phase | |
| Glycerol | 2.00 |
| Hyaluronic acid | 1.00 |
| Aqua | 63.0 |

**Table 4.**
Ingredients of conditioner containing 1% of 50/50 collagen/hyaluronic acid mixture

| Component (INCI) | Precentage [%] |
|---|---|
| Oil phase | |
| Stearic acid | 20.0 |
| Cera alba | 9.00 |
| Ceteareth – 20 | 4.00 |
| Argan oil | 1.00 |
| Water phase | |
| Glycerol | 2.00 |
| Collagen | 0.50 |
| Hyaluronic acid | 0.50 |
| Aqua | 63.0 |

acid were supplied by Sigma Aldrich, Poznań, Poland. Chitosan and hyaluronic acid had a viscosity average molecular weight of $1.8 \times 10^6$ and $0.59 \times 10^6$, respectively. The deacetylation degree (DD, %) of chitosan was 78%.

## Mechanical testing

Long, brown hair from 20-years-old woman was used for mechanical testing. Before attending to mechanical testing, the hair was washed, using a shampoo and then, dried up. The washed and dried up hair was covered with the conditioner for 30 min. After that time, the conditioner was rinsed off and the hair was left to dry up.

The hair was subjected to mechanical tests using the Zwick&Roell testing machine. The mechanical properties such as Young's Modulus [GPa] and elongation during the break [%] were measured for individual hair: the hair without conditioner, the hair covered with the conditioner without biopolymers, the hair covered with the conditioners with biopolymer addition. Analysis was repeated for 10 samples and the standard deviation was calculated.

## Scanning electron microscope (SEM) imaging

The surface of human hair was studied using scanning electron microscope (LEO Electron Microscopy Ltd, England). Samples were covered by gold and images were made with the resolution 50 μm and 10 μm. The thickness of hair shafts was calculated for native hair and for hair covered with the conditioners.

**Table 5.**
Ingredients of conditioner containing 1% of 50/50 collagen/hyaluronic acid mixture with 30% addition of chitosan

| Component (INCI) | Precentage [%] |
|---|---|
| Oil phase | |
| Stearic acid | 20.0 |
| Cera alba | 9.00 |
| Ceteareth – 20 | 4.00 |
| Argan oil | 1.00 |
| Water phase | |
| Glycerol | 2.00 |
| Collagen | 0.35 |
| Hyaluronic acid | 0.35 |
| Chitosan | 0.30 |
| Aqua | 63.0 |

# Results and Discussion

## Mechanical testing

The results of mechanical testing are presented in Figure 1 and Figure 2. The conditioner containing the hyaluronic acid (HA) and the conditioner containing collagen (Coll) both improve the resistance parameters of individual hair. The conditioner containing the additive of collagen (Coll) gives similar results to the conditioner containing the hyaluronic acid (HA), improving the resistance parameters of individual hairs more than the other ones. In the case of the mixture of collagen and the hyaluronic acid (Coll/HA-50/50), one can see significant increase in the Young's Modulus value [GPa], and an increase in the elongation at break [%]. A conditioner with three-component biopolymer mixture (Coll/HA/CS-50/50/30) improves the mechanical properties of individual hair the most between others. Such conditioner gives the greatest increase in the Young's Modulus value and the greatest increase of elongation during the break

## Scanning electron microscope (SEM) imaging

Figure 3 shows SEM micrographs of control sample of hair, hair covered by conditioner without polymer and conditioners with collagen, hyaluronic acid and their mixtures with addition of chitosan. The thickness of hair shafts with and without conditioner covering was calculated from the stereoscopic optical microscopy (Motic SMZ-171 Series) images in three places and it is shown in Table 6. In Figure 4 are presented images showing hair without any conditioner and hair covered by conditioner with addition of three-component biopolymer mixture (50/50/30 – Coll/HA/CTS).

The results have shown that the thickness of a hair shaft with the polymer covering is bigger than without it. SEM images showed that scales of hair are more detached in a shaft without the polymer covering. It was observed that the covering hair with conditioners

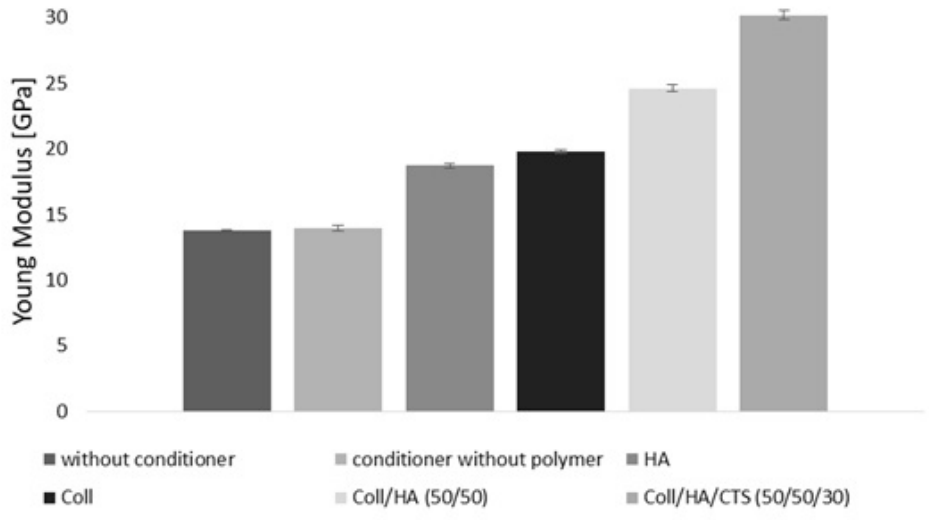


**Fig. 1.**
Young Modulus ($E_{mod}$) [GPa] of hair without conditioner and covered with conditioners of varying concentration rates of biopolymers

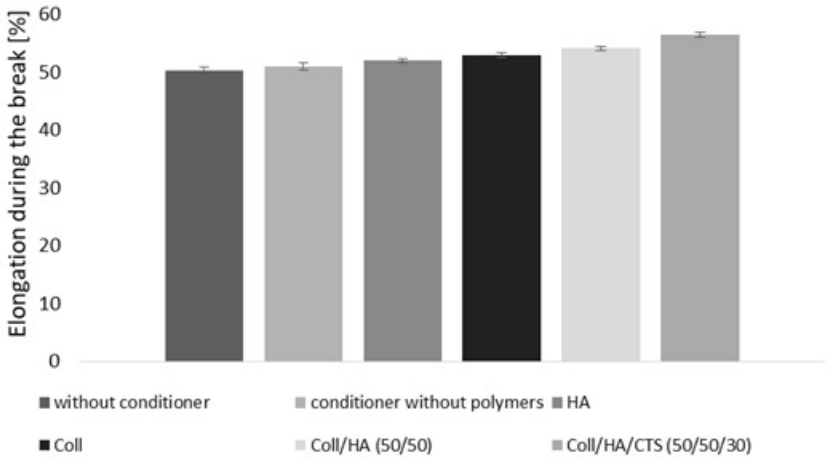


**Fig. 2.**
Elongation at break [%] of hair without conditioner and covered with conditioners of varying concentration rates of biopolymers.

containing biopolymers leads to the formation of film with very good adhesion to the hair surface. The adhesion of biopolymers to hair surface is due to hydrogen bonds and electrostatic interaction.

## Conclusions

Conditioners containing biopolymers such as collagen, chitosan and hyaluronic acid impact the mechanical properties of hair. The use of the hyaluronic acid and collagen in hair conditioning products considerably increases the resistance of hair against mechanical damage. Moreover, the best results can be seen when collagen and hyaluronic acid are mixed together with chitosan. Collagen, hyaluronic acid and chitosan exhibit strong film-forming properties that increase the elasticity and resistance of hair against damage. Therefore, these mixtures can be potentially used in cosmetics preparations as ingredients for hair care products.

## Acknowledgments

Financial support from the National Science Centre (NCN, Poland) Grant No. UMO-2013/11/B/ST8/04444 is gratefully acknowledged.

Grateful acknowledgements to Kamila Kurnik for obtaining hair conditioners and help with preparing the data from analysis.

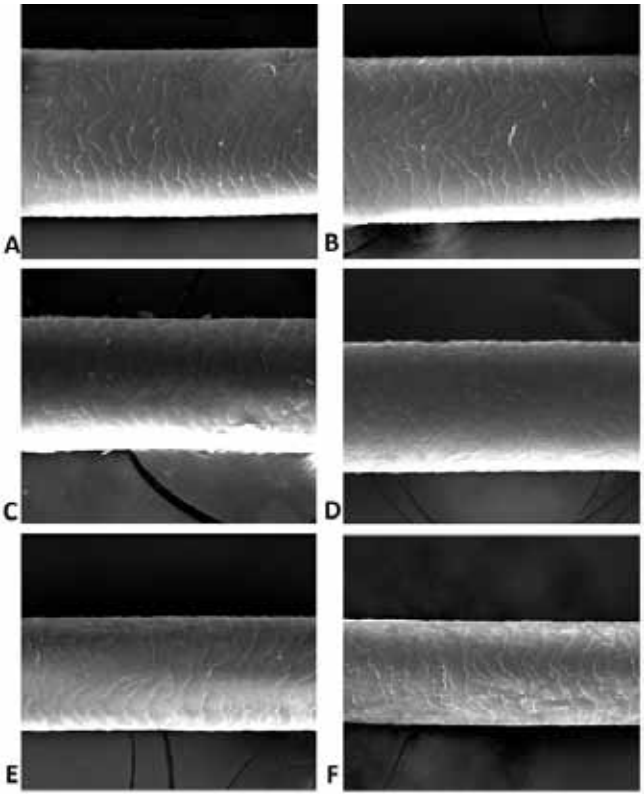


**Fig. 3.**
SEM images of: A. hair without conditioner, B. hair covered by conditioner without biopolymers, C. HA, D. Coll, E. Coll/HA, F. Coll/HA/CTS (with resolution 50μm)

**Table 6.**
The thickness of hair shafts without and with covering by conditioner with biopolymer mixtures

| Haircovering | Thickness [μm] |
|---|---|
| without conditioner | 82.86 |
| conditioner without polymer | 85.88 |
| HA | 88.30 |
| Coll | 94.57 |
| Coll/HA | 119.34 |
| Coll/HA/CTS | 130.43 |

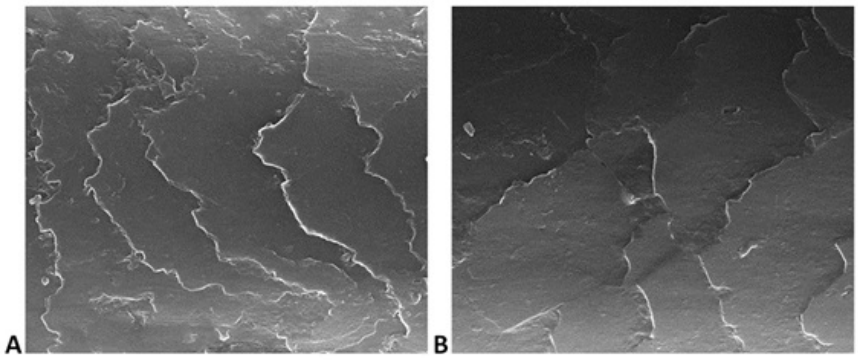


**Fig. 4.**
SEM images of: A. hair covered by conditioner without biopolymers and B. Coll/HA/CTS (with resolution 10μm).

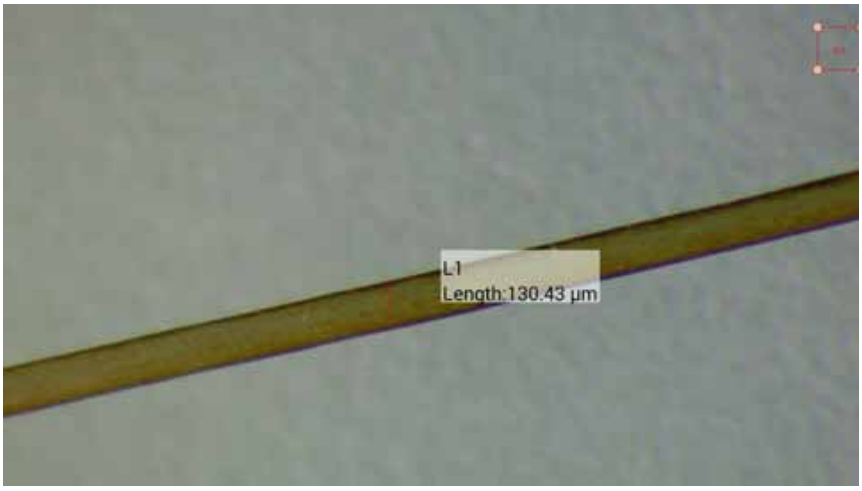


**Fig. 5.**
Stereoscopic optical microscope image of hair covered with conditioner with Coll/HA/CTS mixture

## References


1. Bhushan B. Nanoscale characterization of human hair and hair conditioners. Prog Mater Sci 2008; 53: 585-710.
2. Bhushan B, LaTorre, C. Structural, Nanomechanical and Nanotribological Characterization of Human Hair Using Atomic Force Microscopy and Nanoindentation. [W:] Bhushan B. [red.] Nanotribology and Nanomechanics. Springer, Deutschland 2004.
3. Gavazzoni Dias MR. Hair Cosmetics: An Overview. Int J Trichol 2015; 7: 1-15.
4. Reich C, Su D, Kozubal C, Lu Z. Hair Conditioners. [W:] Barel OB, Paye M, Maibach IM. [red.]. Handbook of Cosmetic Science and Technology, 3rd ed. Informa Healthcare, USA 2009.
5. Sionkowska A, Kaczmarek B, Michalska M, Lewandowska K, Grabska S. Preparation and characterization of collagen/chitosan/hyaluronic acid thin films forapplication in hair care cosmetics. Pure Appl Chem 2017; 89: 1829-1839.
6. Weia G, Bhushan B, Torgerson PM. Nanomechanical characterization of human hair using nanoindentation and SEM. Ultramicroscopy 2005; 105: 248-266.
7. Aranaz I, Acosta N, Civera C, [et al.]. Cosmetics and Cosmeceutical Applications of Chitin, Chitosan and Their Derivatives. Polymers 2018; 10: 213-238.
8. Yang J. Hair Care Cosmetics. [W:] Sakamoto K, Lochhead RY, Maibach HI, Yamashita Y. [red.]. Cosmetic Science and Technology: Theoretical Principles and Applications. Elsevier, Netherlands 2017.
9. Reich C, Su DT. Hair Conditioners. [W:] Barel AO, Paye M, Maibach HI. [red.]. Handbook of Cosmetic Science and Technology. Marcel Dekker, USA 2001.
10. Wolfram LJ. Hair Cosmetics. [W:] Barel AO, Paye M, Maibach HI. [red.]. Handbook of Cosmetic Science and Technology. Marcel Dekker, USA 2001.
11. Lochhead MY. The Use of Polymers in Cosmetic Products. [W:] Sakamoto K, Lochhead RY, Maibach HI, Yamashita Y. [red.]. Cosmetic Science and Technology: Theoretical Principles and Applications. Elsevier, Netherlands 2017.

12. Sionkowska A. Current research on the blends of natural and synthetic polymers as new biomaterials: Review. Prog Polym Sci 2011; 36: 1254-1276.
13. Bhagwat PK, Dandge PB. Collagen and collagenolytic proteases: A review. Biocatal Agric Biotechnol 2018; 15: 43-55.
14. Ahmed S, Annu, Ali A, [et al.]. A review on chitosan centred scaffolds and their applications in tissue engineering. Int J Biol Macromol 2018; 116: 849-862.
15. Larrañet E, Henry M, Irwin NJ, [et al.]. Synthesis and characterization of hyaluronic acid hydrogels crosslinked using a solvent-free process for potential biomedical application. Carbohyd Polym 2018; 181: 1194-1205.
16. Sionkowska A, Grabska S. Incorporation of magnetite particles in 3D matrices made from the blends of collagen, chitosan, and hyaluronic acid. Adv Polym Technol. 2018; 1–10.