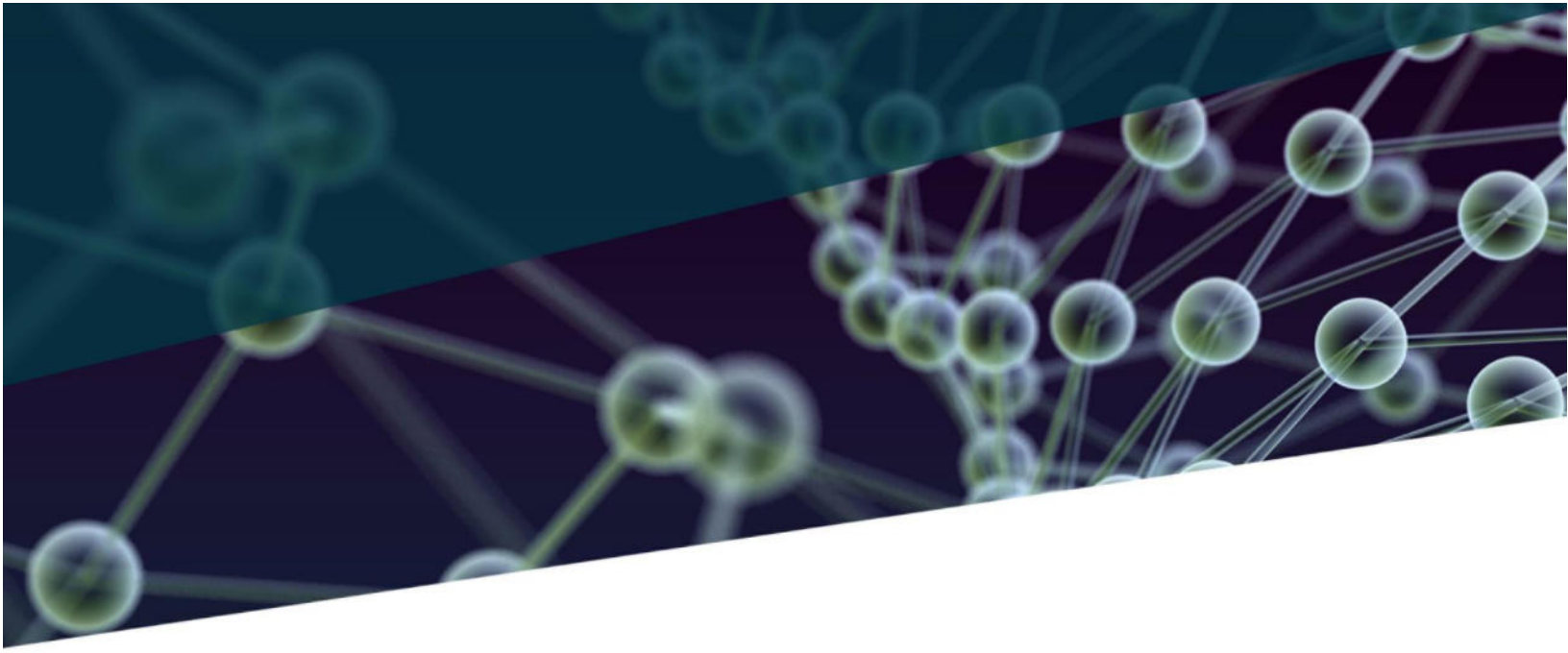
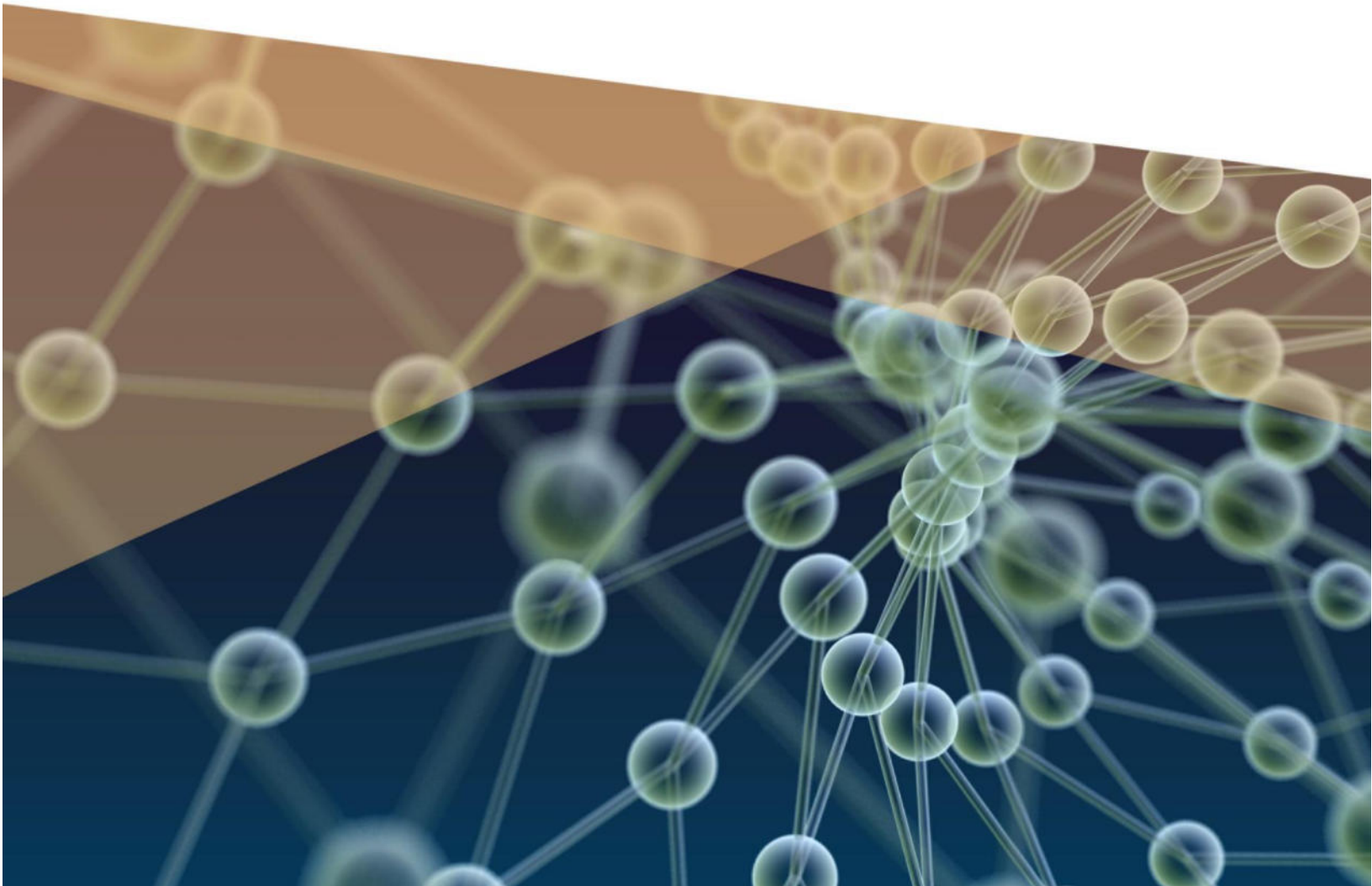


Advanced Polymer Materials and Technologies

Recent Trends and Current Priorities



Ministry of Education and Science of Ukraine
Kyiv National University of Technology and Design
Lviv Polytechnic National University

Advanced polymer materials and technologies: recent trends and current priorities

Перспективні полімерні матеріали та технології: останні тенденції та актуальні пріоритети

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The monograph contains the materials of the 4th International Conference "Advanced Polymer Materials and Technologies", which was held on October 11, 2022 at the Kyiv National University of Technology and Design together with the Lviv Polytechnic National University. The monograph deals with the creation of new polymer composite materials and their processing technologies using extrusion, electroforming, 3D printing, and other methods; development of environmentally-oriented technologies and equipment for the production of polymeric materials for various purposes, including biodegradable ones. Considerable attention is paid to the creation of new polymer composite materials, in particular for environmental protection, using waste from the chemical industry.

The monograph will be useful for teachers, students and graduate students, scientists and manufacturers whose activities are related to the above mentioned topics.

The authors are responsible for the content of the publications.

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WATER-SOLUBLE COLLAGEN EXTRACTION FROM LEATHER WASTE

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The article discusses the main methods of water-soluble collagen obtained from animal raw materials, namely chemical and enzymatic hydrolysis. The advantages and disadvantages of each method are presented. It was established that the method of enzymatic hydrolysis has several advantages over the method of chemical hydrolysis.

Only fully or partially soluble collagen can be used in the production of matrices for tissue engineering, powders, sponges, fibers, or threads. The extraction method is used to isolate collagen. The structure, composition, molecular weight distribution, functional features and properties of collagen depend on conditions of the raw material processing from which it is obtained; raw materials and materials used in the extraction process [1]. It is necessary to select the extraction parameters to obtain the necessary collagen characteristics for each type of raw material. It is difficult to develop a unified method for collagen extraction due to the extreme variety of its tissues and types.

The number of covalent bonds in the collagen structure increases over time and often determines the almost complete insolubility of the resulting product [2]. It is necessary to remove numerous covalent internal and intermolecular cross bonds, ether bonds and bonds with polysaccharides during collagen extraction. The process of extraction and purification of collagen involves [2]:

– raw materials processing at temperature of 25 °C or 4 °C;
– removal of non-collagenous proteins using sodium chloride, sodium hydroxide or calcium hydroxide;
– neutralization with a solution of hydrochloric or acetic acids;
– treatment with an acid or enzyme;
– morphological analysis;

– collagen purification;
– quality control of collagen (analysis of amino acid composition, electrophoresis, determination of denaturation temperature, X-ray diffraction analysis, spectral analysis).

Pre-treatment is carried out to remove non-collagen substances and increase collagen output. Most often, collagen extraction is carried out in neutral salt solutions, acidic solutions, and acidic solutions with the addition of enzymes. Connective tissue collagen dissolves very slowly even in boiling water due to the presence of many hydrogen bonds between adjacent molecules due to its structure. Therefore, to break them, treatment with diluted solutions of acids and alkalis is used. At the same time, the collagen chains remain intact, and the cross-links are partially hydrolysed [1]. For salt hydrolysis of collagen, solutions of sodium chloride, tris-hydroxymethyl, aminomethane hydrochloride, phosphates and citrates are used.

During acid hydrolysis, raw materials are immersed in a solution with an acidic reaction. When the solution penetrates the collagen structure, it increases in volume by two to three times and hydrolysis of non-covalent intermolecular and intramolecular bonds occurs. This method is suited for extracting collagen from raw materials with loosely woven collagen fibers (for example, pig and fish skins). Acid hydrolysis can be carried out using organic (acetic, citric, lactic) and inorganic (chloric) acids. Organic acids can solubilize non-cross-linked collagens, as well as to break individual crosslinks. This leads to a higher solubility of collagen during extraction [3].

Raw materials are added to an acid solution for acid extraction of collagen. Traditionally, 0.5 M acetic acid is used. Raw materials are kept in acid for 24-72 hours at temperature of 4 °C and a constant stirring. Filtration is carried out to separate the supernatant (residue) from collagen, which is in the liquid phase after extraction. To obtain collagen powder, the filtrate is precipitated with sodium

chloride. The precipitate is separated by centrifugation. The precipitate is dissolved in a minimum volume of 0.5 M acetic acid, dialyzed for 2 days in 0.1 M acetic acid and 2 days in distilled water. The solution is changed every 12 hours [4]. The antigenic components of the protein must be removed during collagen purification. These are areas of type I collagen telopeptide fragments. Such purification is more effective after pepsin treatment. Another problem is the long duration of the acid extraction process which is from 1 to 3 weeks. Acid extraction is characterized by high protein loss and partial degradation of collagen peptides. For this reason, the field of application of acid-extracted collagen is limited and the extracted material must be stored in a cold solution of acetic acid or dried. The maximum collagen concentration that can be obtained is also limited to 10 mg/ml [2]. A native triple-helical collagen molecule with intact telopeptides is obtained after acid hydrolysis. This product can form elastic gels.

Alkaline hydrolysis consists in raw materials processing with an alkali solution (for example, sodium hydroxide) for a period of several days to several weeks [1]. Such processing is carried out for thick materials that require aggressive action on the structure.

Alkaline-salt extraction involves the collagen treatment with alkali in the presence of a saturated sodium sulfate solution. Collagen is extracted with acid after pretreatment. The method provides a high yield of soluble collagen with a preserved triple helix. However, aspartic, and glutamic acid residues are deaminated. At the same time, the distribution of charges along the three-helix collagen molecule is disturbed; collagen loses its ability to form fibrils and loses its ability to form gels [1].

Enzymatic hydrolysis is often carried out by proteases (pepsin or trypsin), the action of which does not destroy the triple helix. Only non-collagen structures and proteins are destroyed. At the same time, a native collagen molecule with damaged telopeptides and capability to form inelastic gels is obtained. A 0.5 M solution of

acetic acid containing enzymes is added to the raw material to extract collagen by enzymatic hydrolysis. The mixture was continuously stirred for 48 hours at temperature of 4 °C. After hydrolysis, the mixture is filtered; the filtrate is subjected to dialysis under the same conditions as acid-soluble collagen [4]. Enzymatic hydrolysis has some advantages compared to chemical hydrolysis:

– specificity;
– control of the degree of hydrolysis;
– moderate operating conditions;
– lower salt content in the final hydrolysate;
– enzymes can be used in very low concentrations without mandatory removal from the solution;
– the amount of waste is reduced;
– it is possible to control the process; the product is obtained with a high content of collagen.

The disadvantage of the method is the high cost of enzymatic hydrolysis. The method of extraction can affect the length of polypeptide chains and functional properties of collagen: viscosity, solubility, ability to form gels and emulsions. However, only collagen obtained after acid hydrolysis is suitable for biotechnological use and tissue engineering.

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