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# Biopolymers & Bioplastics

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## Posters

Kenji Tanaka et al., J Bioremed Biodeg 2016, 7:5(Suppl)
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# Biosynthesis of poly(3-hydroxybutyrate-co-3-hydroxyhexanoate) with high $C_6$-monomer composition from $CO_2$ by recombinant of *Ralstonia eutropha*

**Kenji Tanaka**[1], **Shunya Mori**[1], **Kouki Maruo**[1], **Orita Izumi**[2] and **Toshiaki Fukui**[2]
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Poly((R)-3-hydroxybutyrate-co-(R)-3-hydroxyhexanoate) [P(3HB-co-3HHx)], a flexible and practical biodegradable plastic, is generally produced from plant oils and fatty acids by several wild and recombinant bacteria. Fukui and his coworkers constructed many recombinants of *Ralstonia eutropha* for studying biosynthesis of [P(3HB-co-3HHx)] with high 3HHx composition from the structurally unrelated carbon source. The engineered strain with *ΔphaB1* genotype expressing *ccr, phaJ4a, and emd (R. eutropha* strain MF01ΔB1/pBPP-$ccr_{Me}$J4a-emd) produced P (3HB-co-3HHx) composed of 22 mol% 3HHx at high cellular content from fructose (Metabolic Engineering, 27:38–45, 2015). Such high $C_6$–monomer composition was achieved by improving artificial pathway for biosynthesis of monomer unit as follows: (i) Depression of (R)-specific reduction of acetoacetyl-CoA by the deletion of *phaB1* for formation of the $C_6$–monomer unit from fructose driven by crotonyl-CoA carboxylase/reductase (Ccr), (ii) co-overexpression of *phaJ4a*, which encodes medium-chain-length (R)-enoyl-CoA hydratase, with ccr promoted the incorporation of both 3HB and 3HHx units (iii) introduction of $emd_{Mm}$,a synthetic gene encoding ethylmalonyl-CoA decarboxylase derived from mouse which is probably converting ethylmalonyl-CoA generated by the reductive carboxylase activity of Ccr back into butyryl-CoA. *R. eutropha* is a facultative hydrogen-oxidizing bacterium that chemolithoautotrophically grows due to carbon dioxide fixation using $H_2$ and $O_2$ as the energy source. Hence, we also investigated the production of P(3HB-co-3HHx) from $CO_2$ by the engineered strains of *R. eutropha* in chemolithoautotrophic condition using the substrate gas mixture ($H_2$/$O_2$/$CO_2$::8:1:1) and mineral salts medium. As a result, the strain MF01ΔB1/pBPP-$ccr_{Me}$J4a-emd produced P(3HB-co-3HHx) with a remarkably high composition of 3HHx (51.7 mol%) at a high cellular content (65.1 wt%) from $CO_2$.

## Biography

Kenji Tanaka has completed his PhD from Kyushu University. He is a Professor of Depatment of Biological and Environmental Chemistry, School of Humanity-Oriented Science & Engineering, Kindai University. His research field is Bioprocess Engineering. He has published many papers on microbial production of biodegradable plastic from $CO_2$ and biomass.

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## Valorisation of food wastes through acidogenic fermentation

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Food wastes are produced in large quantities in markets, intensive production areas and in canned vegetable companies. Solid waste generation from these companies is a major source of pollution in landfills where they are deposited and have many environmental problems associated. An efficient alternative to prevent this accumulation is the re-valorisation through acidogenic fermentation to produce volatile fatty acids (VFA), precursors for the production of polyhydroxyalkanoates (PHAs). In this work, five different types of wastes were used: Potato solids from a chips factory, salad from vegetable factory and three wine wastes generated in different stages of winemaking process. The diversity of these wastes related with their origin, composition and production period needs to be studied separately. In a batch experiment, we compared all of them to evaluate VFAs productivity and distribution. The highest yield was reached with potato solids (0.8 g VFA/g VS waste), salad waste (0.75 g VFA/g VS waste) and marc grape (0.7 g VFA/g VS waste). The VFA profile showed acetic and butyric as predominant acids in the potato and salad wastes. In the case of two wine substrates produced in different stages of distillery wine, the degree of acidification was lower than 0.25 g VFA/g VS waste added. The predominant acids were acetic and propionic in all of wine wastes. These results will help to optimize the acidogenic fermentation of each particular waste and to stablish a new strategy for their co-digestion.

### Biography

M C Veiga obtained her PhD in the field of Environmental Bioengineering from the University of Santiago de Compostela. Afterwards, she had a Postdoctoral position at Michigan State University. At present, she coordinates the Environmental Engineering Group at University of A Coruña. Her primary research interests are on the development of sustainable processes for the removal of pollutants from wastewater and production of biopolymers from renewable sources.

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# Study on the curing characteristics and synthesis process of modified urea-formaldehyde resin with low formaldehyde release

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The modified urea-formaldehyde resin with low formaldehyde release was synthesized with different kinds of additives in this paper. And the curing characteristics were studied mostly. The results indicated that: the urea-formaldehyde resin with additive 1+2+3 showed the fastest cure rate, which improved about 15% compared with the blank sample, but the mechanical properties was poor. So the synthesis process was optimized based on the addition of assistant 1+2+3, the results showed that:①melamine has a very significant effect on reducing free formaldehyde, when the added amount reached 3%, the formaldehyde release was only 0.28mg/L;②increased the viscosity of the resin can improve the bonding strength of the adhesive obviously.

## Biography

Jiyou Gu is a Professor and the Dean in the College of Material Science and Engineering at Northeast Forestry University. He obtained his BSc degree in 1982 and his MSc degree in 1988 from Northeast Forestry University, and received his PhD degree from Kyushu University in Japan in 1996. He has been a Visiting Professor at the University of Tokyo in Japan and in Finland. His research interests cover the adhesives used on wood and the manufacture of plywood, fiberboard, and other wood products. He is particularly interested in design and synthesis of adhesives, improving the properties of adhesives, manufacture of adhesives, and optimization of adhesives functions.

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## Thermal treatment of soybean protein and its effects on the water resistance of soybean protein adhesive

**Zhen Hua Gao, Binghang Zhang** and **Bo Fan**
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Soy protein isolate is an abundant and renewable industrial crop product that can be an environmental friendly and sustainable alternative to petrochemicals for producing wood adhesives by eliminating its inherent defects such as poor water resistance. In this study, a novel method to improve water resistance of soybean protein was proposed by the thermal treatment in the presence of $Na_2SO_3$ and SDS; based on investigations of the effects of thermal treatment temperature, $Na_2SO_3$, SDS and their combination on the water resistance of protein using FTIR, XRD, TGA and SEM. Partial soybean protein formed stable three-dimensional network during the thermal treatment via the re-polymerization and the rearrangement of soybean protein molecules, which improved the water resistance of soybean protein as confirmed by the increased water insoluble content and hydrothermal-aged wet bond strength. Attributing to the capacities of $Na_2SO_3$ to cleave disulfide bonds and SDS to destroy the hydrophobic interactions of proteins, their combination during thermal treatment released the active groups buried within the globular structure of soybean protein via partial unfolding. This not only further promotes the re-polymerizations of soybean protein molecules but also yield more active sites for crosslinking by post-added crosslinker. This resulted in higher water insoluble content and hydrothermal-aged bond strength compared with the thermal treated soybean protein without $Na_2SO_3$ and SDS. The optimal levels of $Na_2SO_3$ and SDS during thermal treatment were all 1 wt%, producing a modified soybean protein with the best water resistance that can be used to prepare a wood adhesive for structural-use plywood according to JIS K6806-2003 commercial standard.

### Biography

Zhen Hua Gao completed his PhD from Northeast Forestry University and Post-doctoral studies from Wood Composite Department of Forintek Canada Corp in Canada. He is a Professor at College of Material Science and Engineering, Northeast Forestry University in China. He has published more than 40 papers in reputed journals. One article published in *Pigment & Resin Technology* has been chosen as an Outstanding Paper at the Literati Network Awards for Excellence 2008. His five invention patents were authorized. He has finished more than 10 projects as leader so far.

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## Preparation and performance of water-borne acrylic wood coatings modified by rice husk ash

**Shuangying Wei, Shiwei Guo, Xiaoke Bi, Jiuzhou Zhang, Bin Feng** and **Peiliang Liu**
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Rice husk is an important biomass resource on the earth. The rice husk ash is the product of the burning of rice husk and its yield is huge. Its main component is silicon dioxide. The rice husk ash as modifiers has been successfully applied in the fields such as rubber, waterproof coating and so on. Acrylic wood coatings show the excellent comprehensive performance, but the properties in the aspect of the hardness and abrasion resistance are poor. The rice husk ash was added to the acrylic wood coatings system in this study in order to improve the performance of coatings. Firstly, the rice husk ash was treated with different temperature gradient of 600°C, 650°C, 700°C, 750°C and 800°C. They were added respectively to the waterborne acrylic wood coatings as modified fillers after fully grinding. The physical properties, gloss and mechanical properties of the coating film were tested. Scanning electron microscopy (SEM) and atomic force microscopy (AFM) were used to observe and analyze the microstructure of the coating film. The results showed that the rice husk ash handled with temperature of 700°C had the best modification effect. The modified coating film reflected 33.4°C of minimum film forming temperature (MFT), solid content increased to 18.3%, the abrasion resistance increased to 33.3%, hardness increased from HB to H, gloss decreased to 74% and fineness decreased nearly three times. The heat resistance and adhesion of the coating film were not changed, all of which were grade 2. The pigment and filler in the coating system were dispersed evenly with no aggregation.

### Biography

Shuangying Wei completed her Doctor's degree in Biomaterials Engineering in December of 2008 from College of Material Science and Engineering, Northeast Forestry University in China. She has published several papers in reputed journals. One paper authored by her was awarded by the Liang Xi Youth Paper Award in 2012 and was awarded the second prize of the thirteenth Heilongjiang Provincial Natural Science Technology Academic Achievement Award. She was sponsored for one project by the National Natural Science Foundation and Province Youth Science Fund Project of Heilongjiang.

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## Comparative analysis between maize and cassava starch through XPS

**Yanhua Zhang, Shanshan Lv, Junyou Shi, Shuangying Wei, Haiyan Tan** and **Jiyou Gu**
Northeast Forestry University, China

The difference of the performance between corn and cassava starch caused by the different content of amylose and amylopectin were studied contrastively. Fourier transform infrared spectroscopy (FTIR), differential scanning calorimeter (DSC), thermogravimetric analysis (TGA), X-ray diffraction (XRD), X-ray photoelectron spectrometer (XPS), scanning electron microscopy (SEM) and bonding strength were characterized to analyze the difference between corn starch and cassava starch. The results showed that: Both the dry and wet bonding strengths of cassava starch adhesive were higher than that of corn starch. The FTIR results indicated that the number of hydroxyl groups in corn starch structure was higher than that in cassava starch. According to the TGA analysis, the thermal stability of corn starch and cassava starch showed unclear difference, but the residual mass of corn starch was higher than that of cassava starch. XPS data demonstrated that the content of carbon in corn starch was slightly higher than that in the cassava starch. According to the characterization of SEM, the corn starch exhibited an irregular shape while the cassava starch particles were oval.

### Biography

Yanhua Zhang has completed her PhD from Northeast Forestry University and Post-doctoral studies from Northeast Forestry University School of Electrical and Mechanical. She has published more than 25 papers in reputed journals and has been serving as an Editorial Board Member of repute.

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# Zinc oxide nanoparticles control skin infection and improve dermal wound healing in humans

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Zinc Oxide nanoparticles (ZnO-Naps) have been used in different bionanocomposites for wound healing and skin infection based in the antibacterial intrinsic properties. However controversial toxic effects have been identified and preliminary results observed in animal models give limitations for the uses of this nanoparticles in humans. Here we report the benefits observed in dermal wound healing and control of infection in patient diagnosed with allergic dermatitis associated with infected ulcers. Nanotechnology is considered as a multidisciplinary area that is part of nano scale systems that is very important from the materials science, colloidal science, and medical science, among others. Currently nanotechnology is a rapidly growing area primarily for biotechnology and medicine in both the development of new diagnostic techniques and therapeutic treatments aimed at organs and damaged tissues. One of the alternatives with the greatest potential application is the use of ZnO-Naps as an antimicrobial agent and ulcer healing properties. The mechanisms of action are: 1) Cofactor in enzymatic complexes that promote migration of keratinocytes 2) participates in the formation of reactive oxygen species (ROS) which penetrate the bacterial cell membrane producing oxidant injury. According to the mechanisms of action of ZnO Naps could be an alternative as promoters of healing in chronic diabetic foot ulcers and other ulcers associated with allergic dermatitis. The objective of this work is to assess the effectiveness of dressings of calcium alginate impregnated with ZnO-Naps, along with the local application of powder of ZnO-Naps, in the control of infection and healing of ulcers in patients with allergic dermatitis.

## Biography

Rebeca Betancourt Galindo is a Researcher at the Department of Advanced Materials. She has extensive experience in emulsion polymerization, polymer and nanoparticle functionalization, preparation and physico-chemical characterization of polymer nanocomposites, including the determination of antimicrobial properties of polymer nanocomposites. She has published more than 29 papers in reputed journals.

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## Surface modified chitin with silane as reinforcement in cement mortar composites

**Anju Ramakrishnan**
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With increasing global concern over depletion of non-renewable fossil fuel and rising price for petroleum and petroleum derived products, present and future demands natural materials that are eco-friendly (with minimum waste disposal), having light weight, high durable with mechanical properties greater than or equal to those of traditional petroleum based materials. Chitin is such an abundant biopolymer found in cell walls and skeletal structure of numerous invertebrates. But one of the drawback in chitin whisker based composite is the presence of hydrogen bonds in chitin tend the fibers to agglomerate into bundles and unevenly distribute throughout the non-polar polymer matrix during compounding processing; resulting a weak interfacial adhesion. Therefore fiber treatment is beneficial towards improving the water resistance and wettability of the fiber surface by polymers and enhances interfacial adhesion. A coupling agent is a chemical that functions at the interface to create a chemical bridge between the reinforcement and matrix. Mainly organosilanes are efficient coupling agents and they have been extensively used in composites. The hydroxyl groups present on the surface of the chitin powder is allowed to condense with the hydroxyl groups of the silicates under alkaline pH conditions. In this study, chitin whisker surface was modified by the treatment with a suitable silane coupling agent. The properties of surface modified chitin characterized by PXRD, SEM, TGA and FTIR. This reinforcing material was used in mortar composites and the mechanical properties enhancement studied.

### Biography

Anju Ramakrishnan is pursuing PhD from the Department of Chemistry, Indian Institute of Technology - Madras under the guidance of Prof. R Dhamodharan. She has extensive experience in preparation of nanocellulose using banana fiber, surface modification of cellulose and chitin extracted from various natural resources, using silane coupling agents.

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## e-Poster

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# Application of polyhydroxyalkanoates and exopolysaccharides produced by Haloarchaea in biopolymer and bioplastic industry

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Guilan University of Medical Sciences, Iran

Haloarchaea are a distinct evolutionary branch of the domain Archaea, which generally comprise the leading prokaryotic population of hypersaline environments. Haloarchaea mainly produces two major groups of macromolecules that are called exopolysaccharide (EPS) and polyhydroxyalkanoate (PHA). EPSs have several industrial applications, for instance their biosurfactant activity in bioremediation of oil-spilled sites, and its role in pharmaceutical and food-processing fields. PHAs are a group of polyesters. In the presence of excess carbon substrates, certain Haloarchaea synthesize PHAs and deposit them as energy storage intracellular granules. PHAs have thermoplastic features and are biocompatible and biodegradable "green plastics" that are considered as potential substitutes for petrochemical-derived plastics. Therefore they can be employed for daily supplies (plastic bags), biomedical materials (artificial blood vessels) and as biodegradable carriers for slow delivery of drugs. PHAs can be produced from reproducible resources such as carbohydrates, which makes their manufacturing independent of the availability of finite fossil feed stocks and also their biodegradation process resulting merely in $CO_2$ and $H_2O$, the basic materials for the photosynthesis by green plants. The PHAs that are produced by Haloarchaea have several benefits in comparison with those from members of the domain Bacteria; First, they are produced from unrelated cheap carbon sources; second, there is no need for strict sterilization, and third, their isolation is much easier. The archaeon *Haloferax mediterranei* is the best PHA producer of the family *Halobacteriaceae* until now. PHAs currently are industrially produced under the commercial name "Mirel" by the company Metabolix in USA using a recombinant Escherichia coli strain.

## Biography

Masoud Hamidi has completed his PhD from Tabriz University of Medical Sciences. He is Assistant Professor of Pharmaceutical Biotechnology in Guilan University of Medical Sciences. He has published more than 15 papers in reputed journals.

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# Accepted Abstracts

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## Biosynthetic routes for linear diacids from fatty acids feedstocks

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Linear α,ω-dicarboxylic acids have multiple applications in polymers such as polyamides, polyurethanes and polyesters. The majority of these diacids are derived from non-renewables fossil-based feedstocks. Verdezyne has developed technology that produces diacids derived from renewable feedstocks such as vegetable oils. Our first commercial target is BIOLON(TM) dodecanedioic acid (DDDA). This twelve-carbon diacid is used to produce nylon 6, 12, an engineered plastic for applications requiring special properties such as high chemical, moisture and abrasion resistance. We will discuss the technology, feedstock, and commercialization of this molecule. New technology is also being developed that allows the feedstock flexibility to produce different diacids from a variety of vegetable oils and their low-value side streams. We will show examples of producing different diacids such as adipic acid and suberic acid from a variety of different feedstocks. This technology will allow the concept of a biorefinery as seen in the corn industry to be implemented in vegetable crops such as soybean oil and palm oil.

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## A new end-of-life alternative for flexible packages: TIPA's novel biocompostable films and laminates

**Itai Pelled**
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Sixty six percent of the packaging waste by volume (50% by weight) is contributed by food packaging. It is, by far, the dominant worldwide contributor to waste. The food waste packaging is divided in general into rigid and flexible packaging. In terms of end-of-life solution, whilst rigid packaging, mostly manufactured from a single material, can be addressed by collecting the waste and recycle the materials, no sustainable solution was set forth to date for the flexible packaging. These packaging are being manufactured using several materials and thus the recycle solutions are inapplicable. The current biodegradable solutions, however, suffer from several key limitations that preclude their widespread commercial use: (i) poor barrier properties, (ii) limited mechanical properties, and (iii) raw materials cost. TIPA Corp., targeted this flexible packaging challenge in order to deliver to the brand owners and convertors flexible packaging films and laminates that could replace the existing plastic materials with similar properties and without requiring to perform any adaption to the production lines. It is well established that bioplastics present with low barrier to water and oxygen transmission and limited mechanical properties. TIPA Corp. employed several biodegradable polymer admixtures to generate biocompostable flexible film presenting with undetected values for the oxygen transmission and with water transmission of approximately 1 g/m$^2$/day at 38 deg C, RH 90%. These barrier properties are comparable with some of the current conventional plastic commercial products. Furthermore, the mechanical properties of TIPAs' films in terms of Young's modulus, elongation, tear & impact resistance, as well as transparency is in line with conventional rather than compostable polymer-based products. The change in bioplastics production capabilities and regulations revolving waste, at least in the Western Societies, affected the raw material costs, but only to a limited extent. It is conceivable; however, that the aforementioned constrains of the current bioplastics products on the market had limited their market cap. The current proposed solution by TIPA brings higher value to the food packaging industry and together with the demand by end-customers and regulations for such end-of-life products, it may be translated to larger volumes of raw materials, which in turn will lead to raw materials cost reduction. Taken together, TIPA products offer valid packaging solutions that meet the requirements of flexible food packaging combined with an efficient end-of-life solution. This sustainable packaging will contribute to reducing resource wastage and environmental impact, whilst providing economic and social benefits.

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## Biodegradable poly(propylene carbonate)-based composite: An alternative biomaterial to polylactic acid

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Poly(lactic acid) (PLA) and other polyester-based polymers are broadly used in biomedical applications due to their favourable mechanical strength and biodegradable properties. However, the acidic properties of their degradation products may lead to clinical complications, such as inflamation, long-term osteoporosis and other unpredictable issues. In this study, we demonstrate the superior properties of the poly(propylene carbonate) (PPC)-starch composite as an alternative to polyester-based biomaterials. The degradation products of PPC-starch are mainly carbon dioxide and water. Hence, the pH in the surrounding tissues of an implant fabricted from this composite does not decrease. Moreover, the mechanical strength of PPC-starch composites is tuneable within the range of 0.2±0.03 MPa to 33.9±1.51 MPa, by varying the starch content from 0-50 w%. PPC-starch composites are cytocompatible as osteoblast cells adhere and proliferate on their surface within seven days. The long-term biocompatibility of PPC-starch is assessed via subcutaneous implantation in mice. The results of histological analysis demonstrate no symptom of inflammation for PPC-starch composite after eight weeks implantation, while the biodegradation of PLA lead to massive immune cell infusion and inflammation. These results underline that PPC-starch is suitable for biomedical applications and can be used for the musculoskeletal tissue regeneration.

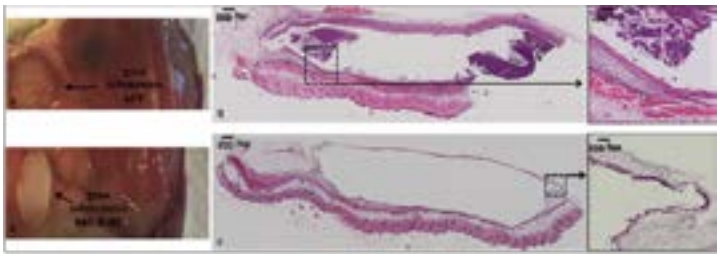

Figure 1: The explanation site of PPC-ST50 (a) and PLA (b) 8 weeks post-surgery, and haematoxylin and eosin staining of paraffin sections of the implantation site at 8 weeks around PPC-ST50 composite (c) and PLA (d). After 8 weeks a prominent foreign body reaction is observed around PLA implantation zone. However, the inflammatory response to the PPC-ST50 composite is resolved dramatically.

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## Preparation of some chitosan derivatives and study of their effect on human genetic material

**Hadi S Al-Lami, Sara H Mutasher** and **Afrodet A Salih**
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Chitosan is a polycation biopolymer material. It has several applications, especially in the biopharmaceutical and biomedical fields. Chitosan was produced from shrimp waste by chemical method involving demineralization, deproteinization and deacetylation. It was characterized by intrinsic viscosity measurement and Fourier transform infra-red in order to determine the average molecular weight and degree of deacetylation of purified chitosan. Chitosan was modified by grafting process with maleic anhydride, poly(adipic anhydride) and poly(sebacic anhydride) to evaluate their effect on binding to the human genomic DNA. The grafted chitosan derivatives appeared as promising materials to be used as a model for DNA and gene delivery. Grafted chitosan-DNA complexes were determined by gel electrophoresis technique and ultraviolet spectroscopy.

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## Balancing performance and sustainability in natural fiber-reinforced composites

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Natural and synthetic fibers have been used increasingly as matrix reinforcements in various applications. While the latter is popular for its generally superior mechanical properties, natural fibers are environmental friendly and sustainable. As more businesses are inclined towards going green, natural fibers are gaining increasing attention in recent years, often as a substitute or as a complementary to glass fibers. However, its utilization is usually bound to applications in not requiring high mechanical performance. In this study, we investigate an extended use of natural fibers in polymeric composites to structural applications requiring higher mechanical performance, through hybridization with carbon fibers, aiming at a good balance between performance and sustainability. Having more than one fiber type in a polymer matrix gives greater flexibility in achieving optimal characteristics with a proper understanding of the material behavior and failure mechanics. Experimental investigation was carried out on various flax-carbon reinforced polymer hybrid systems fabricated using a custom-designed composites prepreg extrusion plant, suitable for large-scale industrial output, to impregnate fibers with a recyclable polymer, which are then hot-pressed, producing composite laminates with high fiber volume fraction. The reinforcing effect of carbon in flax-polypropylene composite at various carbon fibre loadings is determined with regards to the hybrid's strength and stiffness under tension and bending.

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## Reticulation mechanism of advanced diacrylate cis-1,4-polyisoprene with temperature: *In situ* investigations on thin films by infrared and Raman spectroscopies

**Kenza Ayche, Jean François Bardeau, Jean François Pilard** and **Nicolas Delorme**
Institut des Molécules et Matériaux du Mans, France

The increasing number of mobile devices and the race to energy sobriety make the decrease of the size of microelectronic systems (MEMS) a major challenge. Today, lithium micro batteries are currently the best solution for high-power and energy applications. Incorporate them into credit cards containing a screen or associate them to electronic sensors for the supervision is the challenge which raises international companies such as ST Micro Electronics. However, these micro batteries contain some lithium metal which can be dangerous if the metallic lithium is in contact with water or humid air. In addition, the substance can spontaneously ignite in the contact of the humidity. So, in order to avoid the problems of safety, we absolutely have to protect the lithium contained in our micro batteries using an encapsulation layer. Polymeric encapsulation has the advantage, compared with other materials (ceramic, metal), to present a moderate cost of shaping and a low weight. However, such systems of encapsulation are insufficient to guarantee a satisfactory life cycle of components. Indeed, in the presence of humidity or important temperature variation, the mechanical assemblies can be weakened and engender an irreparable break. Our project is thus to develop thin encapsulation layers of polymers based on natural rubber. The interesting physical and chemical properties of such polymers represent an attractive alternative to existing packaging materials. Moreover, in addition to their barrier properties against water and air, these polymers are known to be ecological, very flexible and have a good elasticity. Diacrylate oligoisoprene derived of natural rubber is associated with a thermal initiator known for its capacity to crosslink a large range of polymers. The process consists of forming a thin film by dip coating a substrate into a polymer/di-sulfonyl azide mixture and then thermally anneal the film up to a temperature at which the sulfonyl azide decompose. The effects of both the selected annealing temperature, the heating rate and the reaction time were investigated using Fourier transform infrared spectroscopy and Raman spectroscopy. A full analysis of the vibrational spectra provides significant information regarding the thermal reticulation. Our investigations allowed us to determine both the kinetics of thermal cross linking and the main parameters that can help to develop industrial thermal process. This project is realized in collaboration with ST Micro Electronics and applications in micro batteries will be discussed.

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## Development of plasticized starch biocomposites blended in an original mixer (RMX) based on elongational flows

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This study focuses on the thermo mechanical and rheological behaviour of starch biocomposites formulated by elongational mixer and reactor (RMX). Compared to existing laboratory mixers, RMX device process is characterized by a high contribution of elongational flow and the ability to directly measure the rheological properties of blends. The idea is to promote the elongational flow during mixing of different components and increase the dispersive mixing efficiency. Using RMX, various formulations based on plasticized starch matrix (TPS) have been carried out by varying plasticizer amount, flax fibres content and flax fibers length. After RMX-thermocompression moulding, the impact of process parameters (temperature, speed screw, mixing cycle number) on the viscosity of plasticized starch blends are investigated. Furthermore, morphological and microscopic data on TPS/flax blends prove the high distributive and dispersive mixing efficiency as compared to a classical rotational batch mixer. The evolution of microstructural properties of the starch based biocomposites are also analyzed by X-ray diffraction (DRX), thermo mechanical (DMA) and thermal degradation (TGA) analysis.

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## Cationic xylan-METAC copolymer as a flocculant for clay suspensions

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Now a days removal of clay waste from waste water of various industries is a major challenge due to their charge and properties. Flocculation using synthetic polymers has been regarded as a promising process to address this problem. However, there is a growing concern about the use of synthetic polymers in wastewater. To tackle with this problem, natural based flocculants (i.e. biodegradable flocculants) should be used for this purpose. In this work, xylan based cationic flocculant [xylan-2-(methacryloyloxy)ethyl] trimethylammonium chloride (METAC)) was produced and was characterized using gel permeation chromatography, infrared (FTIR) and elemental analysis. The flocculation potential of produced biopolymer in removal of clay wastes was studied using two different types of clay suspensions viz., kaolin and bentonite. The biopolymer was found to be effective in removal of both types of clays via adsorbing on their surface. The removal of clay from suspensions was due to charge neutralization and polymer bridging mechanisms, which is evident from decrease in relative turbidity of clay suspensions and change in zeta potential of clay particles. The percentage removal of bentonite and kaolin clay particles from suspensions was found to be 98 and 80% respectively. The removal of clay particles depends on amount of flocculant adsorbed on their surface. The floc growth and breakage studies also confirmed the flocculation potential of produced biopolymer. This work suggest that cationic xylan (biopolymer) can serves as an effective flocculant in removal of clay wastes present in waste water of various industries.

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## Electroactive PCL nanofibers coated by polypyrrole for nerve tissue engineering

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Electrically excitable tissues like nerve and muscle have shown promising results in regeneration on conductive scaffolds. In this study, 14% solution of PCL electrospun on a rotating collector forms nanofibres with the average diameter of 430 nm. The fibre mats are dip coated by the conducting polymer PPy (polypyrrole) to form a substrate capable of stimulation of nerve cells. 90% porosity of the conductive scaffold along with the mechanical properties which is improved compared to PCL fibres without coating, meet the required properties of nerve scaffolds. PC12 cells along with nerve growth factor, are cultured on the aligned nanofibers and stimulated by a constant voltage of 0.01 V/cm for 1 h/day for three days. Formation of neurites in the direction of fibres suggests that the electroactive PCL-PPy scaffold can support the differentiation of PC12 cells into nerve cells. The flexible and stable fibrous scaffold with conductivities ranging up to 1.9 S/cm shows the potential applications of these membranes in neural tissue engineering.

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## The effect of ionic charge carriers in 2-hydroxyethyl cellulose solid biopolymer electrolytes doped glycolic acid via FTIR-deconvolution technique

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The Fourier transform infrared (FTIR) spectrum of 2-hydroxyethyl cellulose (2HEC) doped with glycolic acid (GA) solid biopolymer electrolytes (SBE) samples has been deconvoluted in the wavenumber region between 1160 and 1300 $cm^{-1}$ in order to investigate the percentage of free and contact ions in the samples. Through solution casting method, 2HEC was complexed with different composition of GA and sample with 40 wt.% GA achieved the highest ionic conductivity at room temperature of $4.01x10^{-4}$ $S.cm^{-1}$, two magnitude orders higher relative to the parent host polymer. The FTIR of carboxyl stretching mode was deconvoluted representing the bands of free ions, contact ion pairs and ion aggregates to obtain an insight on the ion associations. The results showed that the number of free ions increases and attain maximum at 40 wt.% GA. The correspondence between free ions, contact ion pair, ion aggregates and conductivity is obvious. The increase in ion dissociation improves the conductivity, while the formation of contact ion pair and ion aggregates reduces it. The calculated ionic species of the 2HEC-GA complexed system from Transference Number Measurement (TNM) confirmed that the system is predominantly cationic.

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## Development of high strength biofilm using sodium carboxy methyl cellulose and graphene oxide

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There is great demand of high strength biomaterials in various kinds of industries. In current studies, we developed a strategy for fabricating high strength biofilm from sodium carboxy methyl cellulose and graphene oxide (GO) using simple and facile method. Well known hummer method was used to synthesize GO from graphite powder and a simple two step procedure was adopted to get biofilm having the required superb qualities. This film showed splendid mechanical properties having additional fire retardant behavior comparing with pure sodium carboxy methyl cellulose film. Film surface morphology was studied by scanning electron microscope (SEM) with energy dispersive spectroscopy (EDS) mode. Tensile test of film samples were performed using universal testing machine equipped with 500 N load cells at room temperature and an average humidity 20%. Fourier transform infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy were used to confirm crosslinking mechanism. The nanostructure of prepared biofilm clearly indicated layers under SEM. The stress-strain curve indicated five folds increase in the tensile strength with 0.7% GO and 0.09% borate in biofilm when compared with pure sodium carboxy methyl cellulose film. This modified biofilm showed fire-retardant behavior when exposed to flame, thus confirmed that compactly arranged graphene layers not only improve the mechanical properties but also improve fire resistivity of the biofilm. The simple and novel method used for the preparation of film provides a potential approach that may be utilized in the field of aerospace, tissue engineering and synthesizing flexible supercapacitor electrodes to be used in different electronic devices.

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## Clinical trial: Calcium alginate dressing incorporating nanoparticles in the treatment of diabetic neuropathic foot ulcers zinc oxide nanoparticles skin patches

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**Introduction:** Diabetes Mellitus in developed countries have a prevalence of 11%. Diabetic foot is a complication of diabetes mellitus. The presence of diabetic foot ulcers varies between 4% and 10%. Foot infections are most common cause of hospitalization and often precede amputation. The indicated debridement in almost all ulcers is recommended to maintain a "moist wound healing", using the appropriate dressing.

**Aim:** Aim of the study is to evaluate the effectiveness of a calcium alginate dressing with zinc oxide nanoparticles in the treatment of neuropathic diabetic foot ulcers.

**Materials & Methods:** A prospective randomized controlled trial was conducted in 26 patients. The patients were randomized to two groups: group one (n=28) received treatment with calcium alginate dressings with nanoparticles, while the other group two (n=29) received the treatment (without nanoparticles). The dressing change was performed every 48 h. The duration of observations was at the interval of every 10 weeks.

**Results:** After 10 weeks, healing was achieved in 24 (85.7% of n=28) patients in group one under treatment with calcium alginate nanoparticles versus 21 ( 72% of n=29) in the other group two (calcium alginate without nanoparticles) (p=0.03). The mean time to healing was 36 days±5 in the group one and 42 days±3.4 in group two (p=0.002), with significant differences between the two groups (p<0.028).

**Conclusion:** Most patients included in both groups were not receiving proper treatment of the ulcer, the analysis of the results support the hypothesis that the use of calcium alginate dressings with nanoparticles induces a better tissue regeneration.

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## Cu nanoparticles/PVC composites: Thermal, rheological and antibacterial properties

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The effect of Cu nanoparticle (NP) content (0.3-3.0 wt.%) on antibacterial, thermal and rheological properties of PVC composites prepared by melt blending method was investigated. The composites were characterized by scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDX), transmission electron microscopy (TEM), capillary rheology, thermogravimetric analysis (TGA) and inductively coupled plasma atomic emission spectroscopy (ICP-OES). A homogeneous distribution of copper on the composite surface was observed by SEM-EDX. TEM images of Cu NPs/PVC composite films showed well-dispersed and distributed Cu NPs and microparticles in the PVC matrix, but the size of particles increased with increasing copper content. The shear thinning and power law behavior were observed for all samples. At low shear rates ($100s^{-1}$) apparent viscosity of composites with copper loading lower than 1.2 wt.% exhibited a "ball bearing" effect. The Cu particles enhanced the thermal stability of Cu NPs/PVC composites compared with neat PVC. The copper ion released from Cu NPs/PVC composite films into the aqueous medium was negligible after 6 h of immersion. Polymer films with Cu NP amount higher than 0.6 wt.% showed a similar kinetics of bacterial growth therefore a substantial improvement of antimicrobial activity was not observed with increasing Cu NP content.

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## Chitosan and derivatives modified with HAp/ß–TCP microparticles and nanoparticles

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Bone repair or regeneration is a common and complicated clinical problem in orthopedic surgery. The importance of chitosan and its derivatives and calcium phosphates has grown significantly over the last two decades due to its renewable and biodegradable source, increasing in the knowledge of its functionality in the technological and biomedical applications. The properties of bone in health and disease attract much attention. With an ever greater proportion of the population need those medical devices for hard tissue regeneration and/or replacement, making the pressure on the health systems in all countries. Aging, diseases, fractures and demineralization are musculoskeletal disorder, which contribute and improve the suitability and developments of new materials and methods in hard tissue engineering. The excellent biocompatibility, biofunctionality, and non-antigenic property make those materials a good choice for hard tissue regeneration. This work has shown the composites of chitosan and its derivatives with calcium phosphates in different forms (sponge, fibres) containing organic and inorganic materials, including chemical characterisation, mechanical properties, particles size, morphology, solution stability and also a new method to obtain nanoceramic formation in chitosan solution. All sponge preparations, with MCCh/ß-TCP have a well-shaped 3-dimentional structure, a highly porosity and interconnected, homogenous pore structure to ensure a biological environment conducive to cells attachment and proliferation and passage of nutrient flow. The fibres form showed nanoceramic formation with two different kinds of calcium phosphates, great mechanical properties performance in wet conditions and not finishing agent was required in the wet spinning process of fabrication. These materials can be used in future for medical applications as a base for scaffolds production as implants in regenerative medicine.

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## Preparation of catalyst-loaded viscose rayon fibers with sustainable antimicrobial functionality

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Viscose rayon cellulose fiber was first selectively oxidized on its surface without significant loss of its pristine fiber structure so that carboxylate functional group was introduced on the fiber. Separately, uniformly dispersed silver nanoparticles (AgNPs) having sizes of 2-5 nm were prepared by using amine-terminated fourth generation poly (amido amine) dendrimer as a capping agent. Then, the AgNPs were immobilized on viscose rayon fibers through chemical reaction to form amide bond between terminal amine groups of dendrimer protector with the carboxylic acids on oxidized fibers. The loaded nanoparticles did not release from the fiber even after 60 times washings. The AgNPs-loaded fibers (0.3 wt.%) exhibited excellent biocidal activity against *E. coli.* Therefore, this procedure can be effective for the prolonged sustainment of similar bioactive agents on fibers and maximize the efficiency of the cellulose product for anticipated purposes.

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## Assessment of bioplastic producing potential of *Bacillus subtilis* using some agro residues as carbon source

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The assessment of bioplastic producing potential of *Bacillus subtilis* using a variety of pretreated agro-residues was carried out. The agro residues were rice husks, molasses, bagasse, and corn cobs. Acid, alkaline and oxidative pretreatment of the agro-residues were done using standard procedures. Bioplastics produced were extracted using chloroform precipitation and quantified spectrophotometer. Acid, base and peroxide concentrations in g/L of polyhydroxybutyrate (PHB) were obtained for rice husks 1.52±0.02, 1.82±0.01, and 1.70±0.01; molasses 1.82±0.01, 1.52±0.02, and 1.69±0.01; bagasse 0.87±0.06, 1.10±0.10, and 0.96±0.07 and; corn cobs 0.5±0.00, 0.77±0.06, and 0.60±0.10. The bioplastic yield of the agro-residues for acid, base and peroxide pretreatments were: rice husks 50.33±0.76, 53.69±2.23 and 53.29±0.15; molasses 54.94±0.14, 50.55±0.25 and 53.09±0.17%; bagasse 53.33±6.68, 55.00±0.25 and 54.50±7.12 and; corn cobs 51.85±3.21, 63.94±2.59 and 60.11±8.89. Statistical analysis revealed that PHB concentration of alkaline pretreated rice husk had a significant ($p<0.05$) higher value than other pretreatments. However, among all the agro-residues used peroxide pretreated corn cobs had a significantly ($p<0.05$) higher percentage yield of bioplastic (63.94±2.59).

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## Impact of hydrocolloid (mucilage) edible coatings on the oxidative stability and textural characteristics of deep fat fried potato crisps

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The effects of edible coatings from *A. esculentus* and carrageenan mucilage extracts individually or in combination on deep fat fried potato chips (3 cm X 1.5 mm) during storage at 25°C & relative humidity 55% (8 weeks) is studied. Peroxide value (PV), p-anisidine value and TOTOX (total oxidation products) of chips coated with 1% *A. esculentus* and 1% *A. esculentus*:carrageenan polysaccharide was determined by titrimetric method to analyze the extent of oxidation in comparison with control chips without any coating treatment. The proximate composition of coated potato chips were performed in which a reduction in terms of fiber, ash, reducing sugars contents with a corresponding increase in protein content compared to the uncoated control chips was observed. The potato chips coated with 1% *A. esculentus* and 1% *A. esculentus:*carrageenan mucilage polysaccharide coating showed lower peroxide values (1.04±0.06 and 1.03±0.02) and anisidine values (2.58±0.04 and 2.53±0.06) than the control chips (3.27±0.06 to 2.28±0.02) and (9.74±0.04) during storage. From the above results, the total oxidation stability of the fried product, TOTOX was measured and oxidative stability of chips coated with 1% *A. esculentus* and 1% *A. esculentus:*carrageenan polysaccharide edible coating were higher compared to the control chips without any coating treatment. The texture of the potato chips evaluated by using a TA.XT Plus Texture Analyzer (Texture Technologies, Scarsdale, NY) indicated that the firmness of potato chips coated with 1% *A. esculentus* and 1% *A. esculentus:*carrageenan polysaccharide was higher compared to control. The edible coating from 1% *A. esculentus* and 1% A. esculentus:carrageenan mucilage polysaccharide inhibited the oxidation of potato chips thereby enhancing their shelf life with appreciable sensorial scores and maintained nutrient quality of the potato chips representing a healthier snack for consumers.

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## Preparation, characterization and antifungal properties of polysaccharide-polysaccharide and polysaccharide-protein films

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The effect of the interaction polysaccharide-polysaccharide (P-P) and polysaccharide-protein (P-Pr) blends on thermal and mechanical properties in films as biodegradable alternative of materials for food packaging was studied. Essential oils (cloves and cinnamon) emulsified were successfully incorporated into the films and evaluated as antifungal agents. Films were prepared using the film casting method. The morphological analysis showed that P-Pr films display a fractured rough surface without pores or globular formations and P-P films exhibiting continuous phases and absence of cracks. FTIR spectra evidence interactions between polysaccharides and polysaccharides-protein. Initial degradation temperature ($T_{5\%}$) decreases in two kinds of films with the addition of antifungal agents. P-Pr films showed higher maximum decomposition temperature ($T_{max}$) regarding P-P films. The incorporation of carrageenan in films enhances the tensile strength and elongation at break. Higher antifungal activity against *Botrytis cinerea* and *Rhizopus stolonifer* was revealed in the films containing cinnamon oil.

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## Characterization and degradation properties of sheep milk protein isolated bio-polymer film

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Nowadays, the development of green products is increased rapidly in the aspect of eco- environmental concern and availability of the natural sources. In this study, for the fabrication of composite film compounds, the bacterial derived compounds was synthesized and reinforced as micro filler in protein based matrix with the combination of optimized plasticizer and curing agent. The effect of volume fraction of different plasticizer and cross linkers was studied to the weight% of the content in matrix by trail and error method. The protein rich compounds such as casein, gelatin and sheep milk protein were used as a source of matrix. Glutaraldehyde reacted with the amino groups in the protein and formed excellent intermolecular linkages which lead to the development of biodegradable composite film. The suitable pH value and the temperature were found to be suitable condition for preparing composite film. The characterization of prepared film was performed by FTIR, XRD, tensile and antibacterial testing. The prepared composite film was completely degraded with in 24 hours of soil testing methods. These fabricated biodegradable films can be a possible replacement for food and biomedical applications.

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## Chitosan-polyvinyl alcohol co-polymerized films: Synthesis and exploring its pharmaceutical applications

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Chitosan being a biopolymer can be co-polymerized with polyvinyl alcohol (PVA), which has excellent mechanical properties. The current work focuses on co-processing a natural polymer with a synthetic polymer to obtain a polymer with improved functional properties. The developed co-polymerized films were explored as an excipient and other drug delivery applications. Chitosan was blended to polyvinyl alcohol in different ratios, chemically modified by using initiators and crosslinking agents and the modified co-polymer was converted to films by solvent casting method. The films were evaluated for tensile strength, folding endurance, water uptake capacity, disintegration behavior and elongation. The developed co-polymerized film was found to have excellent film forming ability and thus can have various applications in drug delivery. A model drug was loaded to the co-polymerized film having desired properties and the dissolution experiments were carried out to obtain the drug release profile. The films were characterized using Differential Scanning Calorimetry (DSC), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) to identify the structural and morphological properties. The process and formulation parameters were optimized for the co-polymerized film. The results showed the potential of the developed films for applications in topical, buccal and oral controlled drug release.

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## Removal of heavy metal ions with the use of chelating copolymers obtained by graft copolymerization of vinyl acetate-ethyl acrylate comonomers onto guar gum using ascorbic acid-potassium persulphate redox pair as initiator

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Water is the most essential commodity for our civilization to flourish. Availability of safe drinking water is the most important prerequisite for a sound public health system. The contamination of water by heavy metal, originating either from natural soil sources or from anthropogenic source is a matter of utmost concern to the public health. Remediation of contaminated water is of highest priority since billions of people all over the world use it for drinking purpose. Adsorption represents an efficient, economic and convenient method, which can separate low amounts of substances from large volumes of solution. To develop low cost and environment friendly technologies for removal of metal ions from water systems, a new sorbent material based on guar gum (GG) was prepared by the graft copolymerization of binary monomer mixture of vinyl acetate (VAC) and ethyl acrylate (EA) using potassium persulphate (KPS) and ascorbic acid (AA) as radical initiator. The concentrations of (AA), (KPS), (VAC+EA) and grafting temperature were varied to optimize the binary grafting. The addition of EA as a comonomer has shown a significant increase in graft copolymerization of VAC onto the guar gum. The optimal G% sample (75%) has been extensively characterized using FTIR, TGA, and SEM. The copolymer sample having maximum G% (75%) was evaluated for the removal of mercury and uptake parameters such as affinity of metal ions, sorbent dose, initial Hg (II) concentration, temperature and agitation time were investigated. Kinetic modeling has been studied and the Langmuir and Freundlich adsorption models were applied to explain the isotherms and isotherm constants. Thus, an adsorbent with good metal-chelating properties is obtained for the removal of Hg (II) from synthetic aqueous solutions.

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## Effect of incorporating cellulose nanofiber on biodegradation of poly(vinyl alcohol) nanocomposite in a controlled composting environment

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The aim was to study the effect of incorporating cellulose nanofiber on biodegradation of poly(vinyl alcohol) nanocomposite in a controlled composting environment. The nanocomposite was prepared by freeze-drying and the effect of (5, 10, 20 and 30%) CNF loading on biodegradation properties nanocomposite in controlled composting was characterized. Biodegradation tests were carried out using the standard ASTM D6340-98 which specifies a method for determining the carbon dioxide evolution. The results indicated that the biodegradation of PVA was increased with the introduction of CNF into a polymer matrix. With the addition of 5, 10, 20 and 30% of cellulose nanofiber, rate of biodegradation of nanocomposite increased. Furthermore, loss mass measurements showed that the presence of CNF led to an increase of biodegradability of PVA-based materials. With the addition of 5, 10, 20 and 30% of cellulose nanofiber respectively, increase in the amount of loss mass of the nanocomposite was observed with 4.78, 5.23 and 6.72%.

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