BIOMEDICAL APPLICATIONS OF SOY ISOLATE AND SERICIN-BASED THREE-COMPONENT FILM MATERIALS: THEIR EFFECTIVENESS IN EMULSIFICATION AND SKIN REGENERATION

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Abstract: This article provides an in-depth review of the biomedical applications of three-component film materials based on soy protein isolate (SPI) and silk sericin (SS), specifically analyzing their effectiveness in emulsification processes (stabilization of water and oil phases) and skin regeneration (fibroblast proliferation, collagen synthesis, and epithelialization). It examines in detail the synergistic properties of natural polymers, including the amphipathic nature, essential amino acids, and bioadhesiveness of SPI, the antioxidant, anti-inflammatory, and hydrophilic properties of SS, and the role of third components (e.g., carboxymethylcellulose - CMC, polyvinyl alcohol - PVA, bacterial cellulose - BC) in optimizing mechanical strength and biodegradation. The synthesis methods (solution casting, solvent casting, electrospinning), properties (mechanical strength, water absorption, thermal stability) and advantages in biomedical applications of the materials, including controlled drug release, accelerated wound healing and stability in emulsion formulations, are discussed. Based on in vitro (proliferation and migration experiments in L929 and NIH-3T3 cells) and in vivo (full-thickness wounds in rat models) studies, these films are confirmed to be highly effective in diabetic wounds, burns and other complex conditions by inhibiting inflammation, stimulating angiogenesis and reducing scar formation. The environmental friendliness of the materials (obtained from natural sources, non-toxicity, low allergic reactions) and their advantages over synthetic analogues are also emphasized. The article provides suggestions for future nanotechnological integrations (nanofibrillar structures, microspheres), clinical trials, and cosmetic-pharmaceutical applications (anti-aging agents, pigmentation control), which will contribute to opening new directions in biomedical engineering. Overall, the research demonstrates the potential for providing environmentally and economically sustainable medical solutions through the development of natural biomaterials.

Keywords: soybean isolate, sericin, three-component film, emulsification, skin regeneration, biomaterials, biodegradation, synergistic effect, nanotechnology, wound healing, SPI, SS, CMC, PVA, BC, antioxidant properties, anti-inflammatory, hydrophilic nature, electrospinning, solvent casting, mechanical strength, water absorption capacity, thermal stability, in vitro experiments, in vivo models, diabetic wounds, burn treatment, anti-cancer effect, anti-tyrosinase activity, bioadhesiveness, environmental friendliness, clinical applications, tissue engineering, hydrogel films, nanofibrillar structures, microspheres, anti-diabetic potential, cell migration, ROS inhibition, TNF-α reduction.

Anotatsiya: Ushbu maqola soya izolyati (soy protein isolate, SPI) va seritsin (silk sericin, SS) asosidagi uch komponentli plyonka materiallarining biomedikal qo'llanilishini chuqur o'rganadi, xususan emulsifikatsiya jarayonlarida (suv va yog' fazalarini barqarorlashtirishda) va teri regeneratsiyasidagi (fibroblast proliferatsiyasi, kollagen sintezi va epitelizatsiya) samaradorligini tahlil qiladi. Tabiiy polimerlarning sinergik xususiyatlarini, shu jumladan SPI ning amfipatik tabiati, essensial aminokislotalari va bioadhezivligini, SS ning antioksidant, anti-yallig'lanish va gidrofil xususiyatlarini, hamda uchinchi komponentlar (masalan, karboksimetiltsellyuloza - CMC, polivinil spirti - PVA, bakterial tsellyuloza - BC) ning mexanik mustahkamlik va biodegradatsiyani optimallashtirishdagi rolini batafsil ko'rib chiqadi. Materiallarning sintezi usullari (eritma quyish, solvent casting, elektrospinning), xususiyatlari (mexanik kuch, suv singdirish qobiliyati, termal barqarorlik) va biomedikal qo'llanilishidagi afzalliklari, shu jumladan dori moddalarini nazoratlangan chiqarish, jarohatni davolashni tezlashtirish va emulsiya formulatsiyalarida barqarorlikni ta'minlash haqida muhokama yuritiladi. In vitro (L929 va NIH-3T3 hujayralarida proliferatsiya va migratsiya tajribalari) va in vivo (kalamush modellarda to'liq qatlamli jarohatlar) tadqiqotlar asosida, ushbu plyonkalar yallig'lanishni inhibe qilish, angiogenezni rag'batlantirish va chandiq hosil bo'lishini kamaytirish orqali diabetli jarohatlar, kuyishlar va boshqa murakkab holatlarda yuqori samaraga ega ekanligi tasdiqlanadi. Shuningdek, materiallarning ekologik qulayligi (tabiiy manbalardan olish, toksik bo'lmaganlik, kam allergik reaktsiyalar) va sintetik analoglarga nisbatan ustunliklari ta'kidlanadi. Maqola kelajakdagi nanotexnologik integratsiyalar (nanofibrillar tuzilishlar, mikrosharlar), klinik tajribalar va kosmetik-farmatsevtik qo'llanishlar (anti-aging vositalar, pigmentatsiyani nazorat qilish) haqida takliflar beradi, bu biomedikal muhandislikda yangi yo'nalishlarni ochishga hissa qo'shadi. Umuman, tadqiqot tabiiy biomateriallarning rivojlanishi orqali ekologik va iqtisodiy jihatdan barqaror tibbiy yechimlarni ta'minlash imkoniyatlarini ko'rsatadi.

Kalit so'zlar: soya izolyati, seritsin, uch komponentli plyonka, emulsifikatsiya, teri regeneratsiyasi, biomateriallar, bioyemirilish, sinergik effekt, nanotexnologiya, jarohatni davolash, SPI, SS, CMC, PVA, BC, antioksidant xususiyatlar, anti-yallig'lanish, gidrofil tabiati, elektrospinning, solvent casting, mexanik mustahkamlik, suv singdirish qobiliyati, termal barqarorlik, in vitro tajribalar, in vivo modellar, diabetli jarohatlar, kuyish davolash, anti-kanser ta'sir, anti-tyrozinaz faollik, bioadhezivlik, ekologik qulaylik, klinik qo'llanishlar, to'qima muhandisligi, hydrogel plyonkalar, nanofibrillar tuzilishlar, mikrosharlar, anti-diabetik potentsial, hujayra migratsiyasi, ROS inhibe qilish, TNF-α kamaytirish.

Аннотация: В данной статье представлен углубленный обзор биомедицинского применения трёхкомпонентных плёночных материалов на основе изолята соевого белка (ИСБ) и серицина шёлка (СС), в частности, анализируется их эффективность в процессах эмульгирования (стабилизация водной и масляной фаз) и регенерации кожи (пролиферация фибробластов, синтез коллагена и эпителизация). Подробно рассматриваются синергетические свойства природных полимеров, включая амфипатическую природу, незаменимые аминокислоты и биоадгезивность ИСБ, антиоксидантные, противовоспалительные и гидрофильные свойства СС, а также роль третьих компонентов (например, карбоксиметилцеллюлозы (КМЦ), поливинилового спирта (ПВС), бактериальной целлюлозы (БЦ) в оптимизации механической прочности и биодеградации. Обсуждаются методы синтеза (литьё из раствора, литьё из

растворителя, электропрядение), свойства (механическая прочность, водопоглощение, термостабильность) и преимущества в биомедицинском применении этих материалов, включая контролируемое высвобождение лекарственных средств, ускоренное заживление ран и стабильность в эмульсионных составах. На основании исследований in vitro (эксперименты по пролиферации и миграции на клетках L929 и NIH-3T3) и in vivo (раны на всю толщину на моделях крыс) подтверждена высокая эффективность этих пленок при диабетических ранах, ожогах и других сложных состояниях, поскольку они подавляют воспаление, стимулируют ангиогенез и уменьшают образование рубцов. Также подчеркивается экологичность материалов (получение из природных источников, нетоксичность, низкая аллергическая реакция) и их преимущества перед синтетическими аналогами. В статье представлены предложения по будущей интеграции нанотехнологий (нанофибриллярные структуры, микросферы), клиническим испытаниям и применению в косметике и фармацевтике (омолаживающие средства, контроль пигментации), что будет способствовать открытию новых направлений в биомедицинской инженерии. В целом, исследование демонстрирует потенциал для разработки экологически и экономически устойчивых медицинских решений на основе разработки природных биоматериалов.

Ключевые слова: соевый изолят, серицин, трехкомпонентная пленка, эмульгирование, регенерация кожи, биоматериалы, биодеградация, синергетический эффект, нанотехнологии, заживление ран, SPI, SS, CMC, PVA, BC, антиоксидантные свойства, противовоспалительные, гидрофильные свойства, электропрядение, литье в растворитель, механическая прочность, водопоглощающая способность, термостабильность, эксперименты in vitro, модели in vivo, диабетические раны, лечение ожогов, противораковый эффект, антитирозиназная активность, биоадгезивность, экологичность, клиническое применение, тканевая инженерия, гидрогелевые пленки, нанофибриллярные структуры, микросферы, антидиабетический потенциал, миграция клеток, ингибирование ROS, снижение TNF-α.

Biomedical engineering in the field natural to polymers based of materials development modern medicine main from directions one are, they are synthetic to analogs relatively high biological compatibility, ecological convenience and economy efficiency Soybean isolate (SPI) plant protein from a source is, its in the composition essential amino acids existence because of cell proliferation and tissue in recovery active role plays. Seritsin (SS) silk worm natural glycoprotein polymer as antioxidant, anti- inflammatory and hydrophilic to the features yes, this and the injury treatment and medicine transportation in systems application These two to the component a third element, e.g. carboxymethylcellulose (CMC), polyvinyl alcohol (PVA) or bacterial produced by adding cellulose (BC) was three component film materials mechanic strength, water storage ability and bioactivity optimizes. This the article is about these materials emulsification (water-oil phases) stabilization) and skin regeneration (fibroblast migration, collagen synthesis and epithelialization) processes efficiency scientific literature and experimental data -driven analysis does. Research purpose - natural to polymers based biomaterials clinical potential assessment and future development directions The definition of these materials synthesis, properties and applications in detail seeing is also issued, comparative table and synergistic effects in examples is described.

Soybean extract and sericin based on three component film materials biomedical in the field, in particular emulsification and skin regeneration in the processes important role plays because this materials natural polymers biological compatibility, bioactivity and mechanical features synergistic in a way combine, new biomaterials create opportunity Soy protein isolate (SPI), a plant- based globular protein derived from is, its contains 18 amino acids there is is, of these essential high in amino acids (e.g., arginine, valine, leucine) in quantity it will be, this and cell proliferation and collagen synthesis in encouragement important ; and sericin (silk sericin, SS) is Bombyx mori silk worm by is a naturally occurring glycoprotein produced by molecular weight 20-400 kDa between is serine (30-40%), aspartic acid and glycine such as amino acids with enriched, this antioxidant, anti- inflammatory and hydrophilic features provides. These two to the component third component, e.g. carboxymethylcellulose (CMC), polyvinyl alcohol (PVA) or bacterial by adding cellulose (BC) component film materials harvest is done, this films mechanic strength increase (e.g., stretch) strength up to 15-25 MPa), water storage ability improvement (up to 26 g/g water absorption) and emulsification in the processes stability provide opportunity also provides biodegradation speed control by doing ecological in terms of comfortable biomaterials Research this shows that SPI and SS based films skin of fibroblast cells in regeneration migration and collagen type I synthesis encouraging, injury on the surface faster epithelialization process provides, for example, with SPI enriched sericin in nanofibrils skin external layer recovery is 20-30% faster happened This is the case in in vivo models (rats). complete layered injuries) 14 days inside complete healing to give Emulsification point of view from the point of view of these materials water and oil phases in stabilization natural emulsifier as works because soy isolate amphipathic properties (hydrophilic and hydrophobic) of groups presence of) and sericin hydrophilic nature (serine and threonine such as hydroxyl through groups) emulsion structure save to stay help gives, this and biomedical in the manuals medicine substances delivery to give systems, for example, diabetics in injuries quercetin such as active substances stabilization in doing important ; for example, sericin stabilization made emulgel in formulations emulsion stability 48-72 hours above 95% throughout is, this traditional synthetic emulsifiers relatively ecological and biological advantages also provides inflammation inhibition injury by doing treatment accelerates. In skin regeneration efficacy in in vitro and in vivo experiments approved for example, bacterial Cellulose /SPI composites (BC/7S and BC/11S fractions) reduce inflammation inhibition to make angiogenesis encouragement and hair follicles regeneration injury by doing treatment accelerates, this and diabetic injuries or burns such as complicated in cases application increases, because BC/11S composites collagen deposit increase, scar harvest to be reduces the cost of these materials synthesis usually solution casting method, solvent casting or performed by electrospinning is increased, in which components ratio (for example, SPI:SS:CMC = 1:1:0.5 or SS:CMC:PVA = 45:25:30) of the film transparency, elasticity, water to absorb capacity (up to 26.34 g/g) and bioactivity optimizes ; for example, in electrospinning, a SPI/SF mixture (50/50 ratio) is used formic acid in solution nanofibrils harvest It has a diameter of 71-160 nm, which and ethanol steam with processing beta-list structure by giving increasing, thermal stability improves. From except for sericin antioxidant effect (DPPH radicals) by binding) cell stress reduce, regenerate in the process cell reduce mortality by 40-50% it is possible, this and SPI 's nutritional support (essential) through amino acids) with together synergistic effect creates, for example, fibroblast proliferation in sericin /gelatin composites increases and collagen synthesis is encouraged.

These materials biodegradability and toxicity absence them ecological in terms of comfortable does, because soy and sericin natural from sources obtained and synthetic to polymers relatively less allergic reactions calls, for example, SPI- based films antibiotics (e.g. ciprofloxacin) stable bacterial inhibition to do In the future, these three component films nanotechnologies with by combining, for example, nanofibrillar structures creation, emulsification and regeneration efficiency further increase it is possible, this biomedical in engineering new directions opens, in particular, medicine delivery to give systems and tissues in engineering. Soy isolate and sericin biological features in detail when studied, sericin hydrophilic nature (serine and threonine hydroxyl through groups) water tie ability increases, this on film humidity to save providing, injury the environment in an optimal state hold stands for ; SPI is a substance that mimics the ECM (extracellular matrix) cell via peptides adhesion and migration stimulates, for example, in in vitro experiments in L929 fibroblast cells proliferation 24 hours reaches 89 % in three component systems, for example, SS/CMC/PVA hydrogel films, components through synergy structure (average bribe size 8 μm) yield it will be, this oxygen and water steam conductivity exaggerate the injury from infection protection and regeneration accelerates ; thermogravimetric analysis (TGA), this films up to 301°C thermal to stability has. From this except SPI/SS composites medicine loading of substances (e.g. 5-fluorouracil or metformin) by sorption opportunity gives, this and controlled to release providing, injury treatment efficiency increases, because SPI 's to hydrolysis durability and SS antioxidant effect (ROS) (by reducing) synergistic In vivo models, such as rats, complete layered BC/SPI composites in wounds collagen deposit increasing angiogenesis stimulates and scar harvest to be reduces, this and diabetic in patients application potential increases. Sericin's anti- inflammatory properties properties (TNF-α and IL-1β) by reducing) and SPI bioadhesiveness together when working, films injury on the surface wet environment creating and epithelializing accelerates, for example, fibroblast migration in sericin /PVA gel formulations by 24 hours reaches 89% in.These materials mechanic features for optimization, e.g. electrospinning control parameters (volts, distance, concentration) by making nanofibrils diameter range 30-360 nm delivered, this and porosity increasing, cell infiltration improves. The following in the table various of formulations main properties and biomedical efficiency is compared, this information compiled based on research :

Formulation	**Mechanical strength (MPa)**	**Emulsion stability (%)**	**Water to absorb capacity (g/g)**	**Skin regeneration speed (day)**	**Inflammation inhibition (%)**
SPI/SS/PVA	15-20	90-95	20-25	7-10	40-50
SPI/SS/CMC	12-18	92-97	26-30	5-8	50-60
SPI/SS/BC	18-25	85-90	22-28	6-9	55-65
SPI/SF/SS	14-22	88-94	24-29	8-12	45-55
SS/ Gelatin /PVA	10-15	90-96	25-32	7-11	50-70

this table visible as it stands, CMC is added formulations in emulsification high sustainability and water to absorb shows, and PVA mechanic features improves, while BC inflammation inhibition in doing to advantage yes, this materials injury films, medicine delivery to give systems and tissues on scaffolds adaptation for application opportunity gives. From this In addition, sericin has anti- cancer properties effect (caspase-3) (via activation) and the anti-diabetic properties of SPI potential together When working, these materials complicated in diseases, for example, diabetes in injuries, application possible, because they collagen deposit increasing angiogenesis Stimulates. In vitro cytotoxicity analyses this shows that this films on L929 and NIH-3T3 fibroblast cells toxic impact does not show, on the contrary, proliferation increases, for example, the proliferation of B16F10 melanocytes in SPI/SF nanofibrils proliferation reduced pigmentation control to do opportunity These materials biodegradation lysozyme 20 days in solution during happened is the SPI/SF ratio increasingly degraded speed decreases, this and far term Suitable for use. Sericin has anti- tyrosinase activity activity (polyphenol oxidase inhibition by doing) and SPI 's hydrolysis endurance together films cosmetic and pharmaceutical effective in applications, such as anti -aging products does, because they collagen synthesis stimulating, skin hydration increases. From this except SS/alginate or SS/chitosan composites microspheres in the form of medicine to release providing, injury in treatment stability increases, for example, in sericin /insulin bioconjugates insulin half decomposition time Based on these studies, soy isolate and sericin based on three component films biomedical in engineering new opportunities opens, in particular, ecological in terms of comfortable and high effective materials in creating, but in the future clinical through their experiences safety and effectiveness further confirmation necessary.

Conclusion as when we say soy isolate and sericin based on three component film materials biomedical in the field big to potential has mold, emulsification and skin in regeneration efficiency natural polymers synergistic confirmed by the properties of. Experimental information this shows that these materials mechanic strength, biodegradability and bioactivity in terms of synthetic to analogs relatively to advantage has, in particular, the injury treatment increase speed by 20-50% possible. However, the components ratio and synthesis methods optimization, as well as nanotechnology efficiency through integrations further improve necessary. Future research clinical to the tests attention focus it is necessary, this and these materials are used in real medicine to apply provides. In general naturally biomaterials development ecological and economic in terms of stable biomedical solutions to create contribution Addictive.

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