**TERMIZ DAVLAT UNIVERSITETI
HUZURIDAGI ILMIY DARAJALAR BERUVCHI
DSc.03/2025.27.12.K/T.12.05 RAQAMLI ILMIY KENGASH**

SHAROF RASHIDOV NOMIDAGI SAMARQAND DAVLAT UNIVERSITETI

XUDAYNAZAROV JAHONGIR ORTIQ O‘G‘LI

POLILAKTID ASOSIDA BIOPARCHALANUVCHAN MATERIALLAR: OLINISHI, XOSSALARI VA TEXNOLOGIYASI

02.00.14 – Organik moddalar va ular asosidagi materiallar texnologiyasi

KIMYO FANLARI BO‘YICHA FALSAFA DOKTORI (PhD) DISSERTASIYASI AVTOREFERATI

Termiz – 2026

UO‘K: 547.472.3; 661.746.24

Kimyo fanlari bo‘yicha falsafa doktori (PhD) dissertatsiyasi avtoreferati mundarijasi

Contents of dissertation abstract of doctor of philosophy (PhD) on chemical sciences

Оглавление автореферата диссертации доктора философии (PhD) по химическим наукам

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Kimyo fanlari bo'yicha falsafa doktori (PhD) dissertatsiyasi mavzusi O'zbekiston Respublikasi Oliy ta'lim, fan va innovatsiyalar vazirligi huzuridagi Oliy attestatsiya komissiyasida B2025.2.PhD/K1017 raqam bilan ro'yxatga olingan.

Dissertatsiya Sharof Rashidov nomididagi Samarqand davlat universitetida bajarilgan.

Dissertatsiya avtoreferati uch tilda (o'zbek, rus, ingliz (rezyume)) ilmiy kengash veb-sahifasida (www.tersu.uz) va «ZiyoNet» axborot ta'lim portalida (www.ziyonet.uz) joylashtirilgan.

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KIRISH (falsafa doktori (PhD) dissertatsiyasi annotatsiyasi)

Dissertatsiya mavzusining dolzarbligi va zarurati. Hozirgi kunda dunyoda har yili daryolar orqali okeanga kelib qo‘shiladigan mikroplastik zarrachalarning umumiy miqdori 1,5 mln tonnagacha yetishi aniqlangan bo‘lib, suvda yashovchi tirik organizmlarda o‘tkazilgan tadqiqotlar natijasida, ushbu mikroplastik zarrachalarning to‘planishidan biokimyoviy jarayonlarning buzilishiga sababchi bo‘lishi, ko‘pchilik hollarda yallig‘lanish reaksiyalari, neyrotoksiklik, reproduktiv faoliyatning buzilishi va hatto genotoksiklik bilan kechishi aniqlangan. Bunday halokatli oqibatlarga sabab bo‘luvchi mikroplastik zarrachalarning asosiy qismi polietilen, polipropilen, polistirollarga to‘g‘ri keladi. Polilaktid asosida arzon, yaxshilangan fizik-kimyoviy xossalarga ega bioparchalanish xususiyatli plastik materiallar olish dolzarb vazifalardan biri bo‘lib qolmoqda.

Bugungi kunda jahonda moddalarni maqsadli sintez qilish va ular asosida ekologik va ijtimoiy muammolarini hal etishda istiqbolli xomashyo bazasi, arzon texnologiyalarni qo‘llash asosida bioparchalanuvchan materiallar sinteziga yo‘naltirilgan ilmiy-tadqiqot ishlari olib borilmoqda. Bu borada, organik kimyo sohasida zamonaviy usullardan foydalangan holda yangi yuqori molekulyar birikmalarning fizik-kimyoviy va mexanik xossalarini tadqiq qilish, ularni oziq-ovqat sanoatida qadoqlash mahsulotlarida qo‘llash, olingan moddalar orasida biologik parchalanuvchan turli tabiiy birikmalar asosida ekologik toza bioparchalanuvchan materiallar yaratish muhim ahamiyatga ega.

Respublikamizda mahalliy xomashyolar va ikkilamchi birikmalar asosida oziq-ovqat sanoati va qishloq xo‘jalligi uchun qo‘llaniladigan muhim kimyoviy materiallarni, jumladan bioparchalanuvhan materiallar olish borasida ilmiy va amaliy natijalarga erishilmoqda. Respublikamizda innovatsion texnologiyalarni tatbiq etish orqali sanoat obyektlarini yuritishning ilmiy asoslangan tizimi va atrof-muhitni muhofaza qilishning chora-tadbirlarini amalga oshirishga katta e’tibor qaratilmoqda. “Yangi O‘zbekistonning 2022–2026-yillardagi taraqqiyot strategiyasi”da[1] iqtisodiyotni rivojlantirish ustuvor yo‘nalishlari belgilangan hamda mahalliy xomashyo resurslarini chuqur qayta ishlash asosida, yuqori qo‘shimcha qiymatli tayyor mahsulot ishlab chiqarishni yanada jadallashtirish, sifat jihatdan yangi mahsulot va texnologiya turlarini o‘zgartirish masalalari alohida belgilab qo‘yilgan. Bu borada, biologik parchalanuvchan materiallar olishda turli polimerlar asosida iqtisodiy samarali va ekologik xavfsiz yangi bioparchalanuvchan materiallar olish hamda mavjud texnologiyalarni doimiy ravishda takomillashtirish muhim ahamiyat kasb etadi.

O‘zbekiston Respublikasi Prezidentining 2022-yil 28-yanvardagi PF-60-sonli 2022-2026-yillarga mo‘ljallangan “Yangi O‘zbekistonning taraqqiyot strategiyasi to‘g‘risida”gi, 2020-yil 2-martdagi PF-5953 sonli “Ilm, ma’rifat va raqamli iqtisodiyotni rivojlantirish yilida amalga oshirishga oid davlat dasturi to‘g‘risida”gi, 2018-yil 25-oktyabrdagi PQ 3983-sonli “O‘zbekiston Respublikasida kimyo sanoatini jadal rivojlantirish chora-tadbirlari to‘g‘risida”gi farmonlari va qarorlari hamda mazkur faoliyatga tegishli boshqa me’yoriy-huquqiy hujjatlarda belgilangan

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[1] O‘zbekiston Respublikasi Prezidentining 2022-yil 28-yanvardagi PF-60-son “2022-2026-yillarga mo‘ljallangan Yangi O‘zbekistonning taraqqiyot strategiyasi to‘g‘risida”gi Farmoni

vazifalarni amalga oshirishda ushbu ilmiy tadqiqot natijalari muayyan darajada xizmat qiladi.

Tadqiqotning respublika fan va texnologiyalari rivojlanishining ustuvor yo‘nalishlariga mosligi. Mazkur dissertatsiya ishi tadqiqotlari Republika fan va texnologiyalar rivojlanishining VII. “Kimyo, kimyoviy texnologiyalar va nanotexnologiyalar” ustuvor yo‘nalishiga muvofiq bajarilgan.

Muammoning o‘rganilganlik darajasi. Adabiyotlarda bioparchalanish xususiyatiga ega plastik materiallar sintez qilish va ularning ishlab chiqarish texnologiyalari borasida dunyoning yetakchi ilmiy markazlarida jadal tadqiqotlar olib borilmoqda. Xususan, polilaktidga turli noorganik va organik tabiatli to‘ldiruvchilar qo‘shish orqali, atrof-muhitga zararsiz bo‘lgan, bioparchalanuvchan plastik materiallarni tadqiq etish borasidagi tadqiqotlar dunyoning shu sohadagi yetakchi olimlari: Alethia Vazquez, Tomasz M. Majka, Marcelo A G Bardi, Daniel López, A. N. Zelenetskii, Marco Frediani, Saira Nayab, Yaowalak Srisuwan, Reza Arjmandi, Robert Molloy, C.A.P. Joziasse, Eric Dargent, Steven Verstichel, Mieke Buntinx va boshqalarning tadqiqotlarida ko‘rib chiqilgan.

Polimer kompozision materiallar sintezi va tadqiqoti, shuningdek, bioparchalanuvchan plastik materiallar sohasida respublikamiz olimlaridan H.Akbarov, S.Rashidova, T.Boboyev, G‘.Muxamediyev, I.Asqarov, D.Gafurova, X.Turayev, Sh.Kasimovlar tomonidan tadqiqotlar olib borilmoqda.

Adabiyotlar ma’lumotlaridan polilaktid, modifikatsiyalangan selluloza hamda turli noorganik minerallar – bentonit, kaolin asosida bioparchalanish xususiyatiga ega materiallar olish va ularni ishlab chiqarish texnologiyasi borasidagi tadqiqotlar kam o‘rganilganligi aniqlandi. Yuqoridagilarga asosan, mahalliy xomashyolar asosida atrof-muhit uchun zarar, biologik yo‘l bilan parchalanish xususiyatiga ega plastik materiallar ishlab chiqish va ularning texnologiyasini yaratish nazariy va amaliy ahamiyatga ega.

Dissertatsiya tadqiqotining dissertatsiya bajarilgan oliy ta’lim muassasasining ilmiy-tadqiqot ishlari rejalari bilan bog‘liqligi. Dissertatsiya tadqiqoti Sharof Rashidov nomidagi Samarqand davlat universiteti ilmiy-tadqiqot ishlari rejasining ALM-202310062531 “Tabiiy va sintetik materiallarni sintez qilish, tekshirish va qayta ishlashning yangi usullari” (2023-2024-y.y.) mavzusidagi amaliy loyiha doirasida bajarilgan.

Tadqiqotning maqsadi. Polilaktid, modifikatsiyalangan selluloza hamda noorganik minerallar ishtirokida bioparchalanuvchan materiallar sintezi va xossalarini aniqlashdan iborat.

Tadqiqotning vazifalari. Mahalliy xomashyolar asosida L-sut kislota, polilaktid hamda modifikatsiyalangan selluloza olish uchun maqbul sharoitlarni aniqlash;

bioparalanuvchan materiallar sintezi uchun maqbul sharoit (komponentlar tarkibi, nisbati, katalizator, temperatura va boshqalar) tanlash;

sintez qilingan materiallarning fizik-kimyoviy hamda biologik xossalarini aniqlash;

bioparchalanuvchan materiallar olish texnologiyasi (texnologik sxema, moddiy balans) ni ishlab chiqish;

sintez qilingan bioparchalanuvchan materiallarning laboratoriya va real sharoitlarda sinovlardan o‘tkazish hamda ishlab chiqarishga tavsiya etish.

Tadqiqotning obyekti. L-sut kislota, poli-L-sut kislota, o‘simliklar qoldiqlari sellulozasi, bentonit, kaolin olingan.

Tadqiqotning predmeti. Poli-L-sut kislota, modifikatsiyalangan selluloza hamda noorganik minerallar – kaolin, bentonit asosida bioparchalanuvchan materiallar maqbul tarkibini tanlash, ularning fizik-kimyoviy xossalarini tadqiq etish hamda olish texnologiyasini ishlab chiqish hisoblanadi.

Tadqiqotning usullari. Ishda bioparchalanuvchan materiallar sintezi uchun “solvent casting method” – erituvchi muhitida quyish; “qaynoq presslash” usullari; materiallarning fizik-kimyoviy xossalarini tadqiq etish uchun IQ-spektrometriya (FTIR), energodispersion rentgenfluoressent analizi (ERF), kukun rentgen difraksiyasi (XRD), skanerlovchi elektron mikroskopiya (SEM), termik analiz (TGA, DSC), materiallarning kontakt burchaklarini optik usulda aniqlash, materiallarning mexanik xossalarini aniqlash usullari, shuningdek, dielektrik hamda sitotoksik xossalarini aniqlash usullari va vositalaridan foydalanilgan.

Tadqiqotning ilmiy yangiligi quyidagilardan iborat:

polilaktid, oligolaktid bilan modifikatsiyalangan selluloza va mineral komponentlar: bentonit, kaolin asosida PLA/OLA-g-Selluloza/Bentonit/Kaolin 80:20 + 5/5 tarkibli 9 xil bioparchalanuvchan materiallar sintez qilingan;

Lactiplatibacillus plantarum 3G bakteriyasidan foydalangan holda, mikrobiologik yo‘l bilan L-sut kislota, undan polilaktid va bioparchalanuvchan materiallar olishning maqbul sharoitlari aniqlangan;

materiallar tarkibiga 10 % gacha kaolin yoki 5 % dan kaolin/bentonit kiritilishi natijasida olingan bioparchalanuvchan materiallarning uzayishga nisbatan mustahkamligi 1,4 martaga ortganligi aniqlangan;

mahalliy xomashyolar polilaktid, oligolaktid bilan modifikatsiyalangan selluloza va mineral komponentlar asosida bioparchalanuvchan materiallar olish texnologiyasi ishlab chiqilgan.

Tadqiqotning amaliy natijalari quyidagilardan iborat:

oziq-ovqat mahsulotlari, dorivor preparatlar, qishloq xo‘jaligi hamda boshqa mahsulotlarini qadoqlash, shuningdek, bir martalik foydalaniladigan uy-ro‘zg‘or buyumlari tayyorlashda qo‘llaniladigan bioparchalanuvchan materiallar olingan;

o‘simlik chiqindilaridan olingan sellulozani sut kislota oligomeri bilan kimyoviy modifikatsiyalash komponentlar makromolekulalari orasida o‘zaro ta’sirlarni kuchaytirishi, materiallarning fizik-kimyoviy va mexanik xossalarini yaxshilashi aniqlangan;

materiallar tarkibiga qo‘shilgan kaolin mineralining miqdori ortib borishi bilan parchalanish haroratining 70-80 ºC ga, shishalanish haroratining ~25 ºC ga pasayishiga olib kelishi isbotlangan;

sintez qilingan materiallar mexanik mustahkamligi, ekologik toza, xavfsiz ekanligi, atrof-muhitga tushganda 4-6 oy ichida o‘z-o‘zicha biologik yo‘l bilan 90-96 % ga parchalanishi aniqlangan.

Tadqiqot natijalarining ishonchliligi. Tadqiqotlarda olib borilgan sezilarli hajmdagi tajriba va sanoat miqyosida o‘tkazilgan eksperementlarning natijalari qoniqarli mutanosibligi, tajribaviy natijalar asosida zamonaviy tadqiqot usullari, jumladan, IQ-spektroskopik, rentgent fluoressent, rentgen fazaviy, skanerlovchi elektron mikroskopiya, termik analiz usullari, materiallarning gidrofilligi, dielektrikligi, sitotoksikligi va mexanik xossalarini aniqlashda zamonaviy usullarning qo‘llanilishi hamda sinovdan o‘tkazilganligi va ishlab chiqarishda qo‘llanilganligi asosida olingan natijalarning mos kelishi bilan isbotlangan.

Tadqiqot natijalarining ilmiy va amaliy ahamiyati. Tadqiqot natijalarining ilmiy ahamiyati parchalanuvchan polilaktid, modifikatsiyalangan selluloza makromolekulalari tarkibiga noorganik minerallar – bentonit, kaolinning 10 % gacha miqdorda qo‘shish mumkinligi, ular orasida o‘zaro ta’sir kuchlari yuzaga kelishi orqali bioparchalanuvchan materiallarning fizik-kimyoviy va mexanik xossalarining yaxshilanishi, tannarxining arzonlashishi ilmiy asoslanganligi hamda sintez jarayoni uchun kerak bo‘lgan mahsulotlar mahalliy xom-ashyolardan foydalanganligi bilan izohlanadi;

Tadqiqot natijalarining amaliy ahamiyati mahalliy xomashyolar polilaktid, oligolaktid bilan modifikatsiyalangan selluloza va mineral komponentlar asosida olingan bioparchalanuvchan materiallar atrof-muhitga tushganda biologik yo‘l bilan 2-6 oy mobaynida to‘liq parchalanishi, parchalanish mahsulotlarining zararsiz ekanligi, polilaktidning gidrolizidan hosil bo‘lgan L-sut kislotasi mikroorganizmlar uchun ozuqa bo‘lishi sababli bunday materialarning ishlab chiqarilishi yangi tarkibli, ekologik xavfsiz bioparchalanuvchan materiallar olishga xizmat qiladi.

Tadqiqot natijalarining joriy qilinishi. Polilaktid, modifikatsiyalangan selluloza hamda noorganik minerallar ishtirokida bioparchalanuvchan materiallar sintezi va xossalarini tadqiq etish bo‘yicha olingan natijalar asosida;

olingan bioparchalanuvchan materiallarning namunalari Afyon Kocatepe universiteti (Turkiya) kimyo bo‘limida “Synthesis and characterization of new nanoparticles by green synthesis using Lycium depressum extract” ilmiy loyihasi tadqiqotlari doirasida sitotoksik, antibakterial, antifungal hamda yaralarni bitirish xususiyatlarini aniqlashda qo‘llanilgan (Afyon Kocatepe universitetining 2025-yil 17-fevraldagi ma’lumotnomasi). Natijada, polilaktid, oligolaktid bilan modifikatsiyalangan selluloza va mineral komponentlar asosida antibakterial va antifungal xususiyatlarga ega PLA/OLA-g-Sell/B10; PLA/OLA-g-Sell/K10; PLA/OLA-g-Sell/B5/K5 tarkibli bioparchalanuvchan materiallar olish imkonini bergan;

sintez qilingan materiallar O‘zbekiston-Bolgariya qo‘shma korxonasi “Integra DD” MChJ QKda “Novokain inyeksiya uchun 0,5 % eritma, 5 ml” preparatining ikkilamchi qadoqlash vositasi sifatida qo‘llanilgan (“Integra DD” MChJ QK ning 2025-yil 21-yanvardagi № 8-son ma’lumotnomasi). Natijada, “GOST EN 13432:2015” xalqaro standartlar talablariga mos keluvchi materiallar sintez qilish imkonini bergan.

Tadqiqot natijalarining aprobatsiyasi. Tadqiqotlar natijalari 10 ta: 2 ta xalqaro va 8 ta respublika miqyosida o‘tkazilgan ilmiy-amaliy anjumanlarda ma’ruza qilingan va muhokamalardan o‘tkazilgan.

Tadqiqot natijalarining e’lon qilinganligi. Dissertatsiya mavzusi bo‘yicha jami 18 ta ilmiy ishlar chop etilgan, shundan 8 ta O‘zbekiston Respublikasi Oliy Attestasiya komissiyasining falsafa doktori dissertatsiya asosiy ilmiy natijalarini chop etish tavsiya etilgan ilmiy jurnallarda, jumladan, 3 ta xorijiy jurnallarda, 5 ta respublika ilmiy jurnallarida chop etilgan.

Dissertatsiyaning tuzilishi va hajmi. Dissertatsiya tarkibiga kirish, to‘rtta bob, xulosalar, foydalanilgan adabiyotlar ro‘yxatida iborat. Dissertatsiyaning hajmi 117 bet[2].

DISSERTATSIYANING ASOSIY MAZMUNI

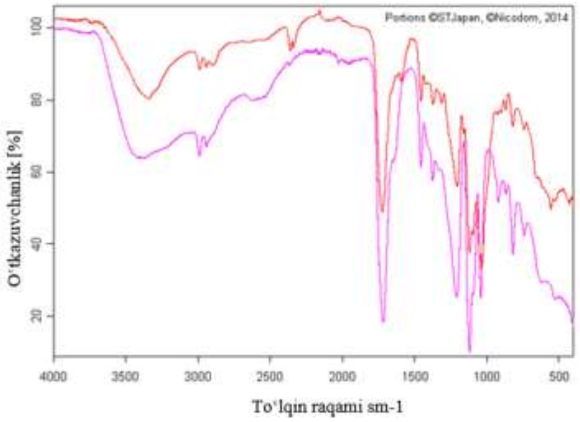
Kirish qismida dissertatsiya mavzusining dolzarbligi va muhimligi asoslab berilgan, tadqiqotning maqsad va vazifalari belgilangan, uning O‘zbekiston Respublikasida fan va texnologiyalarni rivojlantirishning ustuvor yo‘nalishlariga muvofiqligi ko‘rsatilgan, tadqiqotning ilmiy yangiligi va amaliy natijalari bayon qilingan, ularning ishonchliligi asoslangan, tadqiqot natijalarining ilmiy va amaliy ahamiyati ochib berilgan. Amaliyotga joriy qilish istiqboli borasida xulosalar chiqarilgan hamda chop ettirilgan ishlar va dissertatsiyaning tarkibi to‘g‘risida ma’lumotlar keltirilgan.

Dissertatsiyaning “**Bioparchalanuvchan materiallar ishlab chiqarishning zamonaviy holati**” deb nomlangan birinchi bobida, atrof-muhitga tushganda biologik yo‘l bilan parchalanuvchi materiallar olish, ularning fizik-kimyoviy xossalari, shuningdek, ularni ishlab chiqarish texnologiyasi ilmiy adabiyotlar asosida tahlil qilingan. Shuningdek, bioparchalanuvchan materiallarning xossalari hamda ularni qishloq xo‘jaligi, sanoat, biotibbiyot va boshqa sohalarda qo‘llash istiqbolllari ko‘rsatib berilgan.

Dissertatsiyaning **“Oksikislotalar asosida biodegradatsiyalanuvchan materiallar sintezi”** deb nomlanuvchi ikkinchi bobida mahalliy xomashyolar asosida mikrobiologik yo‘l bilan L-sut kislota sintez qilish, undan polilaktid olish hamda polilaktid asosida bioparchalanuvchan materiallar sintez qilish bo‘yicha tajribalar natijalari keltirilgan. L-sut kislotasi ishlab chiqarish uchun mikrobiologik yo‘ldan foydalanildi. L-sut kislota olishning mikrobiologik usuli o‘zining samaradorligi, qulayligi, arzon hamda olingan mahsulotning enantiomer tozalik darajasining yuqoriligi singari afzalliklari bilan ajralib turadi.

Uglevod manbasi sifatida kraxmal (kartoshka, bug‘doy, makkajo‘xori, sharbat ishlab chiqaruvchi korxonalar chiqindilari) dan foydalanildi. Kraxmal va azot manbai sifatida makkajo‘xori ekstrakti muhitida *Lactiplatibacillus plantarum 3G* bakteriyasi 3-5 sutka inkubatsiya qilish orqali L-sut kislotasi sintez qilindi. Olingan mahsulotning chinligini aniqlash uchun IQ-spektrlari olinib, baza ma’lumotlari bilan taqqoslandi va uning L-sut kislotasi ekanligi aniqlandi (1-rasm). 100 ml namunadan cho‘ktirilgan kalsiy laktatning miqdori 8,03 g bo‘lib, bu toza sut kislotaga hisoblanganda 6,63 g bo‘ldi. Sut kislotasining hosil bo‘lish unumi 100 ml ozuqa aralashmasiga nisbatan 6,63 gr ni yoki qo‘llanilgan ozuqa – kraxmalning 100 g namunasiga nisbatan 27,6 % ni tashkil etdi. Jarayon unumini oshirish uchun biotexnologik tadqiqotlarga ehtiyoj bo‘lib, tadqiqotning maqsadiga kirmaganligi sababli o‘rganilmadi.

[2]Kimyo fanlari nomzodi, dotsent S.U.Tillayevga dissertatsiya ishini bajarishda bergan ilmiy maslahatlari uchun minnatdorlik bildiraman.

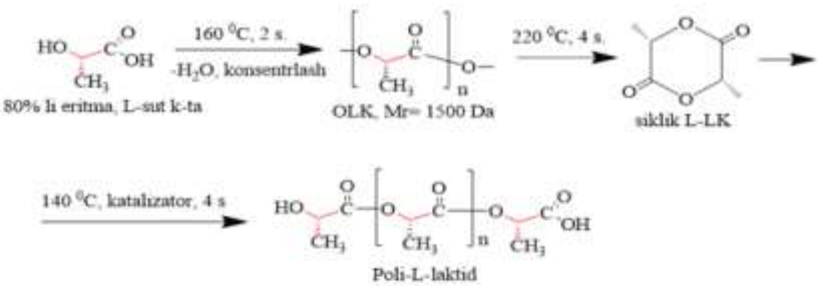


1-rasm. Mikrobiologik yo‘l bilan olingan L-sut kislotaning IQ-spektri (qizil rangda) va uning ma’lumotlar bazasi bilan taqqoslash (pushti rangda) natijasi

L-sut kislotadan polilaktid sintez qilish. Polilaktid sintez qilish uchun bir qator usullar ishlab chiqilgan. Shulardan siklik laktiddan zanjir ochilishi bilan boruvchi (ring-opening polimerization) polimerlanish reaksiyasi ancha ommalashgan usul hisoblanadi. Bunda, oxirgi – uchinchi bosqichda katalizator qo‘llaniladi.

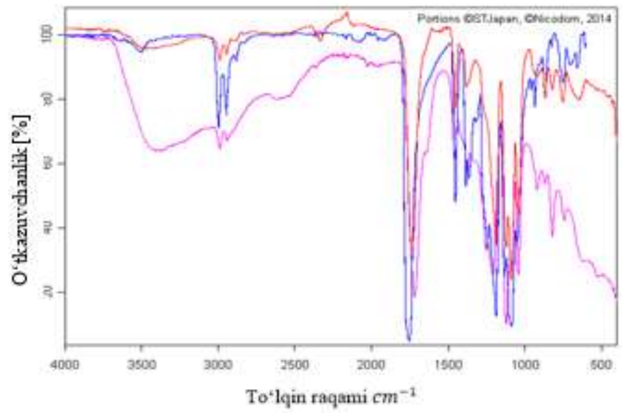
Polilaktid sintezi. Mazkur ishda polilaktid olishning zanjirning ochilishi bilan boruvchi polimerlanish (ring-opening polymerization) usulidan foydalanildi.

Polilaktid sintezi uchun mikrobiologik yo‘l bilan olingan hamda tijoriy L-sut kislotaning 80 % li eritmasi qo‘llanildi. Polilaktid sintezi uch bosqichda amalga oshirildi. ***1-bosqich:*** 2 soat davomida 160±5 °C da laktat kislota kontsentrlandi va suv yo‘qotish orqali sut kislotaning oligomeri ko‘rinishga o‘tadi. Suvni yo‘qotish



inert gaz – azot atmosferasida, normal bosimda o‘tkazildi. Har bir bosqichda olingan mahsulotlar IQ-spektroskopik usulda nazorat qilib borildi. Olingan IQ-spektrlar ATR-LIB-PHARMA-2-472-2.S01 hamda DEMILIB.S01 biblioteka bazalari ma’lumotlari bilan taqqoslanib, moddalar identifikatsiya qilindi. IQ-spektr natijalarini taqqoslab sut kislotaning dastlab oligomer laktidga, keyin siklik laktidga, undan esa polilaktidga aylanganligi to‘g‘risida xulosa qilindi. ***2-bosqich:*** bunda 220±10 °C da 0.02 MPa vakuum sharoitida oligomer mahsulot siklik laktidga aylantirildi hamda haydash yo‘li bilan kondensatsion kolbaga yig‘ildi. Olingan siklik laktid IQ-spektroskopik usulda tadqiq etildi va qayd etilgan spektrlar ma’lumotlar bazasi bilan qiyosiy o‘rganilganda uning haqiqatan ham siklik laktidga tegishli ekanligi aniqlandi. ***3-bosqich***: oxirgi bosqichda olingan siklik laktid katalizator: ZnO/seolit (50:50) bilan aralashtirilib, (massa jihatdan 0,05-0,1 %) 140±10 °C da 4 soat davomida polilaktidga aylantirildi. Sintez qilingan polilaktid IQ-spektroskopik usulda tadqiq etilib, ma’lumotlar bazasi natijalari bilan taqqoslanganda haqiqatan ham polilaktid olinganligi qayd etildi (2-rasm). Polilaktidning hosil bo‘lish unumi bir qancha omillarga, xususan qo‘llanilgan katalizatorning turiga, jarayonning davomiyligiga va boshqa omillarga bog‘liq bo‘lib, mazkur ishda katalizator turiga bog‘liq ravishda maksimum 80-83 % unum bilan borganligi aniqlandi. Qolgan 17-20 % mahsulot sut kislotaning oligomeri ko‘rinishida bo‘lib, agregat holati yopishqoq quyuq massa (suyuqroq konsistensiyaga ega) holatda bo‘ldi. Oligomerning molekulyar massasi viskozimetrik usulda aniqlanganda 450-750 orasida ekanligi, bu esa n ning qiymati o‘rtacha 8-10 ekanligini ko‘rsatdi.

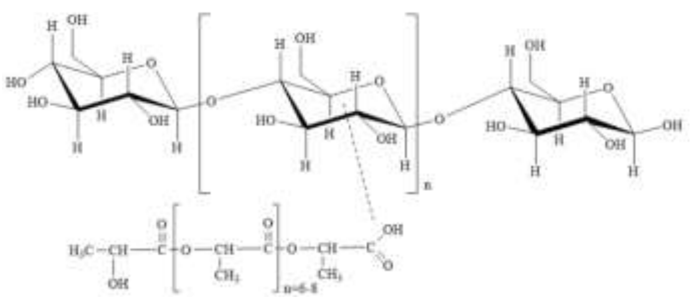
Polilaktid sintezi uchun katalizator tanlash. Sanoat miqyosida polilaktd sintez qilish uchun eng samarali katalizator – qalay oktanoati keng qo‘llaniladi.



2-rasm. Polilaktidning IQ-spektri (qizil rang) (ko‘k rangli polosa ma’lumotlar bazasi asosida Poly(lactide)ga tegishli ekanligi aniqlandi)

Oxirgi yillarda qalay birikmalarining zaharli ekanligidan, atrof-muhitga hamda ishlab chiqarilayotgan mahsulotning sifatiga salbiy ko‘rsatmaydigan, zaharligi kam katalizatorlar ishlab chiqish borasida tadqiqotlar olib borilmoqda. Nisbatan kam o‘rganilgan katalitik tizimlar – seolitlar bo‘lib, so‘nggi yillarda kam sonli tadqiqotlar e’lon qilindi. Ishda katalizator sifatida polilaktid sintez qilishda katalizatorlar – Lyuis kislotalari (Al, Sn, Sb va boshqalar birikmalari), Zn va uning birikmalarining sintetik seolitlar bilan aralashmalaridan foydalanish imkoniyatlari o‘rganildi. Sintetik seolitlar mahalliy dala shpati asosida gidrotermal usulda sintez qilindi. Katalizator sifatida ZnO va uning seolit bilan 1:1 aralashmasidan foydalanilganda 120-140 °C 4-6 soat mobaynida 74-87 % unim bilan mahsulot olinib, uning o‘rtacha molekular massasi 57-74 kDa diapazonda ekanligi aniqlandi. Katalizator sifatida $AlCl_3$, $ZnCl_2$, $FeCl_3$ va ularning seolitlar bilan aralashmasidan foydalanilganda reaksiya unumining 34-85 % orasidan ekanligi, mahsulotning o‘rtacha molekular massasi esa 12-65 kDa ekanligi aniqlandi. Shu sababli keyingi tajribalarda ZnO/seolit 1:1 aralashmadan foydalanildi. Bunda, qalay oktanoat asosida olingan mahsulotning molekular massasi (≈200 – 300 kDa) ga qaraganda nisbatan past molekular massali polilaktid olingan bo‘lsa ham, keyingi tadqiqotlar uchun yaroqli bo‘lganligi sababli, tadqiqotlar shu tipdagi mahsulot asosida davom ettirildi.

O‘simlik chiqindilaridan selluloza olish va kimyoviy modifikatsiyalash. Keyingi tajribalarda ba’zi o‘simliklar chiqindilari (bug‘doy, javdar, sholi, qamish, g‘o‘zapoyasi va boshqalar) poyasidan selluloza ajratib olindi. Ma’lumki, polilaktid makromolekulalarining qutbliligi kam. Chunki, uning yon zanjirida faqat erkin metil ($-CH_3$) guruhlarigina bo‘lib, karboksil va gidroksil guruhlari makromolekula hosil qilishda ishtirok etganligidan, umumiy holda makromolekula qutbsizga yaqin bo‘ladi. Selluloza makromolekulalari esa aksincha, ko‘p miqdorda gidroksil (-OH) guruhlari saqlaganligi uchun kuchli qutbli tabiatga ega.

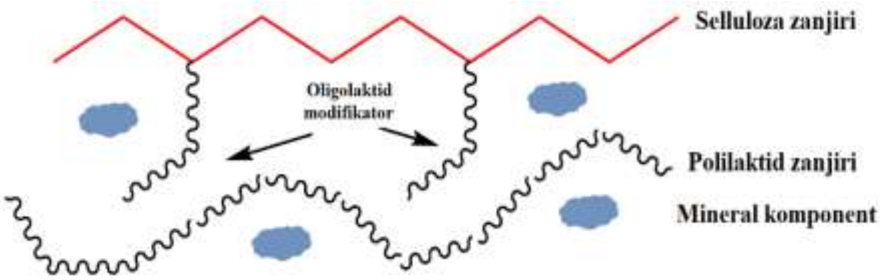


Polilaktid / selluloza asosida materiallar olish uchun ularni o‘zaro tabiatini yaqinlashtirishning yo‘llaridan biri – selluloza makromolekulalarini *modifikatsiyalashdir*. Shu sababli, mazkur ishda sellulozani kimyoviy modifikatsiyalash borasida tadqiqotlar olib borildi. Sellulozani kimyoviy modifikatsiyalash ikki modda ishtirokida: L-sut kislotasi hamda uning oligomeri bilan amalga oshirildi.

Noorganik minerallar (bentonit, kaolin va boshqalar) asosida biodegradatsiyalanuvchan materiallar olish. Noorganik minerallar (bentonit, kaolinit, kaolin, seolitlar va boshqalar) asosida biodergadasiyalanuvchan kompozit materiallar olish borasidagi tadqiqotlar oxirgi yillarda olimlarning diqqat-e’tiborini tortmoqda. Bentonit, kaolin, seolitlar singari tabiiy noorganik minerallarning afzallik tomonlaridan biri shuki, bu moddalar zaharli emas, tirik hujayralar bilan biologik muvofiqligi yuqori bo‘lib, biotibbiy mahsulotlar olishda keng qo‘llaniladi. Shu bilan birga bu moddalar qo‘shilgan degradatsiyalanuvchan materiallar parchalanishidan atrof-muhitga zararsiz bo‘lgan komponentlar ajralishi ularning qo‘llash sohalarini yanada kengaytirmoqda.

Mazkur ishda qo‘llanilgan bentonit minerali “PPD” markali bo‘lib, “Bentonite” MCHJ (O‘zbekiston) dan, kaolin mineralining “AKT-35” markali namunalari “ANGREN KAOLIN” MCHJ (O‘zbekiston) olingan. Ushbu minerallarning kimyoviy element tarkibi rentgenfluoressent analizi usulida tahlil qilindi. Analiz natijalaridan, bentonit hamda kaolin minerali asosan alyumosilikatlardan tashkil topgan bo‘lib, tarkibida nisbatan ko‘proq miqdarda Fe, Mg, K, S; kamroq miqdorda esa P, Cr, Ni, Cu, Zn uchraydi. Og‘ir va zaharli metallar uchramaydi. Kaolinning ushbu ishda foydalanilgan markasida alyuminiy oksidining ulushi 35% dan kam emas. Bentonitning tarkibida asosan montmorillonit saqlagan kulrang gillaridan foydalanildi.

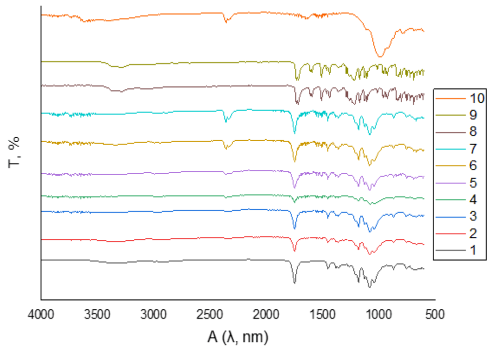
Noorganik minerallar (bentonit, kaolin va boshqalar) ni kimyoviy modifikatsiyalash. Bentonit, kaolin singari minerallarni qo‘llanishidan oldin bir necha bosqichli tozalash-ishlov berish yo‘llari bilan qayta ishlandi. Shundan so‘ng organik modifikatsiyalash uchun, olingan bentonit (kaolin) ning L-sut kislotasi bilan kimyoviy modifikatsiyalandi. Modifikatsiyalash minerallarning yuzasida sodir bo‘lganligi IQ-spektroskopik usulda nazorat qilindi. Minerallarning yuza qismidagi Al-O-Al bog‘lari ishqor ta’sirida uzilib, L-sut kislotasi bilan qizdirilganda, mineral komponentlar L-sut kislota qoldig‘i bilan kimyoviy bog‘lanadi.



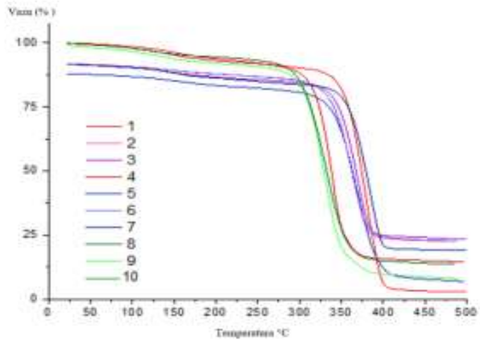
Hosil bo‘lgan mahsulotlar polimer matritsaga yaxshi adgeziyalanib, xossalari yaxshilangan materiallar olishga imkon berishi keyingi tajribalarda isbotlandi.

Polilaktid/modifikatsiyalangan selluloza/mineral komponentlar asosida bioparchalanuvchan materiallar olish. Polilaktid, sut kislota va uning oligomeri bilan modifikatsiyalangan selluloza hamda mineral komponentlar (bentonit, kaolin) asosida bioparchalanuvchan kompozit materiallar sintez qilishda ikki xil usuldan foydalanildi: 1) “qaynoq presslash” usuli 2) erituvchi ishtirokida quyish (formirlash, shakl berish) (solvent casting method) usuli.

Biodegradatsiyalanuvchan materiallar maqbul tarkibini tanlash. Polilaktidga sut kislota yoki uning oligomeri bilan modifikatsiyalangan sellulozaning har ikkalasida ham komponentlar nisbati 60/40 dan 90/10 ga qarab, polilaktid miqdori ortib borishi bilan komponentlarning o‘zaro adgeziyasi, materialning gomogenligi oshib borishi kuzatildi. Kompozit tarkibida massa jihatdan 70 % polilaktid bo‘lgan namunalar gomogenligi yetarli bo‘lishi, 75 % va undan ko‘p bo‘lishi ideal darajada kompozit materiallar olishga imkon berishi aniqlandi. Biodegradatsiyalanuvchan materiallar komponentlaridan polilaktidning tannarxi boshqalariga nisbatan qimmatroq ekanligi sababli, uning miqdorini imkon qadar kam bo‘lishi mahsulot tannarxini pasaytiradi. Shu sababli, tarkibida 70-80 % atrofida polilaktid saqlagan namunalar eng maqbul tarkib sifatida qabul qilindi. Sellulozani sut kislota bilan ham uning oligomeri bilan modifikatsiyalash natijasida olingan mahsulotlarning barchasida polilaktid matritsaga yaxshi adgeziyalanganligi kuzatildi. Namunalarga mineral komponentlar: kaolin hamda bentonit qo‘shish orqali kompozit materiallar olishda namuna tarkibidagi polilaktid/selluloza nisbatini (80:20) o‘zgartirilmasdan saqlangan holda, mahsulotning massasiga nisbatan 20 % gacha noorganik mineral komponentlar qo‘shish orqali kompozitlar hosil qilindi. Namunalar tarkibiga 15 % dan ortiq mineral komponentlar qo‘shilishi materiallarning fizik-kimyoviy hamda mexanik xossalariga salbiy ta’sir qilishi aniqlandi. Shu sababli keyingi tadqiqotlarda tarkibiga 15 % gacha mineral komponentlar qo‘shilgan materiallar namunalari o‘rganildi.



3-rasm. Sintez qilingan namunalarning qiyosiy IQ-spektrlari

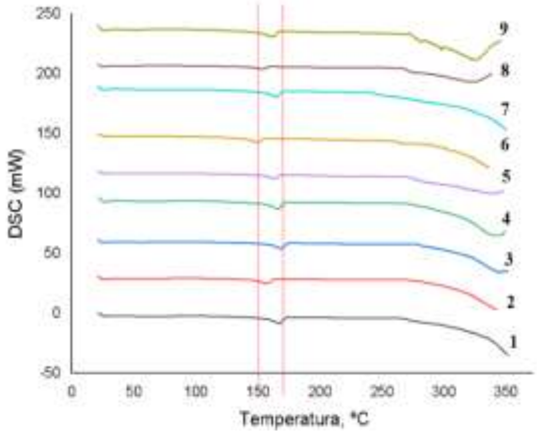


4-rasm. Namunalarning termik xossalarini qiyosiy baholash

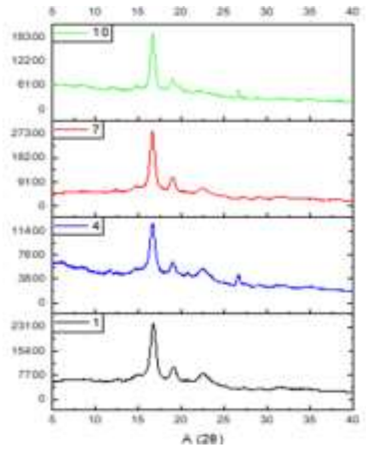
Dissertatsiyaning **“Bioparchalanuvchan materiallarning fizik-kimyoviy, mexanik hamda biologik xossalarini tadqiq etish”** deb nomlanuvchi uchinchi bobda sintez qilingan bioparchalanuvchan materiallarning fizik-kimyoviy, tekstur, mexanik hamda biologik xossalarini tadqiq etish borasidagi tajribalar natijalari keltirilgan. Sintez qilingan materiallar FTIR, TGA, DSC, XRD, SEM, gidrofillik darajasini aniqlashda kontakt burchaklarini optik usulda aniqlash; sitotoksiklik, antibakterial, antifungal, sanitar-gigiyenik xossalarini zamonaviy usullardan foydalangan holda tadqiq etildi.

Bioparchalanuvchan materiallarni IQ-spektroskopiya usulida tadqiq etish natijalaridan, toza PLA / selluloza tarkibli materiallarda ~1750 cm^{-1} sohada chiqqan, karbonil (CO) guruhiga mos polosaning, 5 % dan mineral komponentlar qo‘shilishi natijasida 1734 cm^{-1}, 1718 cm^{-1} sohaga siljiganligi, mineral komponent hamda polimer makromolekulalari orasida koordinatsion ta’sirlar yuzaga kelganligini ko‘rsatadi (3-rasm). ~1080 cm^{-1} sohadagi -C-O- tebranishlariga mos polosalarning 1014 cm^{-1}, 960 cm^{-1} sohaga siljiganligi, shuningdek, xuddi shu polosalarning 981 cm^{-1} sohaga siljiganligi ham polimer makromolekulalari hamda mineral komponentlar orasida kuchli o‘zaro ta’sirlar yuzaga kelganligini ko‘rsatadi.

Materiallarning termik xossalarini tadqiq etishda olingan natijalarga ko‘ra, toza PLA/mod-selluloza asosidagi materiallarning asosiy parchalanishi 350-410 ^{o}C orasida bo‘lib, bentonit mineralining miqdori ortib borishi bilan asosiy parchalanish temperaturasining boshlanish nuqtasi mos ravishda 340-330-320 ^{o}C ga qadar kamayib borganligi; kaolin qo‘shilgan namunalarda esa 330-320-315 ^{o}C gacha pasayib borganligi aniqlandi (4-rasm, 2-4 egriliklar). Namunalar tarkibiga 2,5 % (jami 5 %) dan hamda 5 % dan (jami 10 %) bentonit hamda kaolin minerallari birgalikda kiritilishi ularning asosiy parchalanishning boshlanish temperaturasini 280 ^{o}C ga qadar pasaytirishi kuzatildi (4-rasm, 8-10 egrilik). Kaolin qo‘shilgan namunalarning kul qoldig‘i barcha namunalar ichida kam bo‘lganligi kuzatildi. Bu havo kislorodi ishtirokida material namunasining oksidlanish jarayonida kaolinning katalitik rol o‘ynaganligi bilan izohlanadi.



5-rasm. Materiallaring shishalanish temperaturasi (Tg) ni aniqlash natijalari



6-rasm. Namunalarning rentgenfazaviy analizi

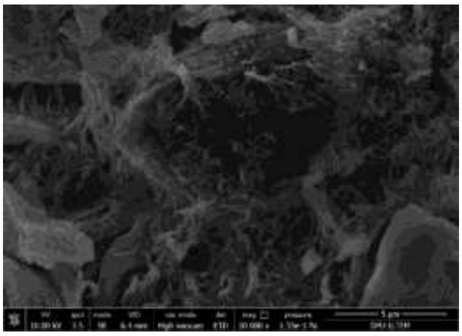
Differensial skanerlovchi kalorimetriya (DSC) usulida namunalarni analiz qilish natijalaridan, toza polilaktid va modifikatsiyalangan selluloza asosida olingan materiallar namunasining T_g qiymati ~170 ºC bo‘lib, namunalarga bentonit minerali qo‘shilishida uning qiymatlari o‘zgarishini ko‘rish mumkin. Eng yuqori qiymat (175 ºC) namunalarga 10 % bentonit kiritilganda kuzatildi (4-rasm, 3-egrilik). Bu namunalar tarkibiga kiritilgan mineralning nanozarrachalari polimer zanjirning harakatchanligini kamaytirishi va erkin fazoning kamayishi hisobiga ro‘y beradi.

T_g dan past bo‘lgan temperaturalarda polimerning zanjiri erkin harakatlana olmaydi va materiallar shishasimon bo‘lib, mo‘rt xossalarga ega bo‘ladi. Bu holatda bentonitning nanozarrachalari erkin fazoni kamaytirishi hisobiga polimer zanjirining harakatlanishi uchun ko‘proq energiya talab etadi.

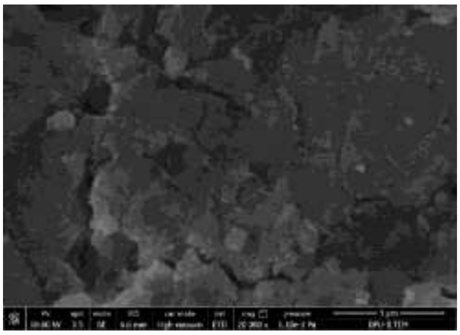
Namunalar tarkibiga kaolinning kiritilishi (5-rasm, 5-7 egriliklar) shishalanish temperaturasi (T_g) ni toza polilaktid/selluloza namunalariga nisbatan pasayishiga va hatto tarkibiga 10 % kaolin kiritilgan namunalarda (6-egrilik) sintez qilingan barcha namunalarga nisbatan eng kam qiymat – 150 ºC kuzatildi. Bentonit va kaolin minerallarini birgalikda 5 % miqdordan kiritilishida shishalanish temperaturasi eng kichik (150 ºC), binobarin erkin fazoning ulushi eng katta bo‘lgan materiallar olishga imkon berishi aniqlandi (5-rasm, 8-egrilik).

Namunalarning rentgenfazaviy analizi natijalaridan, 2θ=15-20º sohada polilaktidga tegishli signallarning intenlivligi namunaga qo‘shilayotgan mineral miqdorining ortishi bilan kamayib borganligi aniqlandi (6-rasm). 2θ = 20-35º sohada signallarning soni va intensivligining oshib borishi qo‘shilgan bentonit miqdoriga proporsional bo‘lib, uning kristalligi hisobiga yuzaga kelganligi bilan izohlash mumkin. PLA/mod-Cell 80:20 tarkibli namunalarga uning massasiga nisbatan 15 % gacha kaolin minerali qo‘shilishidan olingan namunalarning XRD analizi natijalardan, 2θ=15-20º sohada polilaktidga tegishli signallarning intenlivligi bentonit qo‘shilgan mos namunalarga nisbatan yuqori bo‘lib, namunaga qo‘shilayotgan mineral miqdorining ortishi bilan bu yerda ham signallarning umumiy kamayib borganligi kuzatildi. 2θ=20-35º sohada signallarning soni va intensivligining qo‘shilgan kaolin miqdoriga bog‘liqligi kuzatilmadi. Barcha namunalarda signallarning umumiy soni bentonit qo‘shilgan namunalarga nisbatan yuqoriligi kuzatildi.

PLA / mod-Selluloza / Bentonit + Kaolin birgalikda qo‘shilgan namunalar analiz qilinganda, bentonit/kaolin minerallari aralashmasi kiritilishi umumiy kristallik darajasining bentonit qo‘shilgan namularga nisbatan yuqori, kaolin qo‘shilgan namunalarga nisbatan esa kamayishiga olib kelganligi aniqlandi.



7-rasm. PLA/mod-selluloza tarkibli materialning SEM tasviri

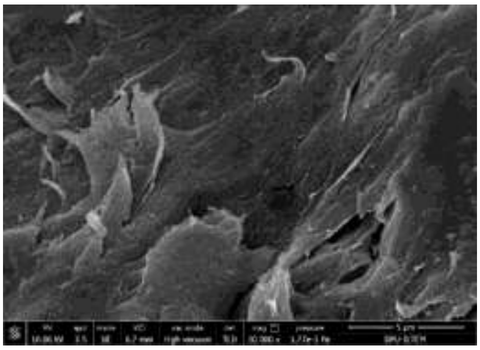


8-rasm. PLA/Sell + B15 materilining SEM tasviri

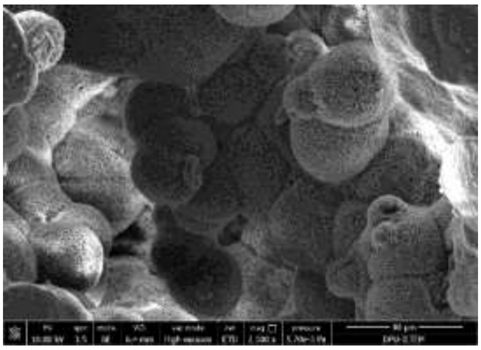
Bioparchalanuvchan materiallarning SEM analizi dastlab, polilaktid hamda modifikatsiyalangan sellyuloza (PLA/OLA-g-Cell 80:20 tarkibli namuna) asosidagi kompozit materiallar tadqiq etildi. SEM analizi natijalaridan, ko‘rishimiz mumkinki, PLA/OLA-g-Cell 80:20 bo‘lgan namunalarda matritsa – polilaktid hamda modifikatsiyalangan sellyuloza orasida juda yaxshi adgeziya sodir bo‘lgan (7-rasm).

Selluloza makromolekulalari alohida bo‘lgan joylarda diametri 20 µm gacha bo‘lgan g‘ovak sohalarning hosil bo‘lishi kuzatildi. Polilaktidning mayda kristallitlari o‘lchami 2-5 µm gacha bo‘lgan sohalar ko‘zga tashlanadi. Namunalarga 10 % gacha bentonit minerali qo‘shilgan materiallarda komponentlar o‘zaro juda yaxshi adgeziyaga ega bo‘lib, o‘lchamlari 2-7 µm bo‘lgan g‘ovak kanalchalar yuzaga kelganligini ko‘rish mumkin. Namunalar tarkibiga 15 % va undan ortiq qo‘shilgan bentonit materiallarning fizik-kimyoviy hamda mexanik xossalariga salbiy ta’sir qilishi, materialning strukturasida mikro- darajadagi yoriqlarning paydo bo‘lganligini ko‘rish mumkin (8-rasm).

Materiallar tarkibiga 10 % gacha kaolin minerali kiritilishi materiallarning mikrostrukturasida komponentlarni o‘zaro yaxshi adgeziyasi ro‘y berganligi kuzatildi. Materiallar tarkibiga 15 % gacha kaolin kiritilishida ham komponentlar orasida adgeziya nisbatan yomonlashganligi aniqlandi. Umumiy holda, namunalar tarkibiga 15 % gacha kaolin minerali kiritilishidan olingan materiallar mikrostrukturalarida yaxshi adgeziyani kuzatish mumkinligini qayd etish o‘rinli. PLA/OLA-g-Cell 80:20 tarkibli namunaga massasiga nisbatan 5-15 % gacha bentonit+kaolin minerallari turli nisbatlarda qo‘shish orqali olingan kompozit materiallar namunalarini tadqiq etilganda, 2.5 % dan (jami 5 %) va 5 % dan (jami 10 %) bentonit hamda kaolin kiritilishidan olingan materiallar mikrostrukturasida o‘lchamlari ~5-15 μm bo‘lgan, muntazam, alohida kristallik klasterlar (qismlar) ning paydo bo‘lganligi aniqlandi. Ushbu kristall klasterlar polimer makromolekulari hamda mineral komponentlarning o‘zaro ta’siridan yuzaga kelganligi ko‘rinadi (9-rasm).



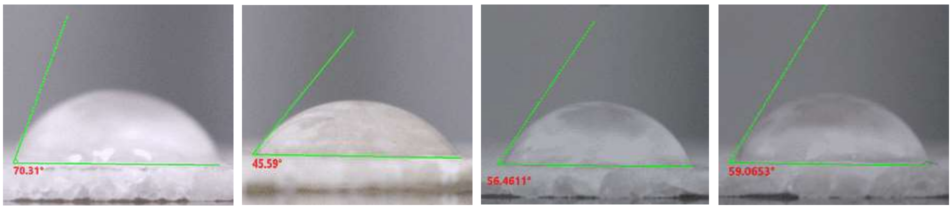
9-rasm. PLA/Sell+K10 tarkibli material SEM tasviri



10-rasm. PLA/Sell+B7.5+K7.5 tarkibli materiallar SEM analizi

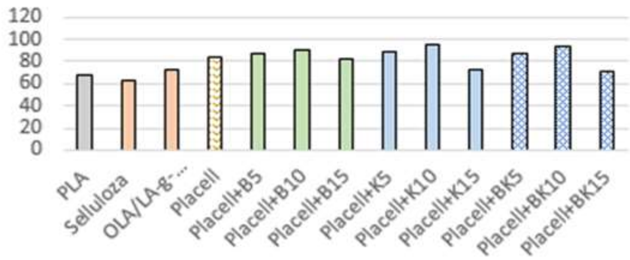
Bentonit+kaolin 7.5 %+7.5 % tarkibli materiallar SEM analizi kristall klasterlarning o‘lchamini ~50-100 μm gacha kattalashishiga olib keladi (10-rasm). Ushbu klasterlar mikro- darajadagi, muntazam, g‘ovak strukturalardan iborat ekanligi kuzatildi. Bunday g‘ovaklarning bo‘lishi bir tomondan materialning biologik parchalanishida ijobiy rol o‘ynasa ham, boshqa tomondan uning mexanik xossalarini yomonlashishi hisobiga salbiy ta’sirga ega bo‘lishi mumkin.

Materiallarning kontakt burchaklarini optik usulda aniqlash bo‘yicha olib borilgan tadqiqotlarda zond suyuqligi sifatida suvdan foydalanildi (11-rasm). Ma’lumki, gidrofillikning oshishi materiallar ishlatilib bo‘lgandan so‘ng atrof-muhitga tushganda, ularning tezroq parchalanishiga olib keladi. Namunalar tarkibiga bentonit hamda kaolin minerallarining kiritilishi ularda yaqqol ifodalangan gidrofillik ($\theta<60°$) xossalarini yuzaga kelishiga sababchi bo‘lishi aniqlandi. Bunda, har ikkala komponentdan birgalikda kiritilishida, ularning miqdori ortishi bilan namunalarda gidrofillik biroz kamayib borishi, ya’ni kontakt burchagining ortib borishi kuzatildi.



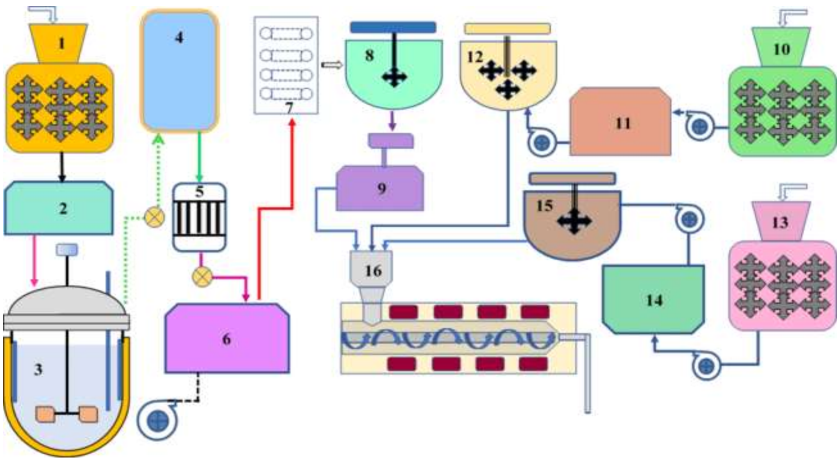
11-rasm. Materiallarning gidrofilligi

Materiallarning mexanik xossalarini tadqiq etishda dastlabki moddalar (PLA, selluloza, modifikatsiyalangan selluloza) hamda ular asosida olingan materiallarning uzayishga nisbatan mustahkamligi aniqlandi (12-rasm).



12-rasm. Materiallarning mexanik xossalari

Mexanik xossalarni aniqlash bo‘yicha olib borilgan tajribalar natijalaridan PLA ga modifikatsiyalangan sellulozaning kiritilishi uning mexanik xossalarining yaxshilanishi, bentonit va kaolinning miqdori 10 % gacha bo‘lgan namunalarda uzilishga nisbatan mustahkamlik oshib borishi, namunalar tarkibiga 10 % dan ortiq mineral komponentlar kiritilishi mexanik xossalarini yomoshlashishiga olib kelishi aniqlandi.



13-rasm. Bioparchalanuvchan materiallar ishlab chiqarish texnologik sxemasi

Dissertatsiyaning **“Bioparchala-nuvchan materiallar olish texnologiyasi va sanitar-gigiyenik xossalari”** deb nomlangan to‘rtinchi bobida PLA/mod-Selluloza + B/K tarkibli, bioparchalanish xususiyatiga ega materiallar ishlab chiqarishning texnologik asoslarini tadqiq etish bo‘yicha tajribalar natijalari keltirilgan. Quyidagi 13-rasmda ushbu jarayonning prinsipial sxemasi keltirilgan.

13-rasmda keltirilgan texnologik sxema quyidagi jarayonlarni o‘z ichiga oladi: dastlab, birinchi blokda L-sut kislota olish uchun zarur bo‘lgan xomashyo (makkajo‘xori, tritikale, arpa, bug‘doy va h.k.) lar maydalanib (1), un ko‘rinishiga keltiriladi. Tarkibidagi kraxmal avval kislotali yoki fermentativ gidrolizga (2) uchratiladi. Gidroliz mahsuloti mikrobiologik yoʻl bilan (3) L-sut kislotaga aylantiriladi. L-sut kislota choʻktirish, kislotali ishlov berish, haydash (4) va boshqa yoʻllar bilan tozalanib (5), dastlab, siklik laktidga (6, 7), undan maxsus reaktor (8) da katalitik polimerlanish yoʻli bilan polilaktidga aylantiriladi. Polilaktidni granula (9) koʻrinishida tayyor mahsulot koʻrinishiga keltirish mumkin. Ikkinchi blokda jarayon selluloza manbasini maydalash (10) va undan sellulozani ajratib olish, tozalash (11) hamda kimyoviy modifikatsiyalash (12) orqali sintez uchun tayyorlanadi. Uchinchi blokda esa mineral komponentlar (bentonit, kaolin) dastlab maydalanadi (13), tozalanadi (14) hamda kimyoviy modifikatsiyalanib (15), sintezga tayyorlanadi. Sintez uchun tayyorlangan komponentlar (9, 12, 15) “solvent casting method” da kompaundlanadi va ekstruder (16) da granulalar koʻrinishida tayyor mahsulotga aylantiriladi.

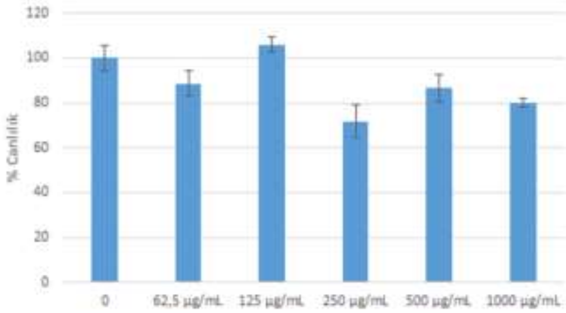
Bioparchalanuvchan materiallarning sanitar-gigenik xususiyatlarini tekshirish boʻyicha “GOST EN 13432—2015” talablari asosida olib borilgan tajribalarda biologik parchalanmaydigan organik komponentlar namuna massasining 1 % ni tashkil etib, asosan kompatibilizator sifatida qoʻllaniladigan polivinil spirti hissasiga toʻgʻri keladi. Poli-L-sut kislota mikroorganizmlar hisobiga bioparchalanish, suv hisobiga kimyoviy gidrolizlanishidan parchalanishi mumkin. Selluloza ham tabiiy komponent boʻlib, u mikroorganizmlar tomonidan parchalanadi. Noorganik tabiatli mineral komponentlar esa material destruksiyasi natijasida tuproq komponentiga qoʻshilib ketadi.

Quruq qattiq qoldiqning umumiy miqdori aniqlanganda namlikning chiqib ketishi natijasida qolgan quruq qoldiq miqdori 96-98,5 % diapazonida boʻldi. Qattiq moddaning yonishida massa kamayishi tekshirilganda ochiq havoda 550 °C gacha qizdirilganda massasining kamayishi 83,9-97,5 % diapazonida ekanligi aniqlandi. Me’yor talablari boʻyicha qattiq namuna yonishida massaning kamayishi modda massasiga nisbatan 50 % dan kam boʻlmasligi kerak. Materiallar tarkibida xavfli moddalar, ogʻir metallar miqdorini aniqlashda materiallar tarkibidagi ogʻir metallar va zaharli komponentlar miqdori me’yor darajasidan oshmasligini aniqlandi.

Aerob kompostlashda yuqoridagi shaklda, faqat ochiq idishlarda tajribalar olib borilib, 12 hafta ichida material namunasining parchalanishi tekshirildi. Bunda namunalarning dastlabki massasining 96-98 % toʻliq parchalanganligi aniqlandi. Oʻlchamlari 2 mm elakdan oʻtkazilganda 2-4 % parchalanmay qolgan mahsulotlar borligi aniqlandi.

Ekologik zaharlilik sinovlari. Ekologik zaharlilik sinovlari tarkibida 50% gacha bioparchalanuvchan materiallar kompostlari qoʻshilgan bogʻ tuprogʻida, standart metodika boʻyicha olib borildi. Nazorat sinovlari toza bogʻ tuprogʻida amalga oshirildi (14-rasm). Kompost namunalari ustiga 100 tadan 1) Cucumis sativa (bodring) 2) Allium cepa (piyoz) urugʻlari ekilib, namunalar sinov vaqtida qorongʻu joyda saqlandi. Sintez qilingan namunalardan olingan kompost hamda toza kompostdagi nihollar miqdori va biomassasiga nisbatan oʻsish tezligi % larda hisoblanganda, oʻsimliklar biomassasining oʻsish normasi etalonga nisbatan 97-103 % ekanligi aniqlandi. Bundan ishlab chiqilgan materiallar zaharli emasligi toʻgʻrisida xulosa qilindi.

14-rasm. Materiallarning kompost nuhitida parchalanish ko‘rinishlari



15-rasm. Sintez qilingan bioparchalanuvchan materiallarning sitotoksik xususiyatlarini tadqiq etish

Sitotoksik xususiyatlarni tadqiq etish. Sintez qilingan namunalarning sitotoksik xususiyatlari A549 va L929 hujayralarida 3-[4,5-dimetiltiazol-2-il]-2,5-difeniltetrazoliy bromid (MTT) usulida aniqlandi.

Namunalarning optik zichliklariga binoan, har bir lunkadagi hujayralarning hayotiylik darajasi nazorat namunasiga nisbatan % larda hisoblandi. Olingan natijalar asosida (15-rasm) sintez qilingan materiallar namunalarida yaqqol ifodalangan sitotoksik xossalari mavjud emasligi to‘g‘risida xulosa qilish mumkin. Hujayralarning eng ko‘p nobud bo‘lishi 30% gacha bo‘lib, bu turli tashqi omillar hisobiga yuz berishi mumkin. Umuman olganda, materiallar suspenziyasi ta’sirida hujayra namunalarining hayotiyligi 86-107% orasida bo‘lganligi aniqlanib, bu materiallarda sitotoksik xossalar mavjud emas degan xulosa qilishga imkon beradi.

Taklif etilgan tarkiblarning raqobatbardoshligini aniqlash borasida olib borilgan izlanishlar ishlab chiqarish uchun sarflanadigan kimyoviy moddalar, katalizatorlar hamda elektr sarf xarajatlarini e’tiborga olindi (1-jadval).

1-jadval.

Taklif etilayotgan bioparchalanuvchan materiallarning tannarxi

Komponent	O‘lchov birligi	So‘m	Minimal xarajat		Maksimal xarajat		Izoh
			Sarfi	Narx, so‘m	Sarfi	Narx, so‘m	
Polilaktid	kg	6985	727,273	5080001,905	727,273	5080001,905	Elektr sarfi “solvent casting” va ekstruziya usullarida turlicha
Selluloza	kg	19350	181,818	3518178,3	181,818	3518178,3	
Bentonit	kg	500	45,4545	22727,25	45,4545	22727,25	
Kaolin	kg	200	45,4545	9090,9	45,4545	9090,9	
Elektr sarfi	kW*soat	900	50	45000	200	180000	
Erituvchi	L	75000	50	3750000	100	7500000	
				12424998,36		**16309998,4**	**14367498,36**

Xomashyolar narxlari O‘zbekiston Respublika tovar-xomashyo birjasida (uzex.uz) 2025 yilning mart oyida o‘tkazilgan birja savdolari kotirovkalari asosida shakllantirildi. Jadval ma’lumotlaridan, 1 kg taklif etilayotgan tarkibli bioparchalanuvchan materiallarni ishlab chiqarish tannarxi o‘rtacha 14367 so‘m (2025 yilning aprel oyidagi Markaziy Bank kursiga ko‘ra 1,114 AQSH dollariga ekvivalent) ekanligini ko‘rish mumkin. Tannarxni hisoblashda quyidagilar asos qilib olindi: 1) L-sut kislota olish jarayoni uchun xom ashyo - makkajo‘xori kraxmali bo‘lib, undagi kraxmalning ulushi 60 %-70 % qiymatda olindi. Mikrobiologik yo‘l bilan L-sut kislota olish unumi: minimal – 50 %; maksimal – 80 %. 2) Poli-L-laktid sintez qilishda reaksiya unumi: minimal – 50 %; maksimal – 70 % deb qabul qilindi. Laboratoriya sharoitida reaksiya unumi 80-83 % ga yetganligi qayd etilgan. Katalizator sarfi, xomashyo massasiga nisbatan: minimal - 0,5 %; maksimal – 1 %. 3) Barcha jarayonlarda sarflangan elektr toki miqdorining minimal qiymati adabiyot ma’lumotlari asosida, maksimal qiymatlari esa qurilmalarning elektr sarflari miqdoridan hisoblab chiqarildi.

XULOSALAR

1. Polilaktid, oligolaktid bilan modifikatsiyalangan selluloza va mineral komponentlar: bentonit, kaolin asosida PLA/OLA-g-Sell/B10; PLA/OLA-g-Sell/K10; PLA/OLA-g-Sell/B5/K5 (80:20+10%) tarkibli bioparchalanuvchan materiallar sintez qilingan.
2. O‘simlik chiqindilaridan olingan sellulozani sut kislota oligomeri bilan kimyoviy modifikatsiyalash komponentlar makromolekulalari orasida o‘zaro ta’sirlarni kuchaytirishi, binobarin materiallarning fizik-kimyoviy va mexanik xossalarini yaxshilashga xizmat qilishi aniqlangan.
3. Materiallar tarkibiga 10 % gacha kaolin yoki 5 % dan kaolin/bentonit kiritilishi materialarning fizik-kimyoviy va mexanik xossalariga ijobiy ta’sir etishi ko‘rsatilgan; materiallar tarkibiga qo‘shilgan kaolin mineralining miqdori ortib borishi bilan parchalanish temperaturasining 70-80 ºC ga pasayishi, shishalanish temperaturasini ~25 ºC ga pasaytirishi, termik parchalanishda katalitik rol o‘ynashi, kul qoldig‘i miqdorining kamayishiga olib kelishi ko‘rsatildi.
4. *Lactiplatibacillus plantarum 3G* bakteriyasidan foydalangan holda, mikrobiologik yo‘l bilan L-sut kislota, undan polilaktid va u asosida bioparchalanuvchan materiallar olishning maqbul sharoitlari tanlangan.
5. Mahalliy xom ashyolar asosida bioparchalanuvchan materiallar ishlab chiqarishning texnologiyasi (texnologik sxema, moddiy balansi) ishlab chiqilgan.
6. Olingan bioparchalanuvchan materiallarning namunalari Afyon Kocatepe universiteti (Turkiya) da “Synthesis and characterization of new nanoparticles by green synthesis using Lycium depressum extract” ilmiy loyihasida; O‘zbekiston-Bolgariya qo‘shma korxonasi “Integra DD” MChJ QKda “Novokain in’yeksiya uchun 0,5 % eritma, 5 ml” preparatining ikkilamchi qadoqlash vositasi sifatida qo‘llashga tavsiya etildi.

SCIENTIFIC COUNCIL ON AWARDING SCIENTIFIC DEGREES DSc.03/2025.27.12.K/T.12.05 AT THE TERMEZ STATE UNIVERSITY

SAMARKAND STATE UNIVERSITY NAMED AFTER SHAROF RASHIDOV

KHUDAYNAZAROV JAKHONGIR ORTIK UGLI

BIODEGRADABLE MATERIALS BASED ON POLYLACTIDE: PREPARATION, PROPERTIES AND TECHNOLOGY

02.00.14 – Technology of organic substances and materials based on them

DISSERTATION ABSTRACT
OF THE DOCTOR OF PHILOSOPHY (PhD) ON CHEMICAL SCIENCES

Termez – 2026

The topic of the dissertation for the degree of Doctor of Philosophy (PhD) in Chemistry is registered with the Higher Attestation Commission under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan under the number B2025.2.PhD/K1017.

The dissertation was completed at Samarkand State University named after Sharof Rashidov.

The dissertation abstract is posted in three languages (Uzbek, Russian, English (resume)) on the website of the Scientific Council (www.tersu.uz) and on the information and educational portal "ZiyoNet" (www.ziyonet.uz).

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Leading organization:	**Urgench State University**

The dissertation defense will be held at the meeting of the Academic Council of Termez State University DSc.03/2025.27.12.K/T.12.05 on «24» 04 at 10[00], 2026. (Address: 190111, Termez city, Barkamol Avlod street, 43. Tel.: (+99876) 22174-55, fax: (+99876) 221-71-17, e-mail: termizdu@umail.uz).

The dissertation is available for review at the Information Resource Center of Termez State University (registered under number № 30). Address: 190111, Termez city, Barkamol Avlod street, 43. Tel.: (+99876) 221-74-55, fax: (+99876) 221-71-17, e-mail: termizdu@umail.uz).

The dissertation abstract was distributed on «07» 04 day, 2026.
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INTRODUCTION (abstract of PhD dissertation)

The relevance and necessity of the dissertation topic. Currently, the total amount of microplastic particles entering the ocean through rivers in the world annually reaches 1.5 million tons, and as a result of studies conducted on living organisms living in water, it has been determined that the accumulation of these microplastic particles is accompanied by endocrine disruption, weakening of the immune system, liver, kidney, gastrointestinal system, oxidation-reduction processes, and in most cases, inflammatory reactions, neurotoxicity, reproductive dysfunction, and even genotoxicity. The main part of the microplastic particles that cause such disastrous consequences is polyethylene, polypropylene, polystyrene. Obtaining inexpensive, biodegradable plastic materials based on polylactide with improved physicochemical properties remains one of the urgent tasks.

Today, in the world, research is being conducted on the synthesis of biodegradable materials based on a promising raw material base and the use of low-cost technologies for the targeted synthesis of substances and their use in solving environmental and social problems. In this regard, it is important to study the physicochemical and mechanical properties of new high-molecular compounds using modern methods in the field of organic chemistry, to use them in packaging products in the food industry, and to create environmentally friendly biodegradable materials based on various natural biodegradable compounds from the obtained substances.

In our republic, scientific and practical results are being achieved in the production of important chemical materials used in the food industry and agriculture, including biodegradable materials, based on local raw materials and secondary compounds. In our republic, great attention is paid to the implementation of measures to protect the environment and a scientifically based system of operating industrial facilities through the implementation of innovative technologies. The “Development [3]Strategy of New Uzbekistan for 2022–2026” sets out priority areas for economic development and specifically identifies issues of further accelerating the production of finished products with high added value based on deep processing of local raw materials, and changing the types of qualitatively new products and technologies. In this regard, obtaining new, economically efficient and environmentally safe biodegradable materials based on various polymers and constantly improving existing technologies is of great importance in the production of biodegradable materials.

Decree No. 60 of the president of the Republic of Uzbekistan dated January 28, 2022 “on the development strategy of New Uzbekistan”dated October 25, 2018 “on the implementation of the state program in the Year of development of Science, Education and digital economy”dated March 2, 2020 “on the development strategy of New Uzbekistan”dated October 25, 2018 "on measures and measures for the rapid development of the industry in the Republic of Uzbekistan" dated in implementation,

[3]Decree of the President of the Republic of Uzbekistan dated January 28, 2022 No. PF-60 “On the Development Strategy of New Uzbekistan for 2022-2026”.

the results of this scientific study serve to some extent.

Compliance of the research with the priority areas of the development of science and technology of the republic. The research of this dissertation work was carried out in accordance with the VII priority area of the development of science and technology of the Republic. “Chemistry, chemical technology and nanotechnology”.

The degree of study of the problem. In the literature, intensive research is being conducted at leading scientific centers around the world on the synthesis of biodegradable plastic materials and their production technologies. In particular, research on the development of environmentally friendly biodegradable plastic materials by adding various inorganic and organic fillers to polylactide has been reviewed in the studies of the world's leading scientists in this field: Alethia Vazquez, Tomasz M. Majka, Marcelo A G Bardi, Daniel López, A. N. Zelenetskii, Marco Frediani, Saira Nayab, Yaowalak Srisuwan, Reza Arjmandi, Robert Molloy, C.A.P. Joziasse, Eric Dargent, Steven Verstichel, Mieke Buntinx and others.

Research is being conducted in the field of synthesis and research of polymer composite materials, as well as biodegradable plastic materials by scientists of our Republic, including H.Akbarov, S.Rashidova, T.Boboyev, G.Mukhamediyev, I.Asqarov, D.Gafurova, H.Turayev, Sh.Kasimov.

From the literature data, it was found that research on the production of biodegradable materials based on polylactide, modified cellulose and various inorganic minerals - bentonite, kaolin and the technology for their production has not been thoroughly studied. Based on the above, the development of environmentally friendly, biodegradable plastic materials based on local raw materials and the creation of their technology are of theoretical and practical importance.

The relationship of the dissertation research to the research plans of the higher education institution where the dissertation was completed. The dissertation research was carried out within the framework of the practical project ALM-202310062531 “New methods for the synthesis, testing and processing of natural and synthetic materials” (2023-2024) of the research plan of Sharof Rashidov Samarkand State University.

The aim of the research is to determine the synthesis and properties of biodegradable materials using polylactide, modified cellulose, and inorganic minerals.

Research objectives. Determining optimal conditions for producing L-lactic acid, polylactide, and modified cellulose based on local raw materials;

selection of optimal conditions (component composition, ratio, catalyst, temperature, etc.) for the synthesis of biodegradable materials;

determination of physicochemical and biological properties of synthesized materials;

developing a technology for obtaining biodegradable materials (technological scheme, material balance);

testing the synthesized biodegradable materials in laboratory and real conditions and recommending them for production.

The objects of the research work. L-lactic acid, poly-L-lactic acid, cellulose from plant residues, bentonite, and kaolin.

The subject of investigation. The aim is to select the optimal composition of biodegradable materials based on poly-L-lactic acid, modified cellulose, and inorganic minerals - kaolin, bentonite, study their physicochemical properties, and develop a production technology.

The methods of research. The work used the “solvent casting method” for the synthesis of biodegradable materials; “hot pressing” methods; IR spectrometry (FTIR), energy-dispersive X-ray fluorescence analysis (EDS XRF), powder X-ray diffraction (XRD), scanning electron microscopy (SEM), thermal analysis (TGA, DSC), optical determination of contact angles of materials, methods for determining the mechanical properties of materials, as well as methods and tools for determining dielectric and cytotoxic properties.

The scientific novelty of the research is as follows:

9 different biodegradable materials with the composition PLA/OLA-g-Cellulose/Bentonite/Kaolin 80:20 + 5/5 were synthesized based on polylactide, oligolactide-modified cellulose and mineral components: bentonite, kaolin;

using the bacterium *Lactiplatibacillus plantarum 3G*, optimal conditions for obtaining L-lactic acid, polylactide and biodegradable materials from it by microbiological means were determined;

it was determined that the tensile strength of biodegradable materials obtained as a result of the introduction of up to 10% kaolin or 5% kaolin/bentonite into the composition of the materials increased by 1.4 times;

a technology for obtaining biodegradable materials based on local raw materials polylactide, oligolactide-modified cellulose and mineral components was developed.

The practical results of the research are as follows:

biodegradable materials used in the packaging of food products, medicines, agricultural and other products, as well as in the manufacture of disposable household items were obtained;

it was found that the chemical modification of cellulose obtained from plant waste with lactic acid oligomer enhances the interactions between the macromolecules of the components, improves the physicochemical and mechanical properties of the materials;

it was proven that increasing the amount of kaolin mineral added to the materials leads to a decrease in the decomposition temperature by 70-80 ºC, and a decrease in the glass transition temperature by ~25 ºC;

it was found that the synthesized materials have mechanical strength, are environmentally friendly, safe, and when released into the environment, they spontaneously biodegrade by 90-96% within 4-6 months.

Reliability of the research results. The results of the significant amount of experience gained in the research and the satisfactory correlation of the results of experiments conducted on an industrial scale, the application of modern research methods, including IR spectroscopy, X-ray fluorescence, X-ray phase, scanning electron microscopy, thermal analysis methods, the use of modern methods for determining the hydrophilicity, dielectric, cytotoxicity and mechanical properties of materials, and the consistency of the results obtained on the basis of testing and use in production, have been proven.

Scientific and practical significance of the research results. The scientific significance of the research results is explained by the fact that inorganic minerals - bentonite, kaolin - can be added to the composition of biodegradable polylactide, modified cellulose macromolecules in an amount of up to 10%, which improves the physicochemical and mechanical properties of biodegradable materials through the occurrence of interaction forces between them, reduces their cost, and uses local raw materials for the synthesis process;

The practical significance of the research results is that biodegradable materials obtained from local raw materials, based on polylactide, oligolactide-modified cellulose and mineral components, completely decompose biologically within 2-6 months when released into the environment, the decomposition products are harmless, and the L-lactic acid formed from the hydrolysis of polylactide is food for microorganisms, so the production of such materials serves to obtain environmentally safe biodegradable materials with a new composition.

Implementation of the research results. Based on the results obtained in the study of the synthesis and properties of biodegradable materials with the participation of polylactide, modified cellulose and inorganic minerals;

the samples of the obtained biodegradable materials were used to determine the cytotoxic, antibacterial, antifungal and wound healing properties of the scientific project “Synthesis and characterization of new nanoparticles by green synthesis using Lycium depressum extract” at the Department of Chemistry of Afyon Kocatepe University (Turkey) (Afyon Kocatepe University reference dated February 17, 2025). As a result, it was possible to obtain biodegradable materials with antibacterial and antifungal properties based on polylactide, oligolactide-modified cellulose and mineral components: PLA/OLA-g-Sell/B10; PLA/OLA-g-Sell/K10; PLA/OLA-g-Sell/B5/K5;

the synthesized materials were used as a secondary packaging medium for the drug “Novocaine 0.5% solution for injection, 5 ml” at the Uzbek-Bulgarian joint venture “Integra DD” LLC (Integra DD LLC JV Reference No. 8 dated January 21, 2025). As a result, it was possible to synthesize materials that meet the requirements of the international standard “GOST EN 13432:2015”.

Approbation of the research results. The results of the research were presented and discussed at 10 scientific and practical conferences: 2 international and 8 national.

The publication of results of investigation. A total of 18 scientific works have been published on the topic of the dissertation, of which 8 were published in scientific journals recommended by the Higher Attestation Commission of the Republic of Uzbekistan for publication of the main scientific results of the Doctor of Philosophy dissertation, including 3 in intrantional journals, and 5 in republican scientific journals.

The structure and volume of dissertation. The dissertation consists of an introduction, four chapters, conclusions, and a list of references. The length of the dissertation is 117 pages[4].

[4] I would like to express my gratitude to PhD, associate professor S.U.Tillayev for his valuable advice during the

MAIN CONTENT OF DISSERTATION

In the introduction justifies the relevance and importance of the dissertation topic, sets out the goals and objectives of the research, indicates its compliance with the priority areas of development of science and technology in the Republic of Uzbekistan, describes the scientific novelty and practical results of the research, substantiates their reliability, reveals the scientific and practical significance of the research results. Conclusions are drawn regarding the prospects for implementation in practice, and information is provided on published works and the composition of the dissertation**.**

The first chapter of the dissertation, entitled "**The current state of biodegradable materials production**", analyzes the production of biodegradable materials, their physicochemical properties, as well as the technology of their production based on scientific literature. The properties of biodegradable materials and the prospects for their application in agriculture, industry, biomedicine and other fields are also presented.

The second chapter of the dissertation, entitled "**Synthesis of biodegradable materials based on oxyacids**," presents the results of experiments on the synthesis of L-lactic acid by microbiological means based on local raw materials, the production of polylactide from it, and the synthesis of biodegradable materials based on polylactide. The microbiological method was used to produce L-lactic acid. The microbiological method of obtaining L-lactic acid is distinguished by its advantages such as efficiency, convenience, low cost, and high enantiomeric purity of the product obtained.

Starch (potato, wheat, corn, waste from juice production plants) was used as a carbohydrate source. L-lactic acid was synthesized by incubating the bacterium *Lactiplatibacillus plantarum 3G* in corn extract medium for 3-5 days as a source of starch and nitrogen. To determine the individuality of the obtained product, its IR spectra were obtained and compared with the database, and it was determined that it was L-lactic acid (Figure 1). The amount of calcium lactate precipitated from 100 ml of the sample was 8.03 g, which was 6.63 g when calculated as pure lactic acid. The yield of lactic acid was 6.63 g per 100 ml of the nutrient mixture or 27.6 % per 100 g of the used nutrient - starch. Biotechnological research was needed to increase the yield of the process, and was not studied, since it was not included in the purpose of the study. Synthesis of polylactide from L-lactic acid. A number of methods have been developed for the synthesis of polylactide. Of these, the ring-opening polymerization reaction from cyclic lactide is a fairly popular method. In this case, a catalyst is used in the last - third step.

Synthesis of polylactide. In this work, the ring-opening polymerization method of obtaining polylactide was used.

For the synthesis of polylactide, an 80 % solution of commercial L-lactic acid, obtained by microbiological methods, was used. The synthesis of polylactide was

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completion of my thesis.

carried out in three stages. **Stage 1:** Lactic acid was concentrated at 160±5 °C for 2 hours and converted to oligomeric lactic acid by dehydration. Dehydration was carried out in an inert gas atmosphere - nitrogen, at normal pressure.

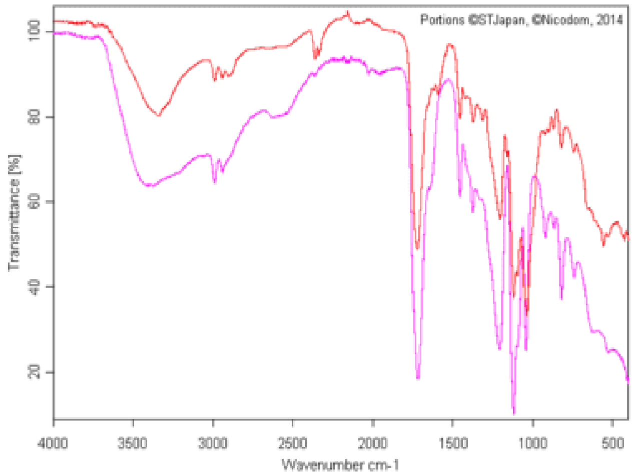
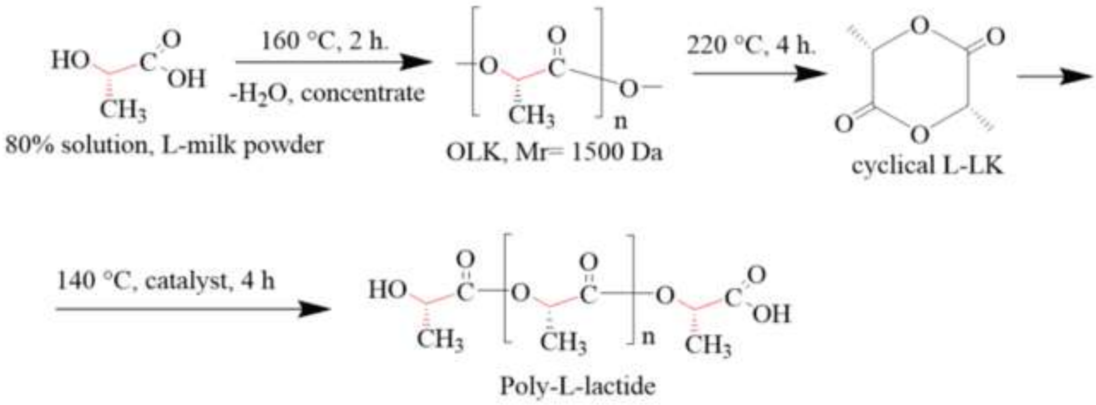


Figure 1. IR spectrum of L-lactic acid obtained by microbiological route (red) and its comparison with the database (pink)

The products obtained at each stage were monitored by IR spectroscopic methods. The obtained IR spectra were compared with the data of the ATR-LIB-PHARMA-2-472-2.S01 and DEMILIB.S01 library databases, and the substances were identified. Comparing the IR spectral results, it was concluded that lactic acid was first converted to oligomeric lactide, then to cyclic lactide, and then to polylactide**.**



Step 2: In this step, the oligomeric product was converted to cyclic lactide under vacuum conditions of 0.02 MPa at 220±10 °C and collected in a condensation flask by suction. The resulting cyclic lactide was examined by IR spectroscopy, and the recorded spectra were compared with the database to determine that it was indeed cyclic lactide. Step 3: The cyclic lactide obtained in the last step was mixed with catalyst: ZnO/zeolite (50:50) and (0.05-0.1 % by mass) was converted to polylactide at 140±10 °C for 4 hours.

The synthesized polylactide was examined by IR spectroscopy and compared with the results of the database, it was noted that polylactide was indeed obtained. The yield of polylactide formation depends on several factors, in particular, the type of catalyst used, the duration of the process and other factors, and in this work, it was found that it was obtained with a maximum yield of 80-83% depending on the type of catalyst. The remaining 17-20 % of the product was in the form of an oligomer of lactic acid, and the aggregate state was a viscous thick mass (with a more liquid consistency). The molecular weight of the oligomer was determined by viscometric method to be between 450-750, which indicated that the value of n was on average

8-10. Selection of catalyst for polylactide synthesis. The most effective catalyst for the synthesis of polylactide on an industrial scale is widely used - tin octanoate.

In recent years, due to the toxicity of tin compounds, research has been conducted on the development of low-toxicity catalysts that do not negatively affect the environment and the quality of the manufactured product. Relatively less-studied catalytic systems are zeolites, and few studies have been published in recent years. The work investigated the possibilities of using catalysts-Lewis acids (compounds of Al, Sn, Sb, etc.), Zn and mixtures of its compounds with synthetic zeolites as catalysts in the synthesis of polylactide. Synthetic zeolites were synthesized hydrothermally based on local feldspar. In case of using ZnO and its 1:1 mixture with zeolite as catalysts, a product with a yield of 74-87 % was obtained at 120-140 °C for

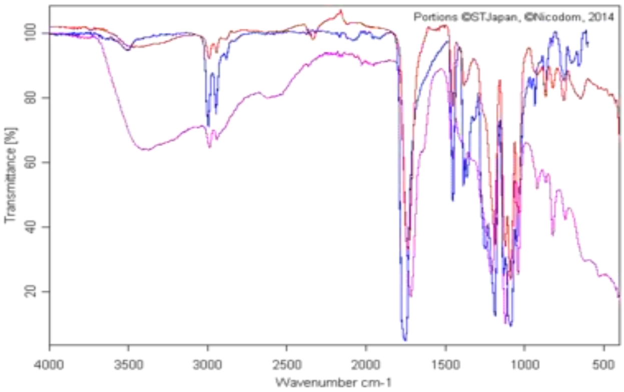
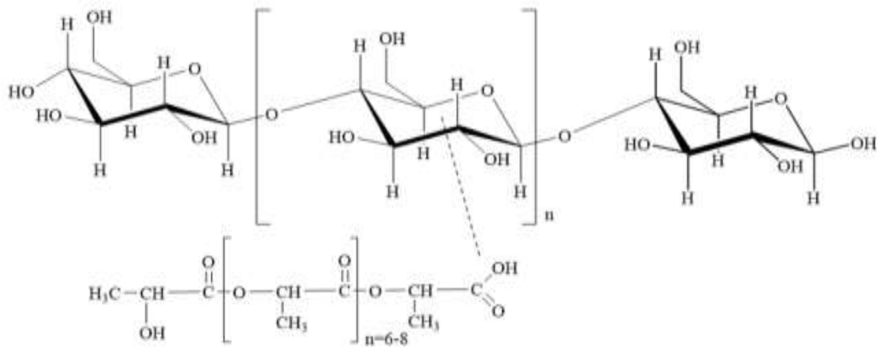


Figure 2. IR spectrum of polylactide (red) (blue band identified as Poly(lactide) based on database)

4-6 hours, and its average molecular mass was found to be in the range of 57-74 kDa. In case of using $AlCl_3$, $ZnCl_2$, $FeCl_3$ and their mixtures with zeolites as catalysts, it was found that the reaction yield was between 34-85 %, and the average molecular weight of the product was 12-65 kDa. Therefore, in subsequent experiments, a 1:1 mixture of ZnO/zeolite was used. Although the obtained polylactide had a relatively low molecular weight compared to the molecular weight of the product obtained based on tin octanoate (≈200 - 300 kDa), the studies were continued on the basis of this type of product, since it was suitable for further studies.

Cellulose extraction and chemical modification from plant waste. In subsequent experiments, cellulose was isolated from the stems of some plant waste (wheat, rye, rice, reed, cotton stalks, etc.). It is known that the polarity of polylactide macromolecules is low. Since its side chain contains only free methyl ($-CH_3$) groups, and carboxyl and hydroxyl groups participate in the formation of the macromolecule, in general, the macromolecule is close to non-polar. Cellulose macromolecules, on the contrary, have a strong polar nature due to the large number of hydroxyl (-OH) *groups.* One of the ways to bring their nature closer to each other to obtain polylactide/cellulose-based materials is to modify cellulose macromolecules. Therefore, in this work, research was conducted on the chemical modification of cellulose. Chemical modification of cellulose was carried out with the participation of two substances: L-lactic acid and its oligomer.

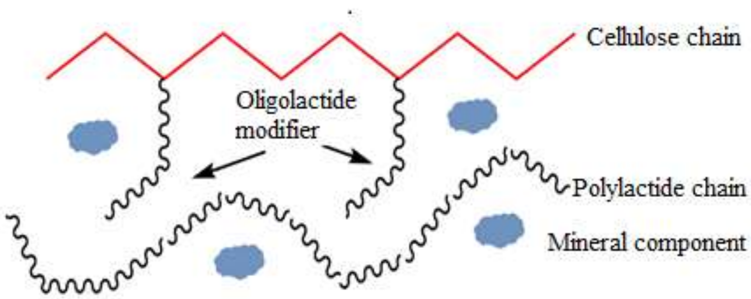
Obtaining biodegradable materials based on inorganic minerals (bentonite, kaolin, etc.). Research on obtaining biodegradable composite materials based on inorganic minerals (bentonite, kaolinite, kaolin, zeolites, etc.) has attracted the attention of scientists in recent years. One of the advantages of natural inorganic minerals such as bentonite, kaolin, zeolites is that these substances are non-toxic, have high biocompatibility with living cells, and are widely used in the production of biomedical products. At the same time, the release of environmentally friendly components from the decomposition of degradable materials to which these substances are added further expands their areas of application.



The bentonite mineral used in this work is of the “PPD” brand, obtained from “Bentonite” LLC (Uzbekistan), and the kaolin mineral samples of the “AKT-35” brand were obtained from “ANGREN KAOLIN” LLC (Uzbekistan). The chemical element composition of these minerals was analyzed by X-ray fluorescence analysis. The analysis results showed that bentonite and kaolin minerals are mainly composed of aluminosilicates, with relatively large amounts of Fe, Mg, K, S; and smaller amounts of P, Cr, Ni, Cu, Zn. Heavy and toxic metals are not found. The content of aluminum oxide in the brand of kaolin used in this work is not less than 35 %. Gray clays containing mainly montmorillonite were used in the bentonite composition.

Chemical modification of inorganic minerals (bentonite, kaolin, etc.). Minerals such as bentonite and kaolin were processed through several stages of purification and processing before use. After that, for organic modification, the obtained bentonite (kaolin) was chemically modified with L-lactic acid. The fact that the modification occurred on the surface of the minerals was monitored by IR spectroscopy. When the Al-O-Al bonds on the surface of the minerals are broken by alkali and heated with L-lactic acid, the mineral components are chemically bonded to the L-lactic acid residue. It was proven in subsequent experiments that the resulting products have good adhesion to the polymer matrix and allow obtaining materials with improved properties.

Obtaining biodegradable materials based on polylactide/modified cellulose/mineral components. Two methods were used to synthesize biodegradable composite materials based on polylactide, cellulose modified with lactic acid and its oligomer, and mineral components (bentonite, kaolin): 1) "hot pressing" method 2) solvent casting method.



Selection of the maqbul composition of biodegradable materials. In both polylactide and cellulose modified with lactic acid or its oligomer, the ratio of components from 60/40 to 90/10 was observed, with an increase in the amount of polylactide, the mutual adhesion of the components and the homogeneity of the material increased. It was found that samples with a mass content of 70 % polylactide in the composite composition had sufficient homogeneity, and 75 % and more allowed to obtain composite materials at an maqbul level. Since the cost of polylactide is more expensive than others among the components of biodegradable materials, its amount should be as low as possible to reduce the cost of the product. Therefore, samples containing about 70-80 % polylactide were considered the most maqbul composition. It was observed that all products obtained as a result of modification of cellulose with lactic acid and its oligomer had good adhesion to the polylactide matrix. Mineral components of the samples: when obtaining composite materials by adding kaolin and bentonite, composites were formed by adding up to 20 % inorganic mineral components by weight of the product, while maintaining the polylactide/cellulose ratio (80:20) in the sample composition. It was found that the addition of more than 15 % mineral components to the sample composition negatively affects the physicochemical and mechanical properties of the materials. Therefore, in further studies, samples of materials with up to 15 % mineral components were studied.

The third chapter of the dissertation, entitled **"Study of the physicochemical, mechanical and biological properties of biodegradable materials",** presents the results of experiments on the study of the physicochemical, textural, mechanical and biological properties of synthesized biodegradable materials. The synthesized materials were studied using modern methods, including FTIR, TGA, DSC, XRD, SEM, optical determination of contact angles to determine the degree of hydrophilicity; cytotoxicity, antibacterial, antifungal, sanitary and hygienic properties. From the results of the study of biodegradable materials using IR spectroscopy, it was found that the band corresponding to the carbonyl (CO) group, which appeared in the region of ~1750 cm^{-1} in pure PLA / cellulose-containing materials, shifted to the region of 1734 cm^{-1} and 1718 cm^{-1} as a result of the addition of 5 % mineral components, indicating that the mineral component and the polymer shows that coordination effects have occurred between polymer macromolecules (Fig. 3). The shift of the bands corresponding to the -C-O- vibrations in the ~1080 cm^{-1} region to the 1014 cm^{-1} and 960 cm^{-1} regions, as well as the shift of the same bands to the 981 cm^{-1} region, also indicates the occurrence of strong interactions between polymer macromolecules and mineral components.

According to the results obtained in the study of the thermal properties of the materials, the main decomposition of pure PLA/mod-cellulose-based materials was between 350-410 ^oC, and with an increase in the amount of bentonite mineral, the starting point of the main decomposition temperature decreased to 340-330-320 ^oC, respectively; in samples with the addition of kaolin, it decreased to 330-320-315 ^oC (Figure 4, curves 2-4). It was observed that the introduction of 2.5 % (total 5 %) and 5 % (total 10 %) bentonite and kaolin minerals into the composition of the samples reduced their starting temperature of the main decomposition to 280 ^oC (Figure 4, curves 8-10).

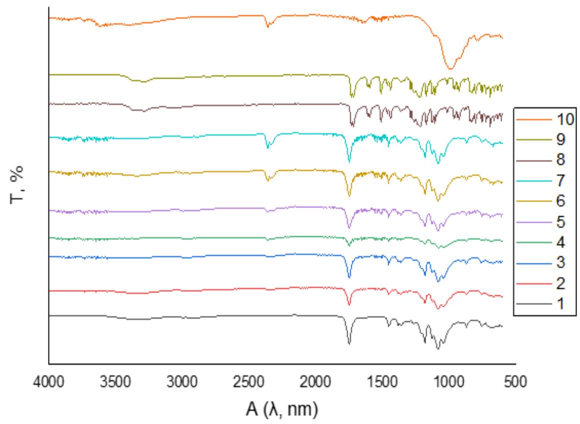


Figure 3. Comparative IR spectra of synthesized samples

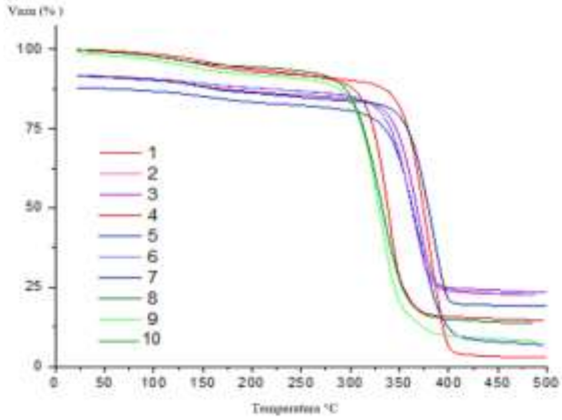


Figure 4. Comparative evaluation of thermal properties of samples

It was observed that the ash residue of the samples with the addition of kaolin was lower than that of all the samples. This is explained by the catalytic role of kaolin in the oxidation process of the material sample in the presence of atmospheric oxygen.

The results of the analysis of the samples by the differential scanning calorimetry (DSC) method show that the, T_g value of the samples of materials based on pure polylactide and modified cellulose is ~170 ºC, and it can be seen that its values change when bentonite mineral is added to the samples. The highest value (175 ºC) was observed when 10 % bentonite was added to the samples (Fig. 4, curve 3). This is due to the fact that the nanoparticles of the mineral included in the samples reduce the mobility of the polymer chain and reduce the free space.

At temperatures below T_g, the polymer chain cannot move freely and the materials become glassy and brittle. In this case, bentonite nanoparticles require more energy to move the polymer chain due to the reduction of free space. The introduction of kaolin into the samples (Figure 5, curves 5-7) led to a decrease in the glass transition temperature (T_g) compared to pure polylactide/cellulose samples, and even in samples with 10 % kaolin (curve 6), the lowest value was observed among all synthesized samples - 150 ºC. It was observed that the introduction of bentonite and kaolin minerals together in an amount of 5% allowed to obtain materials with the lowest glass transition temperature (150 ºC), and therefore the largest proportion of free space (Figure 5, curve 8).

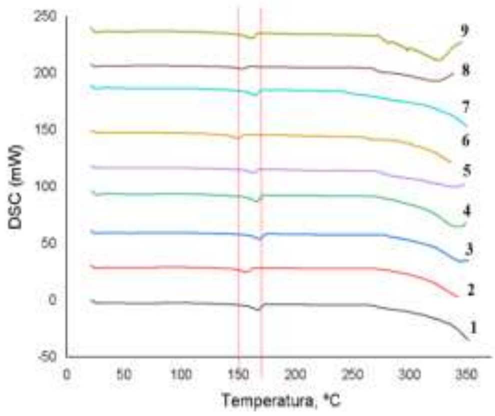


Figure 5. Results of determining the glass transition temperature (Tg) of materials

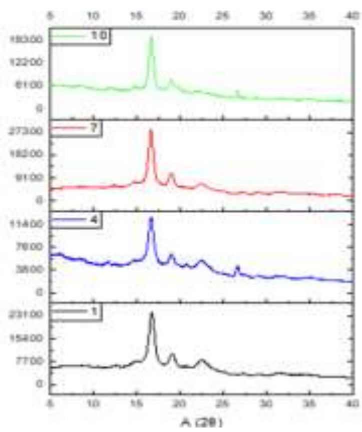


Figure 6. X-ray diffraction analysis of samples

The results of X-ray phase analysis of the samples showed that the intensity of signals related to polylactide in the, 2θ=15-20º region decreased with an increase in the amount of mineral added to the sample (Fig. 6). The increase in the number and intensity of signals in the 2θ=20-35º region is proportional to the amount of added bentonite and can be explained by its crystallinity. The XRD analysis of samples obtained from the addition of up to 15 % kaolin mineral to the PLA/mod-Cell 80:20 composition compared to its mass showed that the intensity of signals related to polylactide in the 2θ=15-20º region was higher than in the corresponding samples with the addition of bentonite, and an overall decrease in signals was observed here with an increase in the amount of mineral added to the sample.

In the 2θ=20-35º region, the dependence of the number and intensity of signals on the amount of added kaolin was not observed. The total number of signals in all samples was observed to be higher than in samples with bentonite added.

When analyzing samples containing PLA / mod-Cellulose / Bentonite + Kaolin, it was observed that the introduction of a mixture of bentonite/kaolin minerals led to a higher overall crystallinity level compared to samples containing bentonite, and a lower level compared to samples containing kaolin.

SEM analysis of biodegradable materials First, composite materials based on polylactide and modified cellulose (sample with a composition of PLA/OLA-g-Cell 80:20) were studied. From the SEM analysis results, we can see that in samples with PLA/OLA-g-Cell 80:20, very good adhesion occurred between the matrix - polylactide and modified cellulose (Figure 7).

In places where cellulose macromolecules are separated, the formation of porous spheres with a diameter of up to 20 μm was observed. Small crystallites of polylactide are visible in spheres with a size of up to 2-5 μm. In materials with up to 10 % bentonite mineral added to the samples, it can be seen that the components have very good adhesion to each other, and porous channels with a size of 2-7 μm are formed. It can be seen that bentonite added to the sample composition in an amount of 15% or more negatively affects the physicochemical and mechanical properties of the materials, and microcracks appear in the structure of the material (Fig. 8).

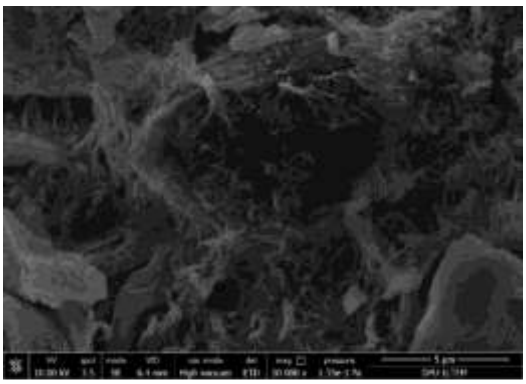


Figure 7. SEM image of PLA/mod-cellulose composite material

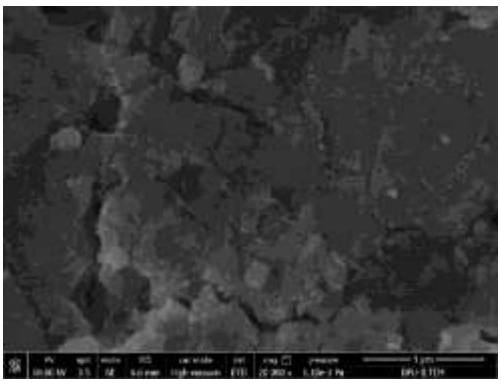


Figure 8. SEM image of PLA/Sell + B15 material

It was observed that good adhesion of components occurred in the microstructure of materials with the introduction of up to 10 % kaolin mineral into the composition of the materials. It was also found that adhesion between components deteriorated relatively when kaolin was introduced into the composition of the materials. In general, it is worth noting that good adhesion can be observed in the microstructure of materials obtained with the introduction of up to 15 % kaolin mineral into the composition of the samples. When studying the samples of composite materials obtained by adding bentonite + kaolin minerals in various ratios of 5-15 % by weight to the PLA / OLA-g-Cell 80:20 composition, it was found that in the microstructure of materials obtained from the introduction of 2,5 % (total 5 %) and 5 % (total 10%) of bentonite and kaolin, regular, separate crystal clusters (parts) with sizes of ~5-15 μm appeared. (Fig. 9).

It is evident that these crystal clusters are formed due to the interaction of polymer macromolecules and mineral components.

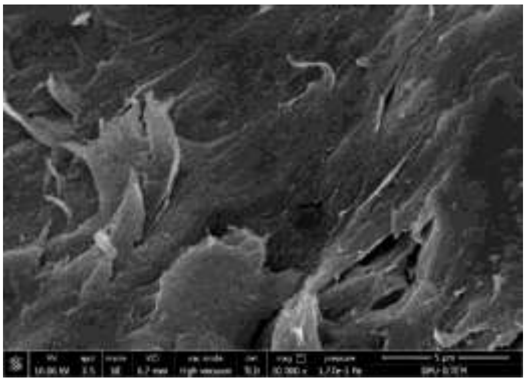


Figure 9. SEM image of PLA/Sell+K10 composite material

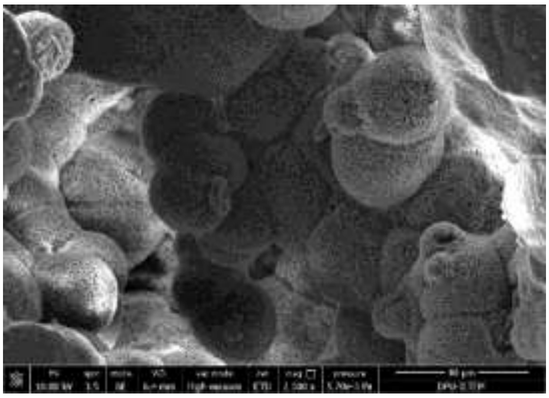


Figure 10. SEM analysis of PLA/Sell+B7.5+K7.5 composite materials

SEM analysis of materials with a composition of bentonite + kaolin 7.5 % + 7.5 % leads to an increase in the size of crystal clusters to ~50-100 μm (Fig. 10). It was observed that these clusters consist of micro-level, regular, porous structures. Although the presence of such pores plays a positive role in the biodegradation of the material on the one hand, on the other hand, it can have a negative effect due to the deterioration of its mechanical properties.

In studies conducted on the optical determination of the contact angles of materials, water was used as the probe fluid (Fig. 11). It is known that an increase in hydrophilicity leads to a faster degradation of materials when they are released into the environment after use. It was found that the introduction of bentonite and kaolin minerals into the composition of the samples causes the appearance of pronounced hydrophilic properties (θ<60°). In this case, it was observed that when both components are introduced together, with an increase in their amount, the hydrophilicity of the samples slightly decreases, that is, the contact angle increases.

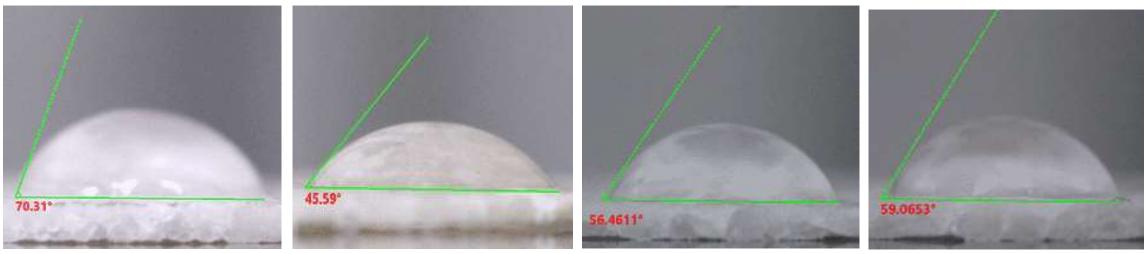


Figure 11. Hydrophilicity of materials

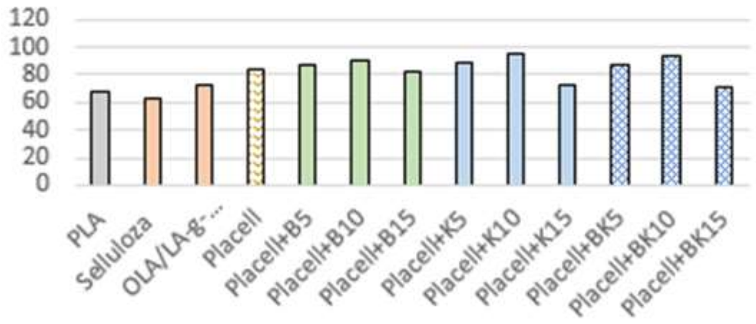


Figure 12. Mechanical properties of materials

In studying the mechanical properties of materials. The tensile strength of the starting materials (PLA, cellulose, modified cellulose) and the materials obtained from them was determined (Figure 12). From the results of experiments conducted to determine the mechanical properties, it was found that the introduction of modified cellulose into PLA improves its mechanical properties, that the tensile strength increases in samples with a bentonite and kaolin content of up to 10%, and that the introduction of more than 10% mineral components into the sample composition leads to a deterioration in its mechanical properties.

The fourth chapter of the dissertation, entitled **"Technology of obtaining biodegradable materials and their sanitary and hygienic properties,"** presents the results of experiments on the study of the technological foundations of the production of biodegradable materials consisting of PLA/mod-Cellulose + B/K. Figure 13 below shows a schematic diagram of this process.

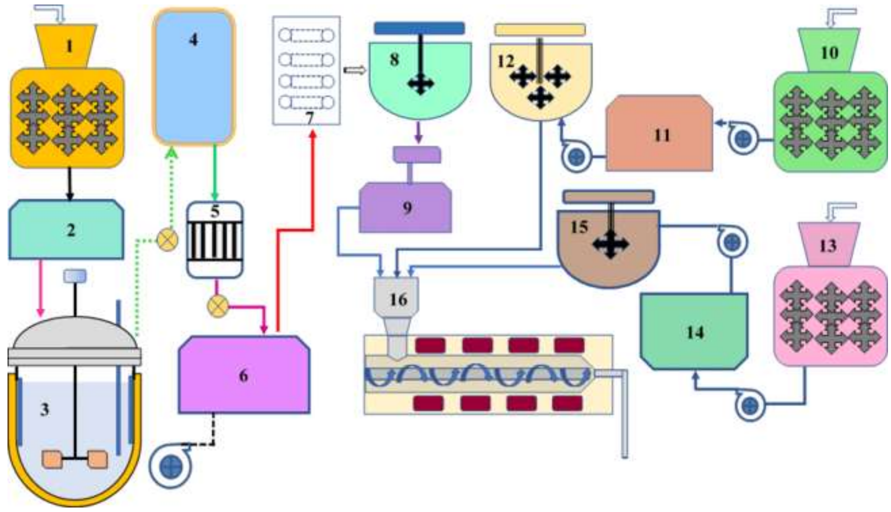


Figure 13. Technological scheme for the production of biodegradable materials.

The technological scheme presented in Figure 13 includes the following processes: initially, in the first block, the raw materials necessary for obtaining L-lactic acid (corn, triticale, barley, wheat, etc.) are ground (1) and brought to the form of flour. The starch contained in it is first subjected to acidic or enzymatic hydrolysis (2). The hydrolysis product is converted into L-lactic acid by microbiological means (3). L-lactic acid is purified by precipitation, acid treatment, distillation (4) and other means (5), and is first converted into cyclic lactide (6, 7), and then into polylactide by catalytic polymerization in a special reactor (8). Polylactide can be brought to the form of a finished product in the form of granules (9). In the second block, the process prepares the cellulose source for synthesis by crushing (10) and separating the cellulose from it, purifying (11) and chemically modifying it (12). In the third block, the mineral components (bentonite, kaolin) are first crushed (13), purified (14) and chemically modified (15) and prepared for synthesis. The components prepared for synthesis (9, 12, 15) are compounded in the "solvent casting method" and converted into a finished product in the form of granules in an extruder (16).

On testing the sanitary and hygienic properties of biodegradable materials In experiments conducted in accordance with the requirements of "GOST EN 13432—2015", non-biodegradable organic components account for 1 % of the sample mass, mainly due to polyvinyl alcohol used as a compatibilizer. Poly-L-lactic acid can be degraded by microbial biodegradation and chemical hydrolysis by water. Cellulose is also a natural component that is degraded by microorganisms. Inorganic mineral components are added to the soil component as a result of material destruction.

When determining the total dry solids content, the dry residue remaining as a result of moisture removal was in the range of 96-98.5 %. Mass loss during combustion of a solid when tested, it was found that the mass loss when heated to 550 °C in the open air was in the range of 83.9-97.5 %. According to the requirements of the standard, the mass loss during combustion of a solid sample should not be less than 50% of the mass of the substance. When determining the amount of hazardous substances and heavy metals in the materials, it was determined that the amount of heavy metals and toxic components in the materials did not exceed the standard level. In aerobic composting, experiments were conducted in the same way as above, only in open containers, and the decomposition of the material sample was checked within 12 weeks. It was found that 96-98% of the initial mass of the samples was completely decomposed. When passing through a 2 mm sieve, it was found that 2-4% of the products remained undecomposed

Ecotoxicity tests. Ecotoxicity tests were conducted on garden soil containing up to 50% biodegradable compost, according to standard methods. Control tests were conducted on clean garden soil. 100 seeds of 1) Cucumis sativa (cucumber) 2) Allium cepa (onion) were sown on compost samples, and the samples were kept in the dark during the test.

Figure 14. Decomposition patterns of materials in a compost heap

The growth rate of the plants in the compost obtained from the synthesized samples and the number and biomass of seedlings in the clean compost was calculated in %. it was determined that the biomass growth rate was 97-103%

compared to the standard. From this, it was concluded that the developed materials are nontoxic.

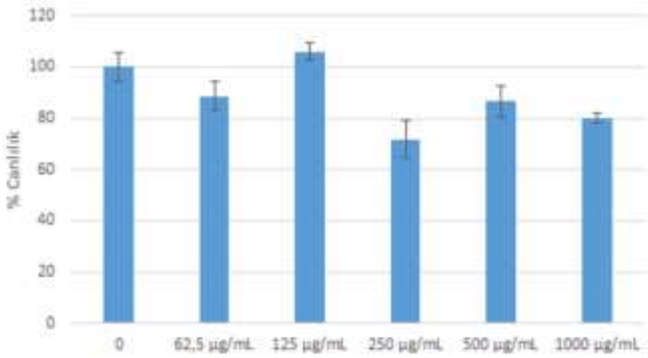


Figure 15. Investigation of the cytotoxic properties of synthesized biodegradable materials

Study of cytotoxic properties. The cytotoxic properties of the synthesized samples were determined in A549 and L929 cells using the 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide (MTT) method. Based on the optical densities of the samples, the viability of the cells in each well was calculated in % compared to the control sample. Based on the results obtained (Fig. 15), it can be concluded that the synthesized material samples do not have pronounced cytotoxic properties. The maximum cell death was up to 30 %, which could be due to various external factors. In general, it was found that the viability of cell samples exposed to the suspension of materials ranged from 86-107 %, allowing us to conclude that these materials do not have cytotoxic properties.

The research conducted to determine the competitiveness of the proposed compositions took into account the costs of chemicals, catalysts and electricity consumed for production (Table 1).

Table 1.

Cost of proposed biodegradable materials

Component	Unit of measu-rement	Unit price*, UZS	Minimum cost		Maximum cost		Note
			Spend	Price, UZS	Spend	Price, UZS	
Polylactide	kg	6985	727,273	5080001,905	727,273	5080001,905	Electricity consumption is different in solvent casting and extrusion methods
Cellulose	kg	19350	181,818	3518178,3	181,818	3518178,3	
Bentonite	kg	500	45,4545	22727,25	45,4545	22727,25	
Kaolin	kg	200	45,4545	9090,9	45,4545	9090,9	
Electricity consumption	kW* hour	900	50	45000	200	180000	
solvent	L	75000	50	3750000	100	7500000	
				12424998,36		**16309998,4**	**14367498,36**

Raw material prices were formed based on exchange trading quotations held on the Uzbekistan Republican Commodity Exchange (uzex.uz) in March 2025.From the table data, it can be seen that the average cost of producing 1 kg of biodegradable materials with the proposed composition is 14,367 UZS (equivalent to 1,114 USD according to the Central Bank exchange rate in April 2025). The following were taken as the basis for calculating the cost: 1) The raw material for the L-lactic acid production process is corn starch, with a starch content of 60 %-70 %. The yield of L-lactic acid production by microbiological methods: minimum – 50 %; maximum – 80 %. 2) The reaction yield in the synthesis of poly-L-lactide was assumed to be: minimum – 50 %; maximum – 70 %. In laboratory conditions, the reaction yield reached 80-83 %. Catalyst consumption, relative to the mass of raw materials: minimum – 0,5 %; maximum – 1 %. 3) The minimum value of the amount of electricity consumed in all processes was calculated based on literature data, and the maximum values were calculated from the amount of electricity consumed by the devices used.

CONCLUSION

1. Biodegradable materials with the composition PLA/OLA-g-Sell/B10; PLA/OLA-g-Sell/K10; PLA/OLA-g-Sell/B5/K5 (80:20+10 %) were synthesized based on cellulose modified with polylactide, oligolactide and mineral components: bentonite, kaolin.
2. It has been found that chemical modification of cellulose obtained from plant waste with lactic acid oligomer enhances interactions between the macromolecules of the components, thereby improving the physicochemical and mechanical properties of the materials.
3. It has been shown that the addition of up to 10 % kaolin or 5 % kaolin/bentonite to the materials has a positive effect on the physicochemical and mechanical properties of the materials; it has been shown that with an increase in the amount of kaolin mineral added to the materials, the decomposition temperature decreases by 70-80 ºC, the glass transition temperature decreases by ~25 ºC, plays a catalytic role in thermal decomposition, and leads to a decrease in the amount of ash residue.
4. Optimal conditions for the microbiological production of L-lactic acid, polylactide from it, and biodegradable materials based on it were selected using the bacterium *Lactiplatibacillus plantarum 3G*.
5. A technology (technological scheme, material balance) for the production of biodegradable materials based on local raw materials has been developed.
6. The obtained biodegradable materials were recommended for use in the scientific project “Synthesis and characterization of new nanoparticles by green synthesis using Lycium depressum extract” at Afyon Kocatepe University (Turkey); as a secondary packaging material for the drug “Novocaine injection 0.5 % solution, 5 ml” at the Uzbek-Bulgarian joint venture “Integra DD” LLC.

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САМАРКАНДСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ ИМЕНИ ШАРОФА РАШИДОВА

ХУДАЙНАЗАРОВ ЖАХОНГИР ОРТИК УГЛИ

БИОРАЗЛАГАЕМЫЕ МАТЕРИАЛЫ НА ОСНОВЕ ПОЛИЛАКТИДА: ПОЛУЧЕНИЕ, СВОЙСТВА И ТЕХНОЛОГИЯ

02.00.14 - Технология органических веществ и материалов на их основе

АВТОРЕФЕРАТ ДИССЕРТАЦИИ
ДОКТОРА ФИЛОСОФИИ (PhD) ПО ХИМИЧЕСКИМ НАУКАМ

Термез - 2026

Тема диссертации доктора философии (PhD) зарегистрирована в Высшей аттестационной комиссии при Министерстве высшего образования, науки и инноваций Республики Узбекистан за номером B2025.2.PhD/K1017.

Диссертация выполнена в Самаркандский государственный университет имени Шарофа Рашидова.

Автореферат диссертации на трех языках (узбекский, русский, английский, (резюме)) размещен на веб-странице Научнова совета (www.ik-kimyo.nuuz.uz) и на информационно-образовательном портале "Ziyonet" по адресу (www.ziyonet.uz).

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Защита диссертации состоится на заседании ученого при совета на базе ученого совета за номером DSc.03/2025.27.12.K/T.12.05 по присуждению ученой степени при Термизском государственном университете «08» 24 в 04 г. 2026. (Адрес: 190111, г. Термез, ул. Баркамол Авлод, 43.Тел.: (+99876) 221-74-55, факс: (+99876) 221-71-17, e-mail: termizdu@umail.uz).

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ВВЕДЕНИЕ (аннотация диссертации доктора философии (PhD))

Целью исследования является определение синтеза и свойств биоразлагаемых материалов с использованием полилактида, модифицированной целлюлозы и неорганических минералов.

В качестве объекта исследования работы; выращ исходных материалов были выбраны L-молочная кислота, поли-L-молочная кислота, целлюлоза из растительных остатков, бентонит и каолин.

Научная новизна исследования заключается в следующем:

на основе полилактида, олиголактид-модифицированной целлюлозы и минеральных компонентов: бентонита и каолина было синтезировано 9 различных биоразлагаемых материалов с составом PLA/OLA-g-целлюлоза/бентонит/каолин 80:20 + 5/5;

с использованием бактерии Lactiplatibacillus plantarum 3G были определены оптимальные условия получения L-молочной кислоты, полилактида и биоразлагаемых материалов из нее микробиологическим путем;

было установлено, что прочность на разрыв биоразлагаемых материалов, полученных в результате введения до 10% каолина или 5% каолина/бентонита в состав материалов, увеличилась в 1,4 раза;

была разработана технология получения биоразлагаемых материалов на основе местного сырья: полилактида, олиголактид-модифицированной целлюлозы и минеральных компонентов.

Внедрение результатов исследования. На основании результатов, полученных в ходе исследования синтеза и свойств биоразлагаемых материалов с участием полилактида, модифицированной целлюлозы и неорганических минералов, образцы полученных биоразлагаемых материалов были использованы для определения цитотоксических, антибактериальных, противогрибковых и ранозаживляющих свойств в рамках научного проекта «Синтез и характеристика новых наночастиц методом «зеленого» синтеза с использованием экстракта Lycium depressum» на кафедре химии Университета Афьон Коджатепе (Турция) (номер заявки Университета Афьон Коджатепе от 17 февраля 2025 г.). В результате удалось получить биоразлагаемые материалы с антибактериальными и противогрибковыми свойствами на основе полилактида, олиголактид-модифицированной целлюлозы и минеральных компонентов: PLA/OLA-g-Sell/B10; PLA/OLA-g-Sell/K10; PLA/OLA-g-Sell/B5/K5;

Синтезированные материалы были использованы в качестве вторичной упаковки для лекарственного препарата «Новокаин 0,5% раствор для инъекций, 5 мл» на узбекско-болгарском совместном предприятии ООО «Интегра ДД» (номер регистрации ООО «Интегра ДД»: 8 от 21 января 2025 г.). В результате удалось синтезировать материалы, отвечающие требованиям международного стандарта «ГОСТ ЭН 13432:2015».

Структура и объем диссертации. Диссертация состоит из введения, четырех глав, заключения и списка литературы. Объем диссертации составляет 117 страниц.

E’LON QILINGAN ISHLAR RO‘YXATI
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I bo‘lim (I part; I часть)

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II bo‘lim (II часть; II part)

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