



Faculty of Pharmacy
Universitas Padjadjaran



Bedah Buku : NANOTEKNOLOGI BERBASIS POLISAKARIDA UNTUK APLIKASI BIOMEDIS



Kuliah Tamu
Program Studi Farmasi
Universitas Lambung Mangkurat
20 Juni 2026



Nanoteknologi
Berbasis
Polisakarida

untuk Aplikasi Biomedis

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<https://farmasi.unpad.ac.id>

The faculty of excellence



Perkenalan



Prof. apt. Nasrul Wathoni, Ph.D.

Education :

- Undergraduate, 2000-2004
Faculty of Pharmacy, Universitas Padjadjaran, Bandung-Indonesia
- Pharmacist, 2004-2005
Faculty of Pharmacy, Universitas Padjadjaran, Bandung-Indonesia
- Master of Pharmaceutic, 2007-2009
School of Pharmacy, Institut Teknologi Bandung, Bandung-Indonesia
- Doctor, 2014-2017
Physical Pharmaceutic Department, Kumamoto University, Kumamoto-Japan

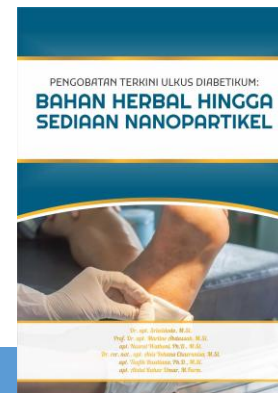


2024, 2025

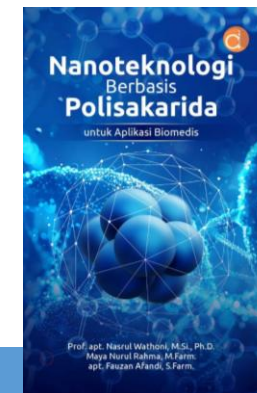
Publications

	Scopus	GScholar
Article	122	183
Citation	4025	5027
Cited Document	111	158
H-Index	33	37
i10-Index	76	93

Books



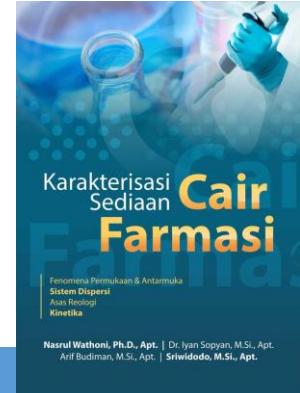
2020



2025



2018



2018

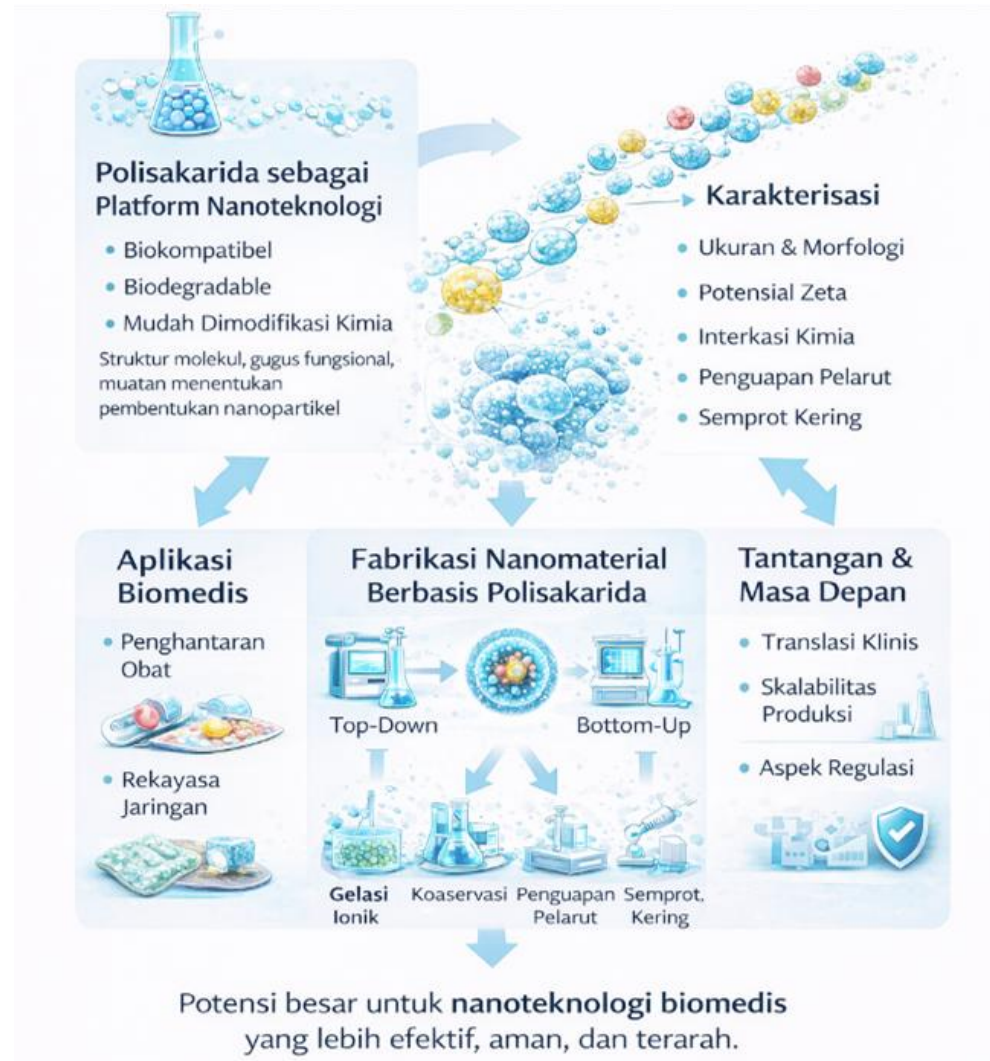
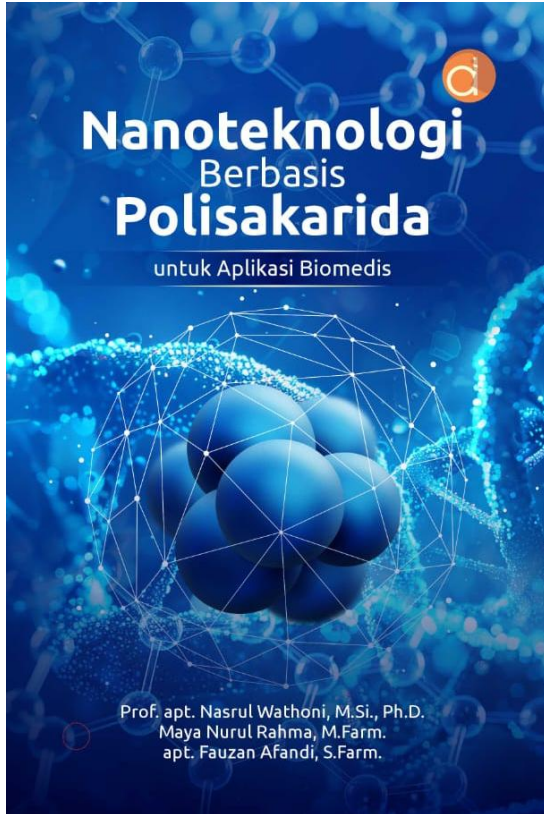


Link Materi Handout



<https://bit.ly/BukuPolisakaridaULM>

Intisari

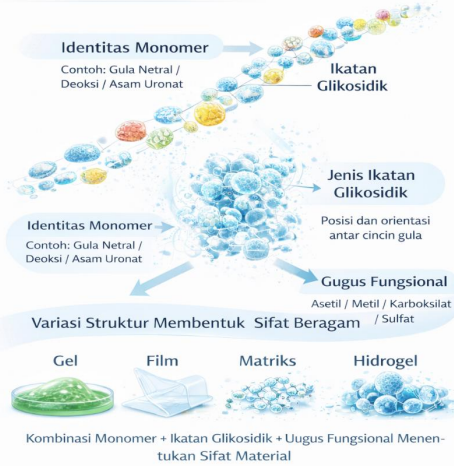


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Polisakarida sebagai Biomaterial Unggulan

Apa itu Polisakarida?
Struktur dan Klasifikasi



Bagian 2: FABRIKASI DAN KARAKTERISASI NANOMATERIAL BERBASIS POLISAKARIDA

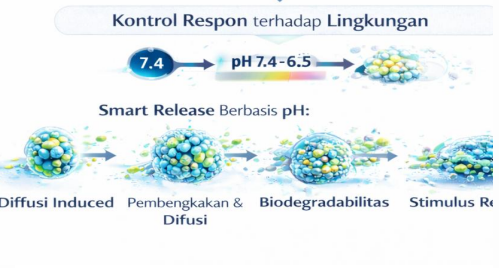
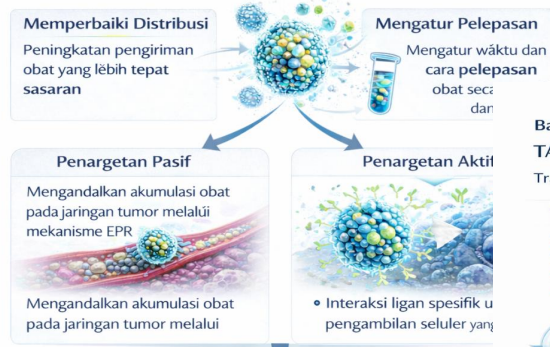
Metode Fabrikasi Nanopartikel Polisakarida
Top-Down dan Bottom-Up pada Fabrikasi



Bagian 3:
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Sistem Penghantaran Obat (Drug Delivery Systems)

Penghantaran Obat Tertarget dan Terkontrol



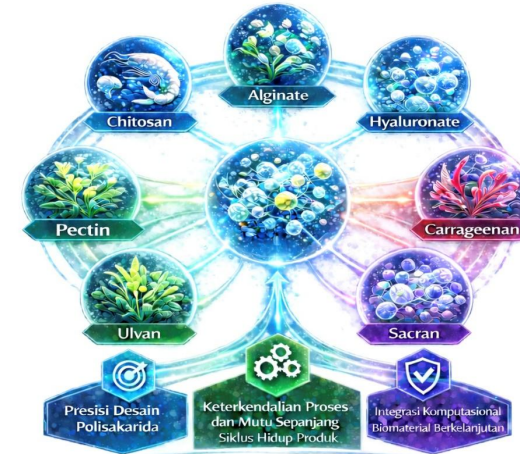
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Translasi Nanoteknologi Polisakarida dari Laboratorium ke Kli



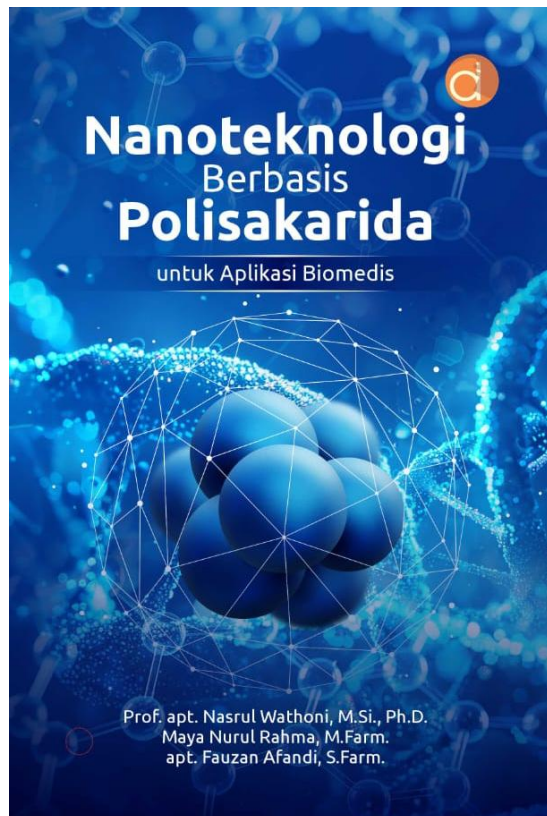
Bagian 5: PENUTUP
KESIMPULAN DAN REFLEKSI VISI MASA DEPAN

Nanoteknologi Berbasis Polisakarida



Presisi Desain Polisakarida + Kontrol Proses & Regulasi = Masa Depan Biomedis yang Aman & Berkelanjutan

Bagian 1



Bagian 1:
PENDAHUUAN DAN KONSEP DASAR

Polisakarida sebagai Biomaterial Unggulan

Apa itu Polisakarida?
Struktur dan Klasifikasi

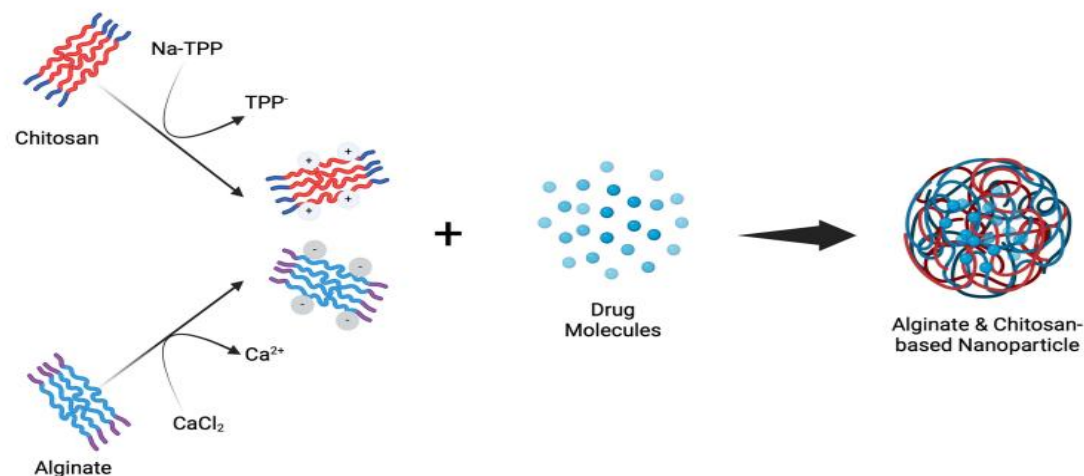
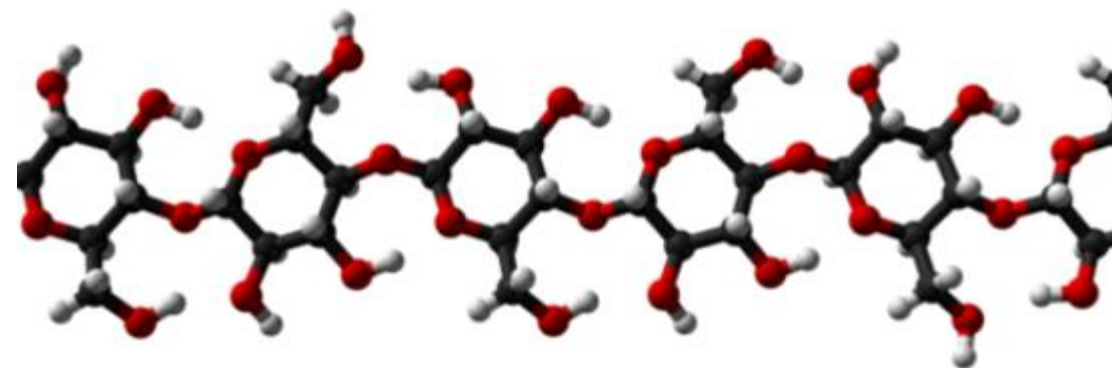


Apa itu Polisakarida: Struktur dan Klasifikasi

Polisakarida adalah **polimer karbohidrat** kompleks yang tersusun dari unit monosakarida berulang yang terhubung melalui ikatan glikosidik.

Variasi arsitektur molekul menentukan perilaku material pada skala nano, termasuk:

- Kelarutan dalam lingkungan berair
- Konformasi rantai molekul
- Interaksi dengan ion dan biomolekul lain



(Wathoni et al., 2024).

Tiga Pilar Arsitektur Molekul



Identitas Monomer

Gula netral, gula deoksi, atau turunan asam uronat yang menentukan sifat dasar kimiawi.



Ikatan Glikosidik

Posisi ikatan antar cincin gula yang menentukan orientasi dan fleksibilitas rantai polimer.



Gugus Fungsional

Gugus asetil, karboksilat, atau sulfat yang mengubah polaritas dan hidrasi material.

(Herdiana et al., 2024; Wathoni et al., 2024; Yuniarsih et al., 2024)

Klasifikasi Berdasarkan Komposisi



Homopolisakarida

Tersusun dari satu jenis monomer tunggal dalam rantai panjang.

Contoh: Selulosa, Pati, Glikogen.



Heteropolisakarida

Memuat lebih dari satu jenis monomer dalam struktur yang sama.

Contoh: Pektin, Karagenan, Heparin.

(Wathoni et al., 2024; Yuniarsih et al., 2024)

Klasifikasi Berdasarkan Muatan

3

Kategori Utama Muatan

Kationik (+)

Memiliki gugus amina (contoh: Kitosan). Penting untuk interaksi dengan membran sel.

Anionik (-)

Memiliki gugus karboksilat atau sulfat (contoh: Alginat, Sacran). Bersifat polielektrolit kuat.

Netral (0)

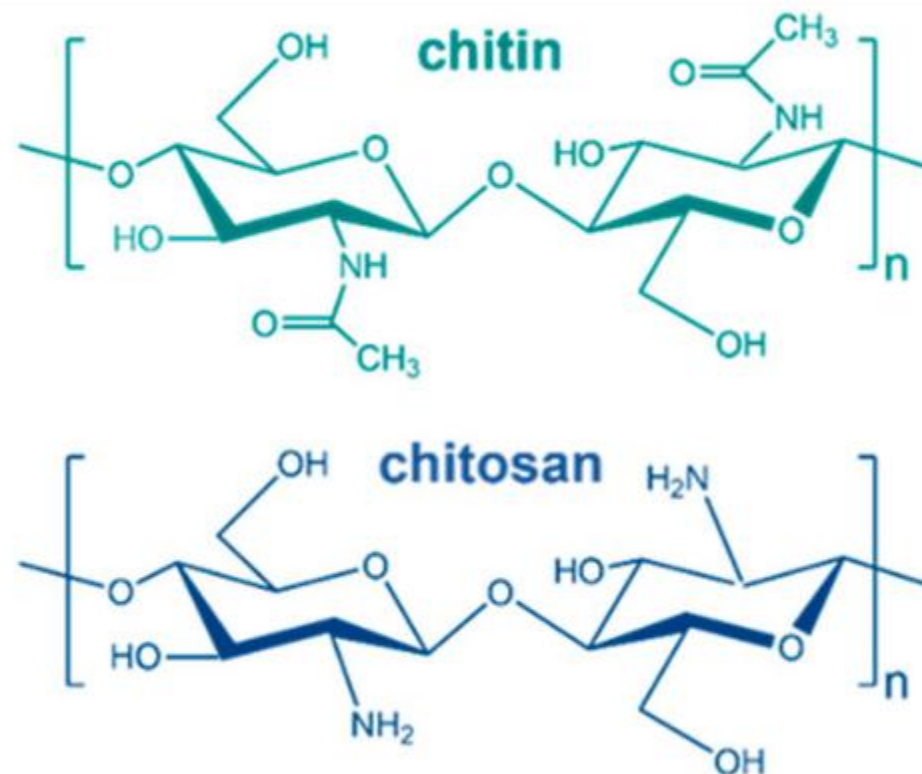
Tanpa muatan dominan, berperan stabil dalam kondisi fisiologis luas.

(Herdiana et al., 2024; Wathoni et al., 2024; Sulastri et al., 2025)

Kitosan: Platform Kationik Utama

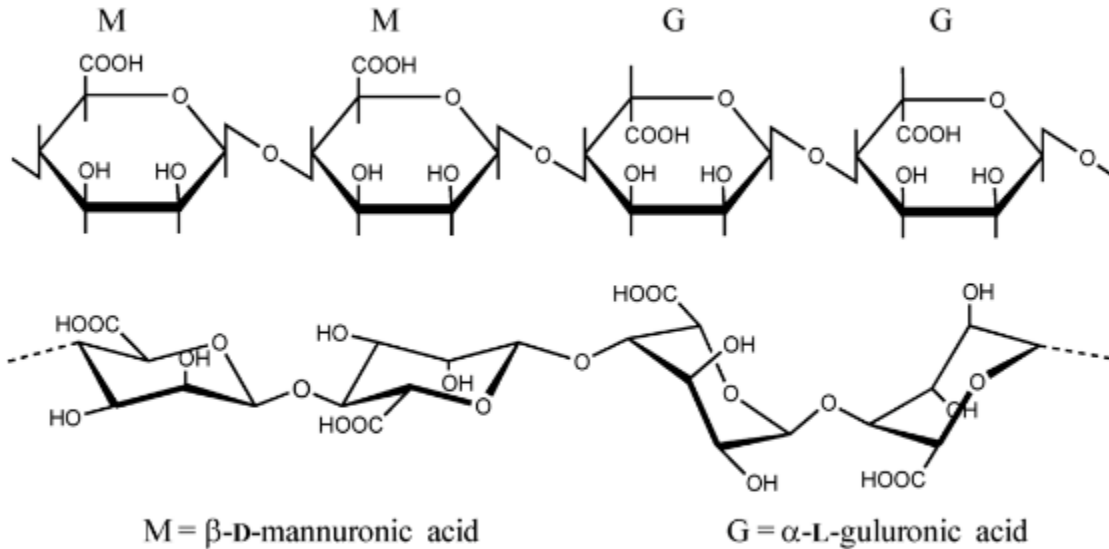
Berasal dari deasetilasi kitin, kitosan adalah platform paling populer dalam nanomedis.

- **Gugus Amina:** Memungkinkan protonasi di pH asam.
- **Mucoadhesion:** Melekat pada lapisan mukus negatif.
- **Modifikasi:** Mudah dimodifikasi secara kimia untuk fungsionalitas baru.



(Herdiana et al., 2024; Wathoni et al., 2024; Suharyani et al., 2025)

Alginat dan Karagenan (Anionik)

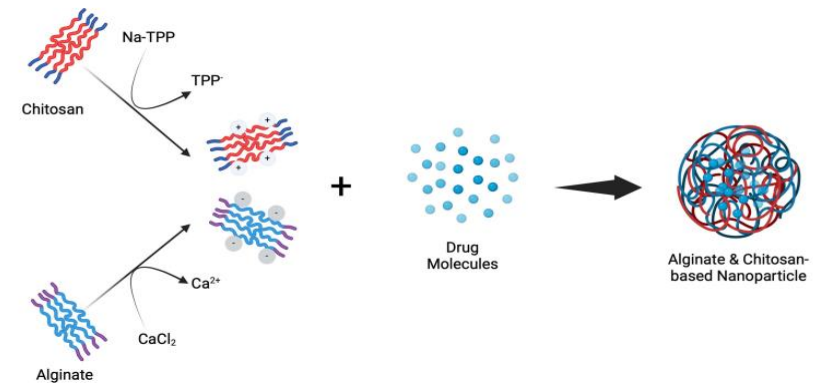


Dua raksasa anionik dari sumber laut (alga coklat dan merah).

Kompleks Polielektrolit

Mampu membentuk jaringan ionik saat bertemu dengan kitosan (kationik), menghasilkan nanopartikel tanpa reagen kimia berbahaya.

Ideal untuk enkapsulasi obat dan pelepasan terkontrol.



(Wathoni et al., 2024; Milanda et al., 2022; Sulastris et al., 2025)

Polisakarida Kompleks Spesifik

Sacran


Polisakarida megamolekuler tersulfatasi dengan kapasitas hidrasi luar biasa.


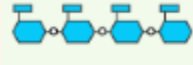


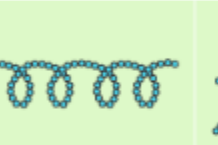
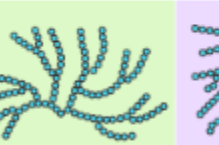
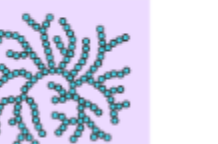

Ulvan

Berasal dari alga hijau, memiliki unit rhamnosa tersulfatasi yang unik.

Pektin

Kaya akan galakturonat, komponen struktural dinding sel tanaman.



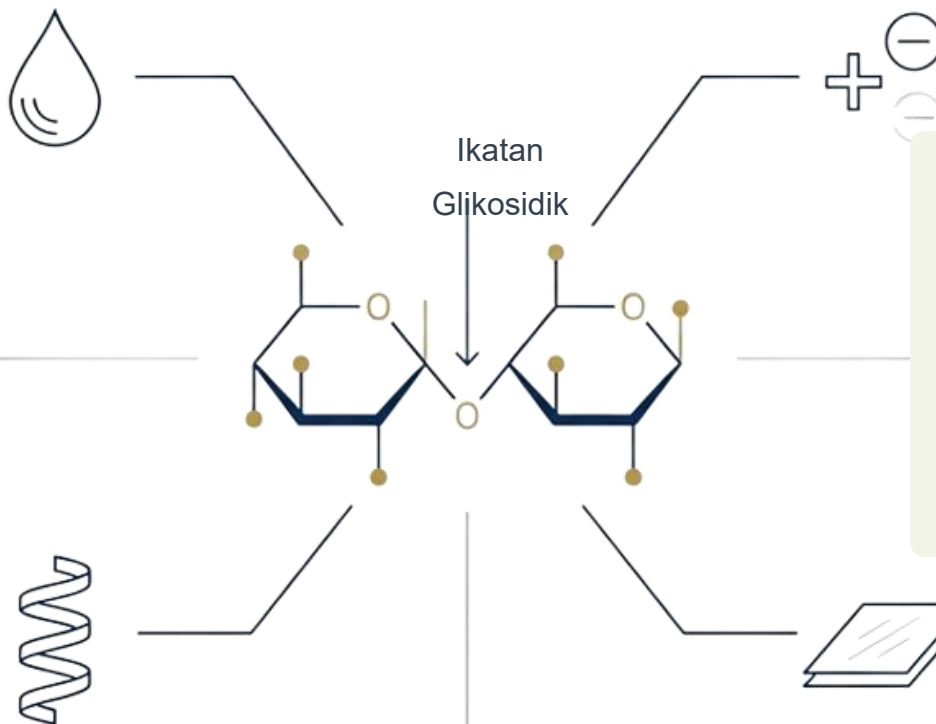
	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β -glucose	α -glucose	α -glucose	α -glucose
Bonds	1-4	1-4	1-4 and 1-6	1-4 and 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

(Sulastri et al., 2023; Yuniarsih et al., 2024)

Peran Vital Ikatan Glikosidik

Interaksi Molekuler

Memiliki gugus hidroksil, karboksilat, sulfat, dan amina yang memungkinkannya berinteraksi kuat dengan air, ion, dan biomolekul.



Aplikasi Biomedis

Mampu membentuk jaringan terhidrasi yang menyerupai lingkungan biologis tubuh manusia, diaplikasikan sebagai hidrogel, film, dan matriks.

Polimer karbohidrat berulang yang dihubungkan oleh ikatan glikosidik. Sifatnya ditentukan oleh jenis monomer, percabangan, dan muatan.

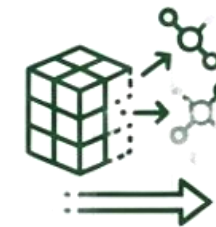
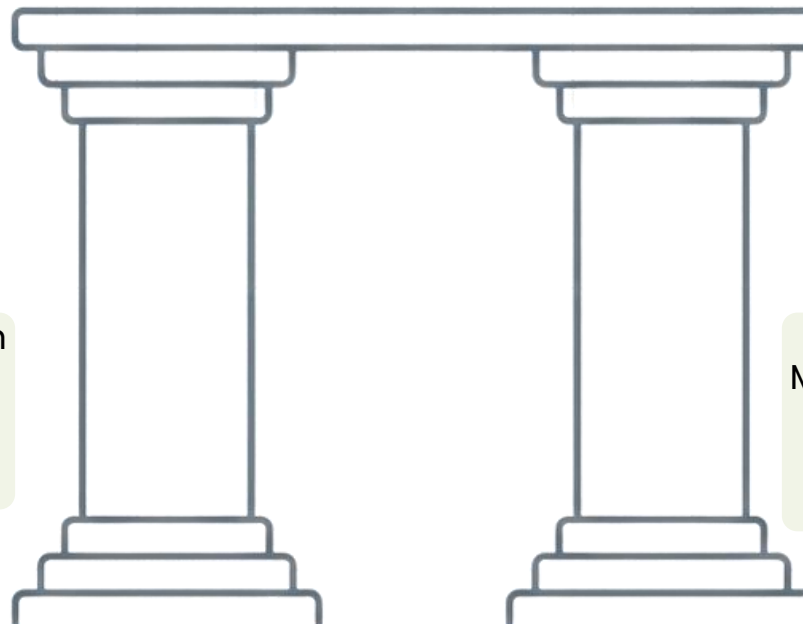
(Wathoni et al., 2024;
Yuniarsih et al., 2024;
Milanda et al., 2022)

Keunggulan Polisakarida



Biokompatibilitas

Material berinteraksi dengan jaringan tubuh tanpa menimbulkan respon inflamasi atau toksisitas



Biodegradabilitas

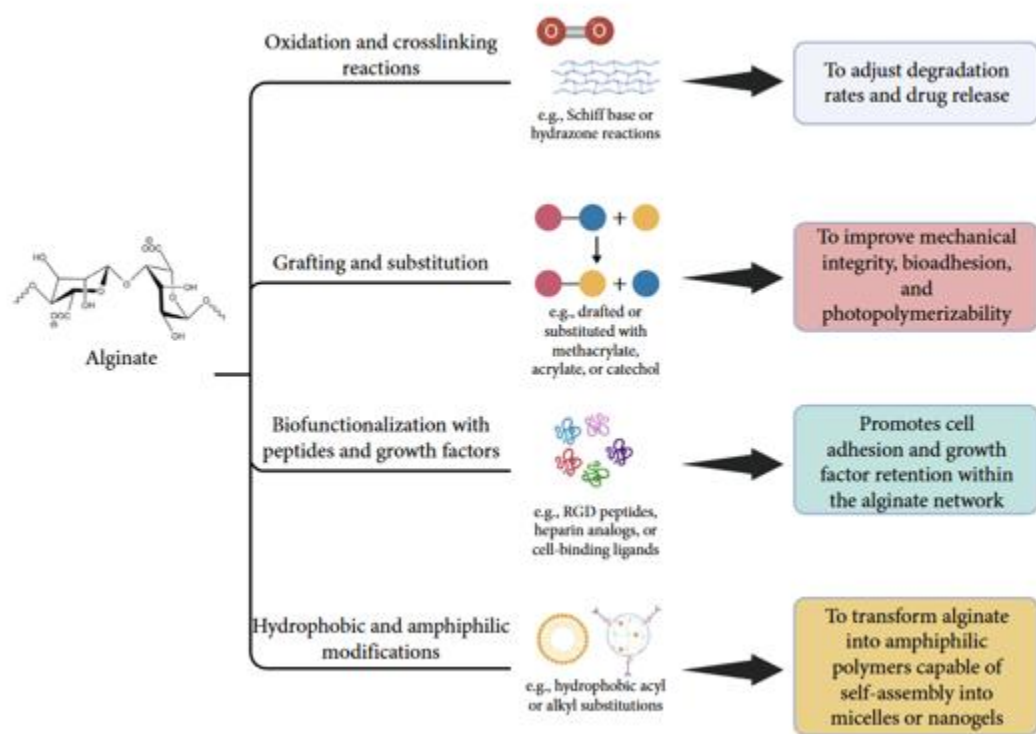
Material dapat terurai secara biologis dan aman

Strategi Modifikasi Struktural

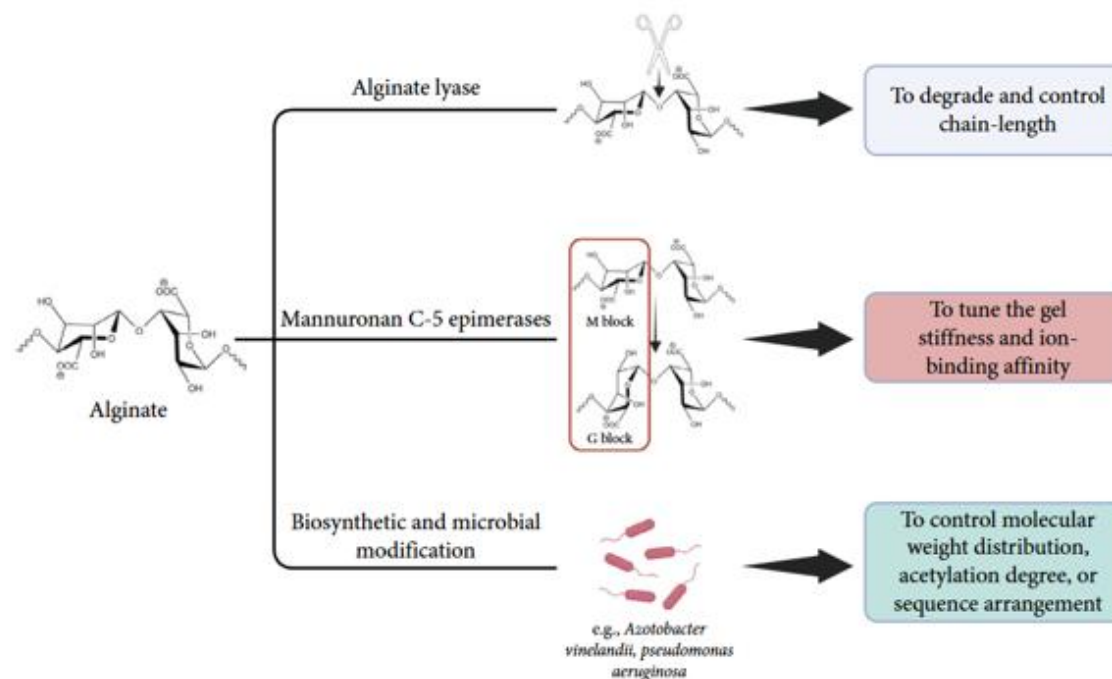
Fungsi dasar dapat diperkuat dengan cara crosslinking, grafting, konjugasi ligan dan pelapisan permukaan

(Yuniarsih et al., 2024; Wathoni, Suhandi, Purnama, et al., 2024; Arifka et al., 2022)

Modifikasi Kimia Polisakarida untuk Meningkatkan Fungsionalitas



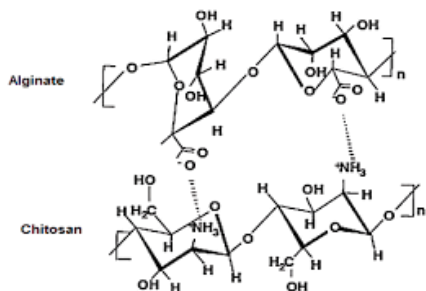
Gambar 1. Skema jalur modifikasi kimia polisakarida



Gambar 2. Skema modifikasi alginat melalui jalur enzimatik dan biosintetik

(Wathoni et al., 2026; Wathoni, Suhandi, Purnama, et al., 2024; Yuniarsih et al., 2024)

Peran Polisakarida dalam Nanoteknologi Biomedis

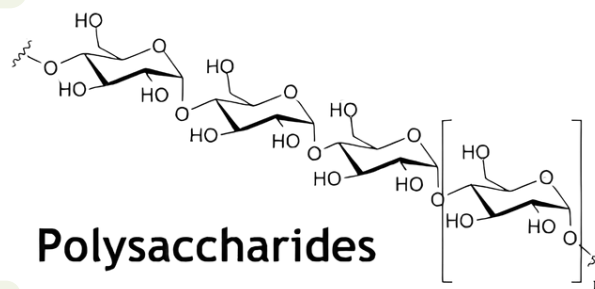


Sistem Cerdas

Kitosan yang bermuatan positif dengan alginat atau ulvan yang bermuatan negatif

Penargetan Spesifik

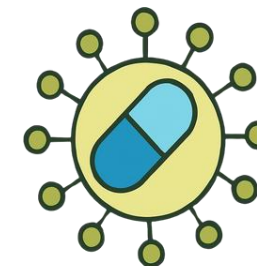
Sistem berbasis polisakarida juga dapat dibuat responsif terhadap lingkungan, misalnya terhadap perubahan pH, sehingga pelepasan obat dapat lebih terarah



Polysaccharides



Enkapsulasi Obat



Stabilitas meningkat



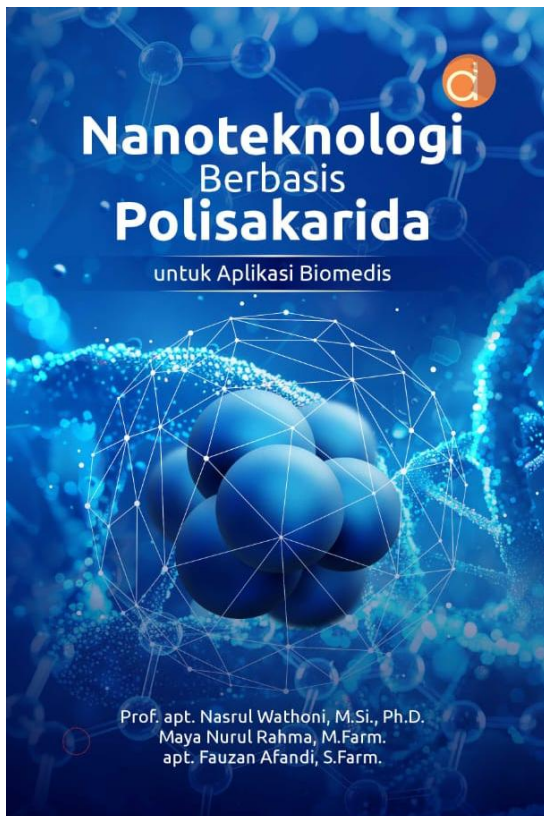
Mengatur Pelepasan Obat



Mengurangi efek toksik

(Wathoni, Herdiana, et al., 2024; Herdiana et al., 2024; Sulastri et al., 2025; Yuniarsih et al., 2024)

Bagian 2



Bagian 2: FABRIKASI DAN KARAKTERISASI NANOMATERIAL BERBASIS POLISAKARIDA

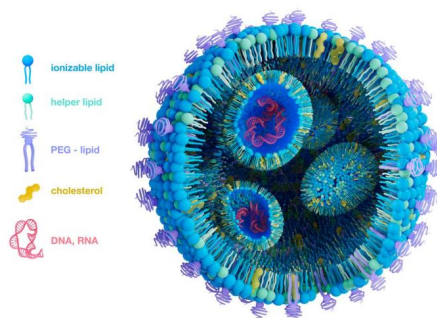
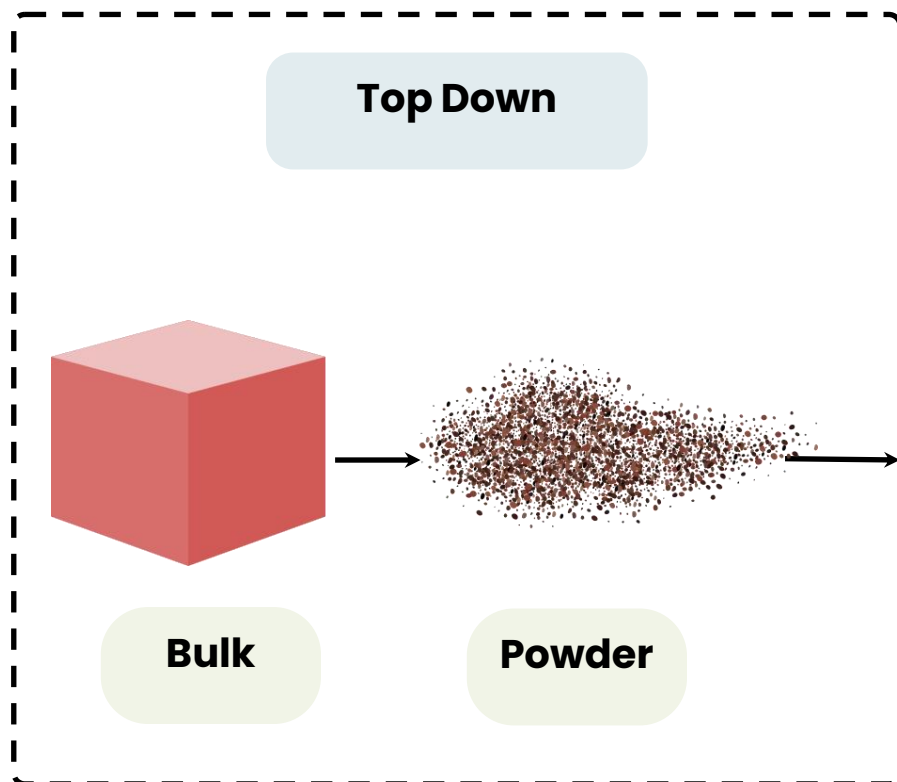
Metode Fabrikasi Nanopartikel Polisakarida
Top-Down dan Bottom-Up pada Fabrikasi



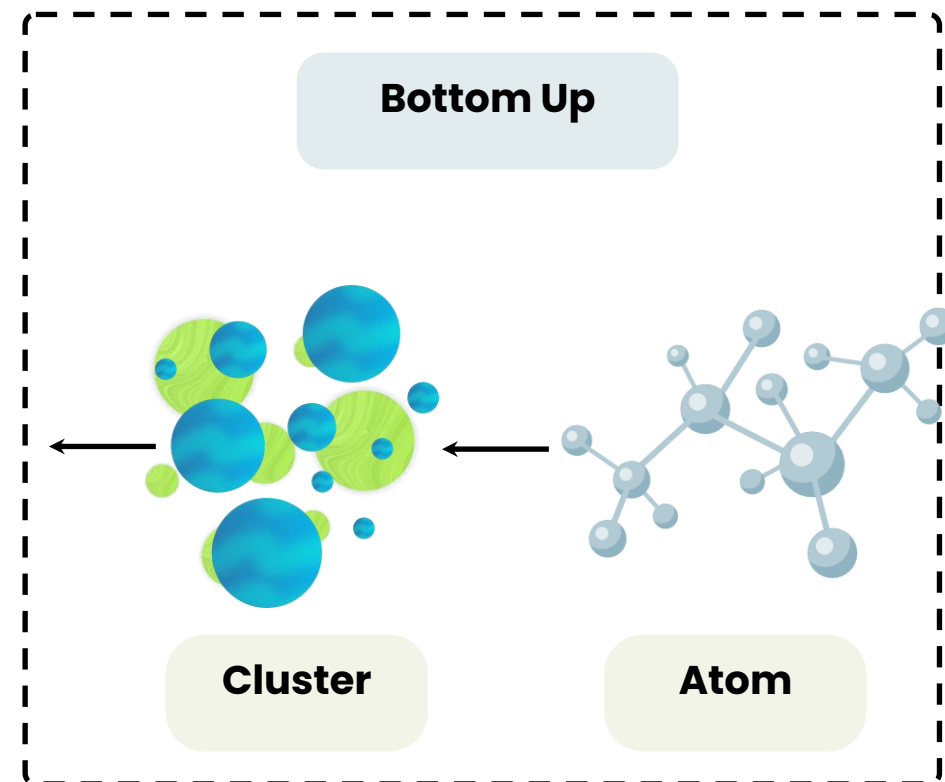
Pendekatan yang berbeda menghasilkan ukuran, morfologi, dan susunan partikel yang berbeda.



Fabrikasi Nanopartikel Polisakarida



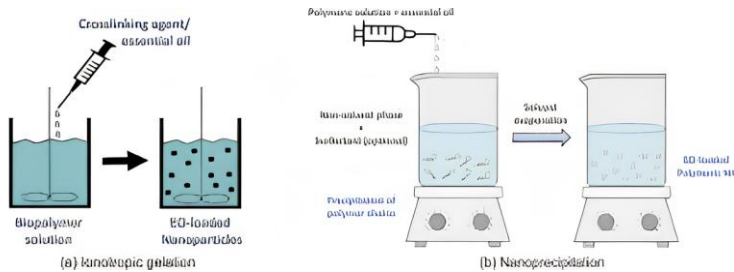
Nanopartikel



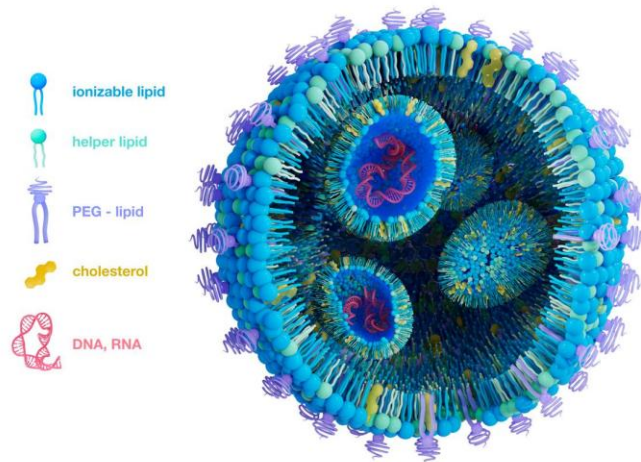
(Herdiana et al., 2022; Herdiana et al., 2024; Yuniarsih et al., 2024)

Metode Umum dalam Pembentukan Nanopartikel

Gelasi Ionik

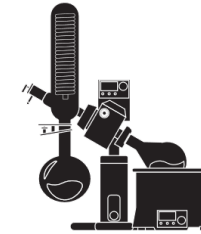


Koaservasi

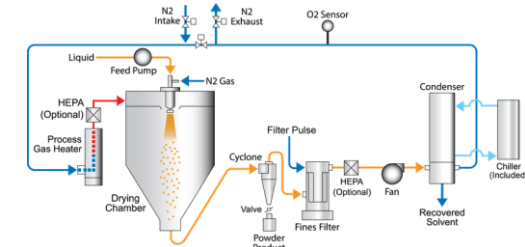


Nanopartikel

Penguapan Pelarut



Spray Drying



Sangat dipengaruhi oleh pH, urutan pencampuran, konsentrasi polimer, laju penambahan, pengadukan, dan proses pengeringan (Wathoni, Herdiana, et al., 2024; Yuniarsih et al., 2024; Sulastri et al., 2025; Sriwidodo et al., 2022)

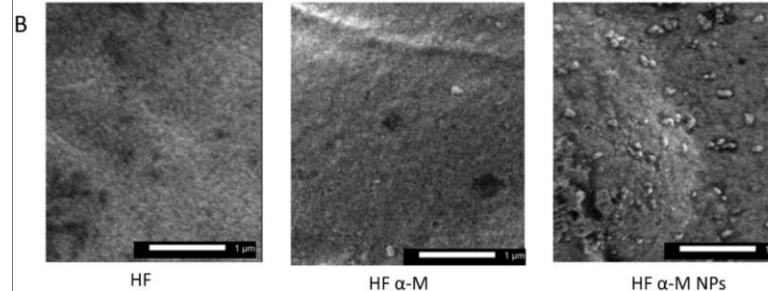
Analisis Ukuran, Distribusi, dan Morfologi Nanopartikel

Dynamic Light Scattering

Formulation	Particle Size (nm)	PDI	Zeta Potential (mV)
AM-CS	229.133 ± 5.685	0.382 ± 0.015	33.83 ± 1.92
AM-CS/HA1	304.833 ± 6.288	0.382 ± 0.038	-24.43 ± 1.76
AM-CS/HA2	369.300 ± 2.467	0.360 ± 0.028	-28.44 ± 2.26
AM-CS/HA3	412.767 ± 6.001	0.346 ± 0.034	-33.31 ± 1.85

Mengukur ukuran partikel dan PDI dimana PDI yang rendah mengurangi terjadinya agregasi

Scanning Electron Microscopy (SEM)



Bentuk permukaan

Transmission Electron Microscopy (TEM)

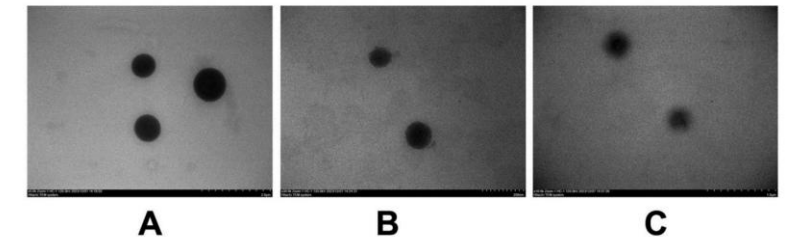
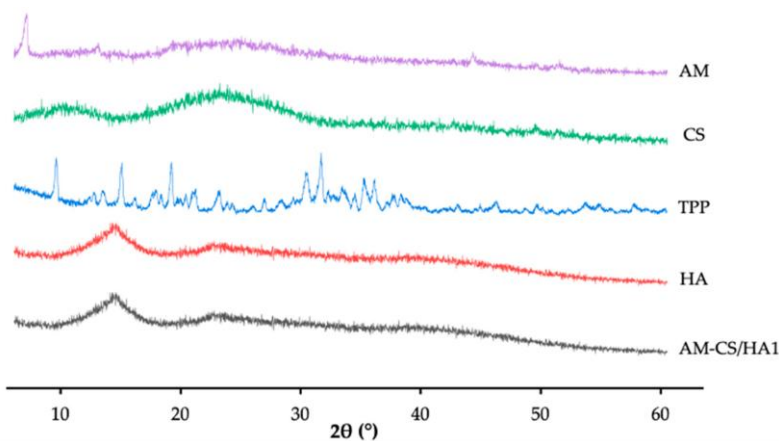


Fig. 2. Transmission electron microscopy (TEM) images of HFSS formulations: CH1 without α -mangostin (HFSS-Nanopropolis) (A), HFSS-Nanopropolis- α M without polymer base (without polymer) (B), and optimized HFSS-Nanopropolis- α M (CH1) (C). The images show the morphology and distribution of the nanostructured lipid carriers in each formulation.

Melihat bentuk dan memperlihatkan susunan struktur

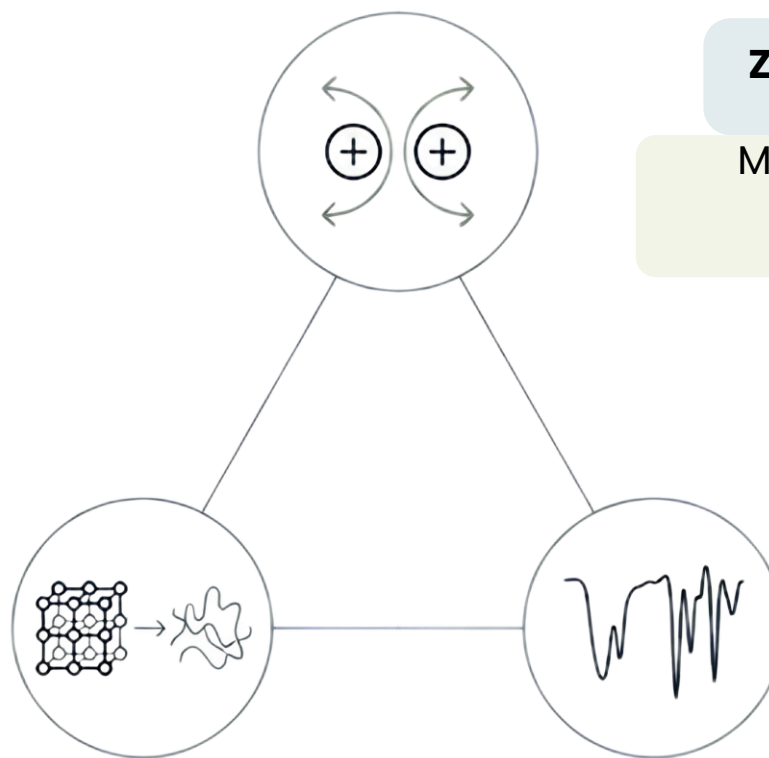
(Meylina et al., 2023; Muchtaridi et al., 2023; Yuniarsih et al., 2026)

Zeta Potensial dan Interaksi Kimia dalam Sistem Nanopartikel



XRD

Melihat perubahan struktur padat, terutama apakah zat aktif masih bersifat kristalin atau berubah menjadi amorf

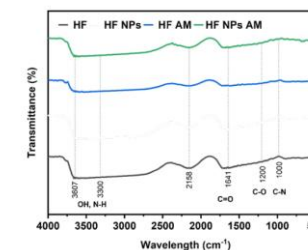


Zeta Potensial

Menilai muatan permukaan

FTIR

Menganalisis interaksi gugus fungsi



(Meylina et al., 2023; Muchtaridi et al., 2023; Yuniarsih et al., 2026; Wulansari et al., 2026)

Efisiensi Enkapsulasi dan Pemuatan Obat sebagai Indikator Keberhasilan Sistem

Efisiensi Penjerapan

Menunjukkan persentase obat yang berhasil masuk dan tertahan di dalam pembawa dibandingkan jumlah obat awal yang digunakan



Drug loading

menunjukkan kapasitas muat obat, yaitu seberapa besar kandungan obat dibandingkan total massa partikel atau sistem pembawa

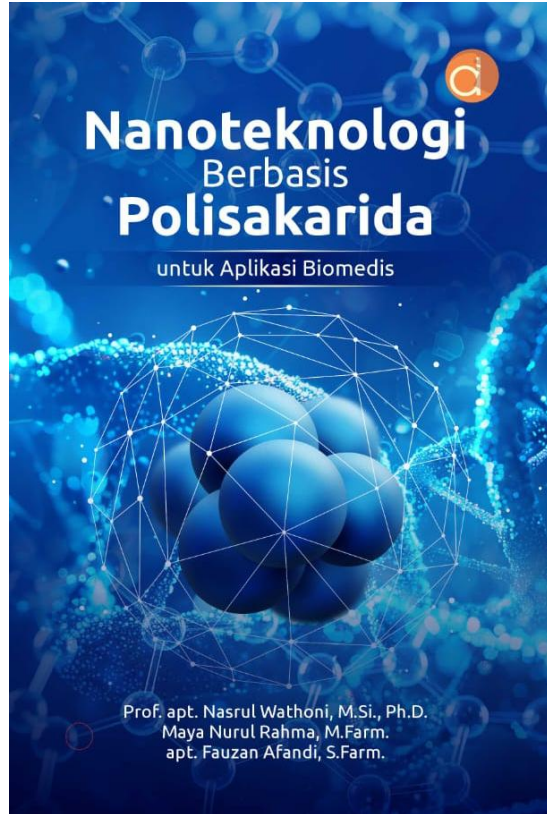


Formulation	EE (%)	DL (%)
AM-CS	88.325 ± 3.340	8.674 ± 0.018
AM-CS/HA1	90.404 ± 2.161	8.514 ± 0.007

Pada nanopartikel polisakarida, kemampuan menahan obat dipengaruhi oleh kerapatan jaringan, interaksi ionik, ikatan hidrogen, pelapisan permukaan, serta kekuatan interaksi obat dengan matriks

(Meylina et al., 2023; Muchtaridi et al., 2023; Herdiana et al., 2022; Yuniarsih et al., 2026)

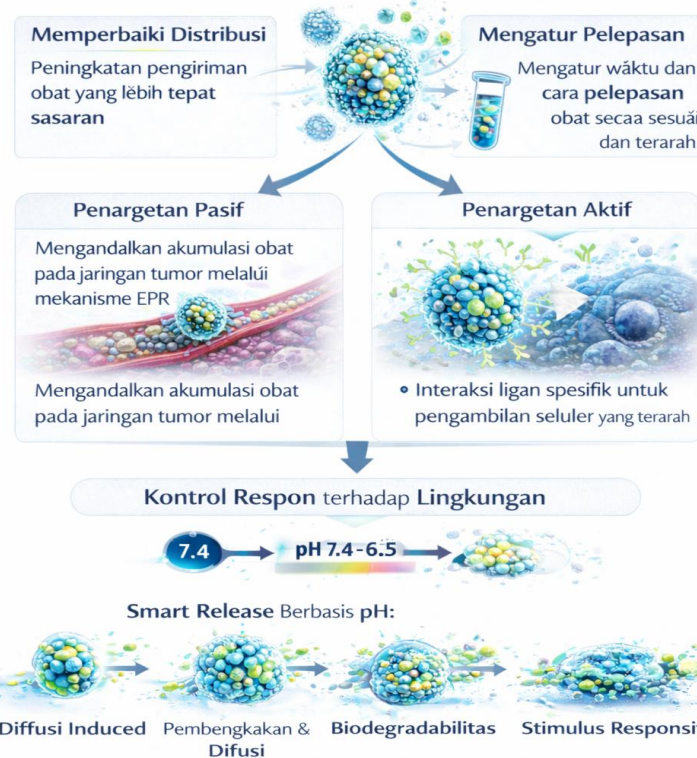
Bagian 3



Bagian 3:
APLIKASI BIOMEDIS

Sistem Penghantaran Obat (Drug Delivery Systems)

Penghantaran Obat Tertarget dan Terkontrol



Nanoteknologi Berbasis Polisakarida

untuk Aplikasi Biomedis



Berangkat dari ketertarikannya pada hubungan antara struktur molekul dan fungsi biologis, **Prof. apt. Nasrul Wathoni, M.Si., Ph.D.** beserta tim risetnya mengembangkan keahlian di bidang farmasetika dan nanoteknologi berbasis *biopolymer*. Lulusan Kumamoto University, Jepang, ini merupakan Profesor di Departemen Farmasetika dan Teknologi Farmasi, Fakultas Farmasi, Universitas Padjadjaran dengan fokus riset pada sistem penghantaran obat dan kosmetik berbasis polisakarida.

Buku ini merefleksikan bidang keilmuan yang ia tekuni dimulai dari pemahaman struktur dan klasifikasi polisakarida, metode fabrikasi dan karakterisasi nanomaterial, hingga desain sistem penghantaran obat tertarget dan terkontrol. Pembahasan mencakup kitosan, alginat, hialuronat, karagenan, ulvan, pektin dan sacran sebagai platform desain biomaterial dengan pendekatan struktur, proses dan fungsi.

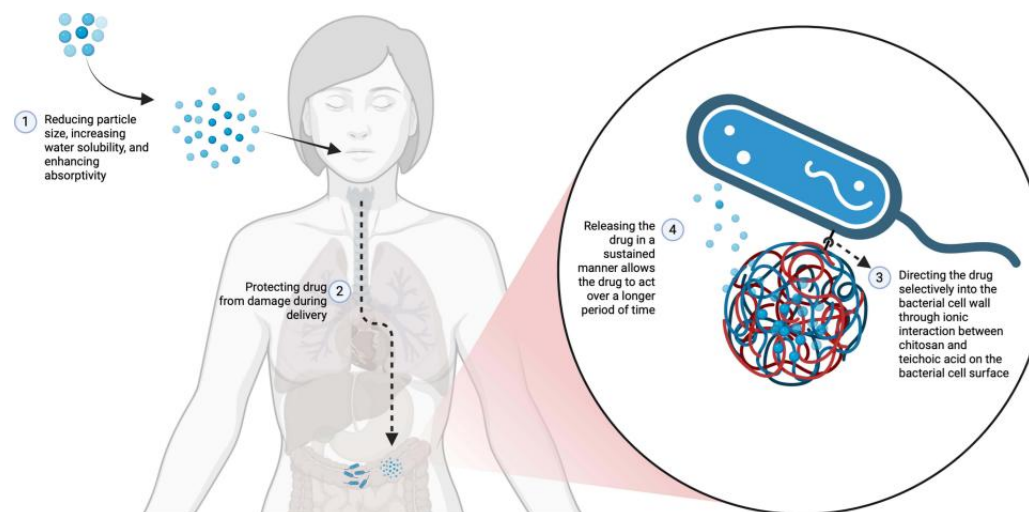
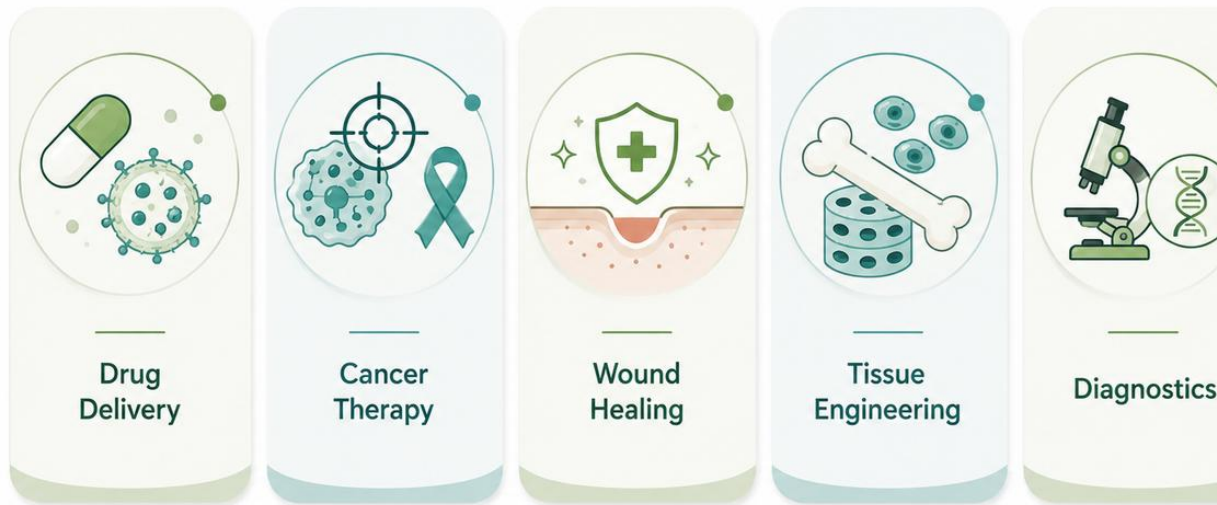
Selain aspek teknis, buku ini juga menyoroti tantangan konsistensi mutu, keamanan biologis, translasi klinis, serta pentingnya integrasi *Quality by Design* dan kesiapan regulatori. Melalui pendekatan ilmiah yang sistematis dan reflektif, penulis mengajak pembaca melihat nanoteknologi polisakarida sebagai bidang yang bergerak dari eksplorasi menuju penerapan yang matang dan berkelanjutan.

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Aplikasi Nanopartikel dalam Biomedis



Pelepasan obat terkontrol dan penghantaran tertarget

Meningkatkan efektivitas terapi dan mengurangi efek samping

Mendukung regenerasi jaringan dan penyembuhan luka

Scaffold dan hidrogel untuk rekayasa jaringan

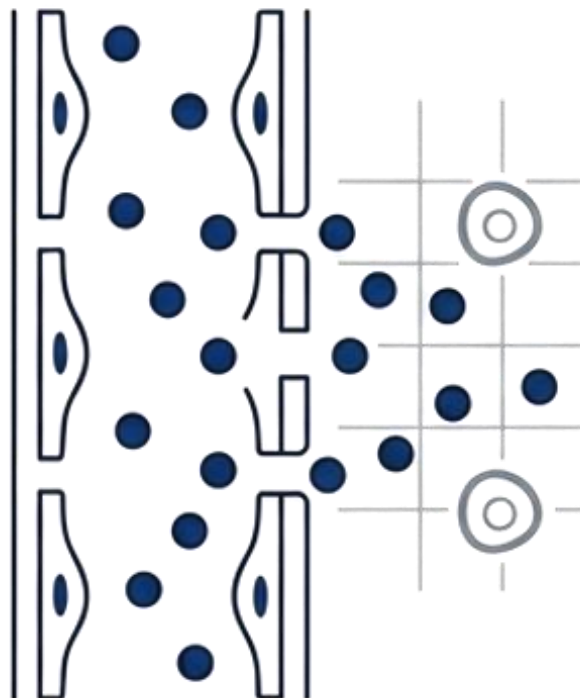
Sistem deteksi dan pencitraan biomolekul

(Wathoni et al., 2024; Wilar et al., 2024; Yuniarsih et al., 2024; Fitriani et al., 2025; Wathoni et al., 2026)

Prinsip Penghantaran Obat Tertarget dan Terkontrol

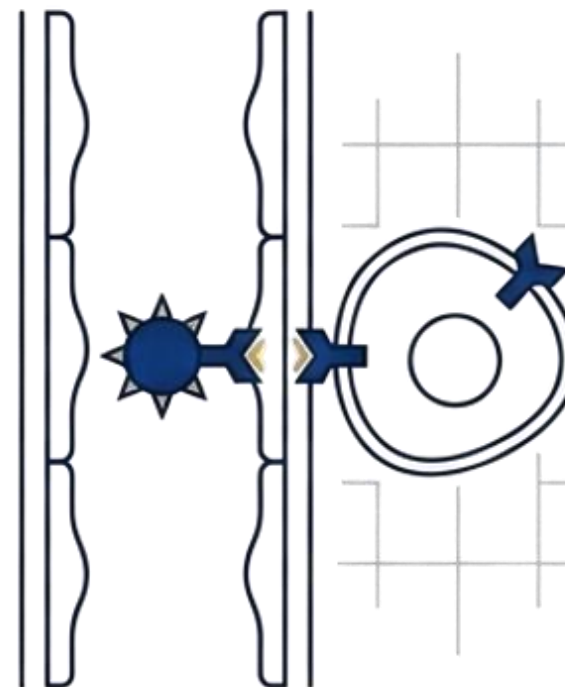
Penargetan Pasif

Membantu pembawa terakumulasi di jaringan tertentu



Penargetan Aktif

Menggunakan interaksi ligan-reseptor untuk meningkatkan *intake* obat oleh sel target



(Puluhulawa et al., 2022; Meylina et al., 2023; Wathoni et al., 2022)

Sistem Mukoadhesif Berbasis Polisakarida untuk Oral dan Okular

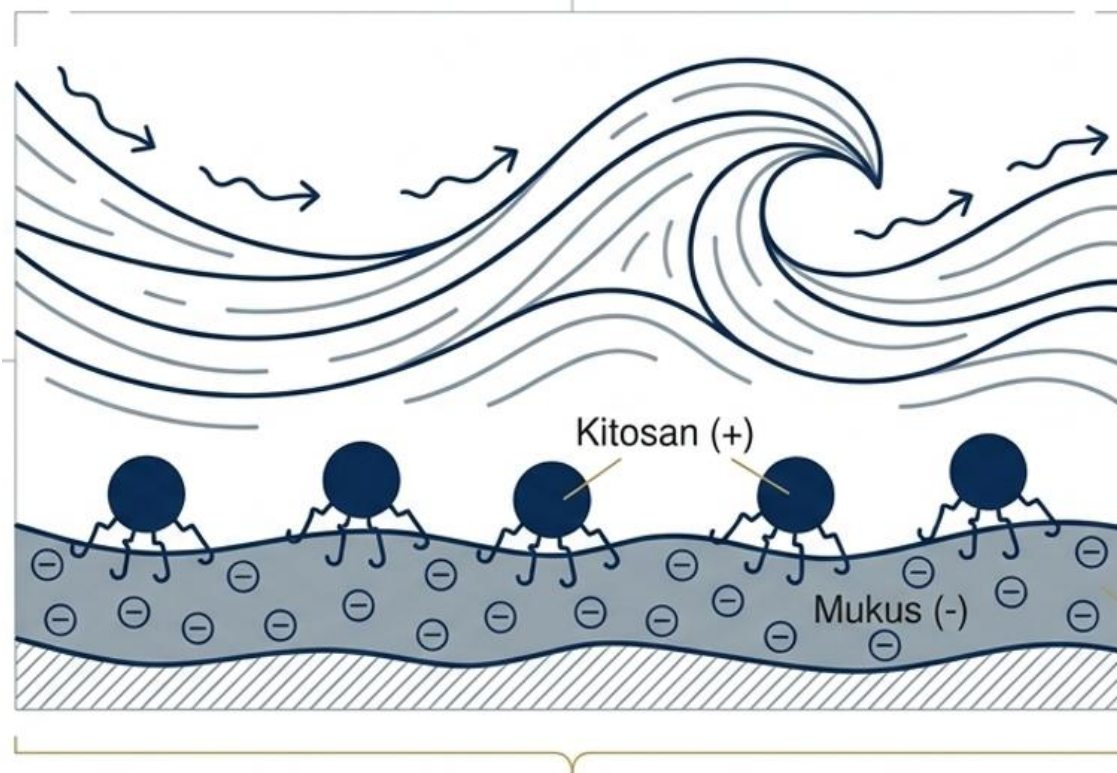
Tantangan

Rute Oral

Perubahan pH, enzim, gerak peristaltik, dan pembaruan mukus yang dapat mempercepat hilangnya sediaan.

Rute Okular

Air mata dan kedipan yang membuat obat cepat terbang



Mekanisme

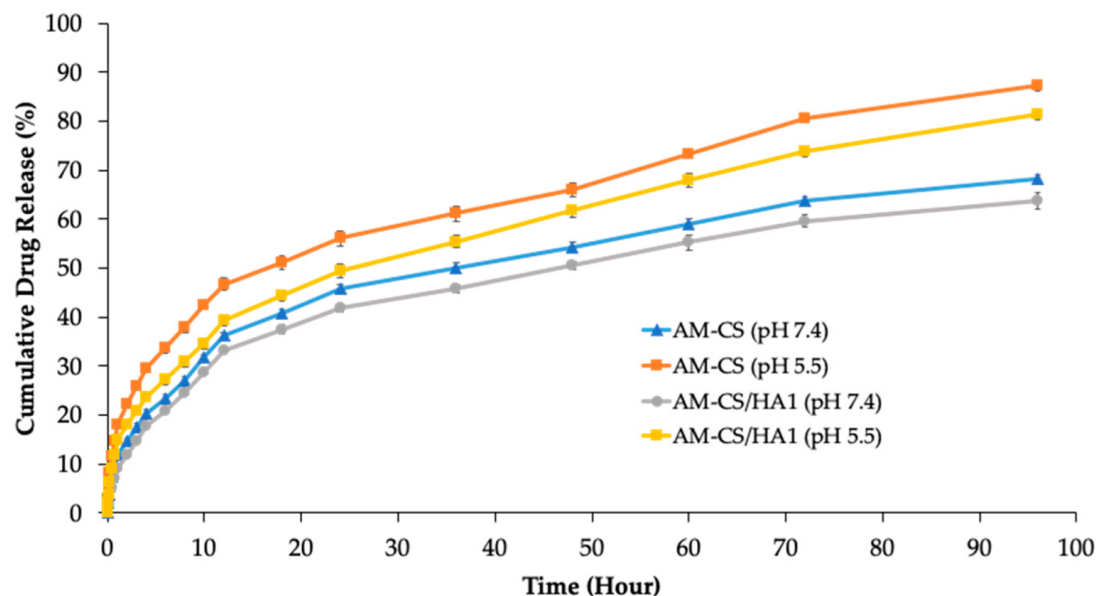
Sistem mukoadhesif dirancang agar pembawa obat dapat melekat lebih lama pada lapisan mukus, sehingga waktu kontak obat dengan jaringan meningkat dan obat tidak cepat terbang

Kombinasi kitosan dengan alginat atau hyaluronic acid dapat membentuk kompleks polielektrolit yang memperkuat retensi, mengatur muatan permukaan, dan membantu pelepasan obat secara bertahap

Pelepasan Berkelanjutan dan Strategi untuk Obat Hidrofobik-Hidrofilik

Pelepasan berkelanjutan bertujuan mempertahankan paparan obat dalam waktu lebih lama, terutama

Matriks polisakarida seperti kitosan–alginat dapat membentuk jejaring polielektrolit yang menahan obat, memperpanjang jalur difusi, dan memperlambat pelepasan dari partikel



Obat hidrofobik memerlukan strategi untuk meningkatkan kelarutan semu, menjaga dispersi, dan mencegah rekristalisasi, sedangkan obat hidrofilik perlu ditahan agar tidak terlalu cepat berdifusi keluar

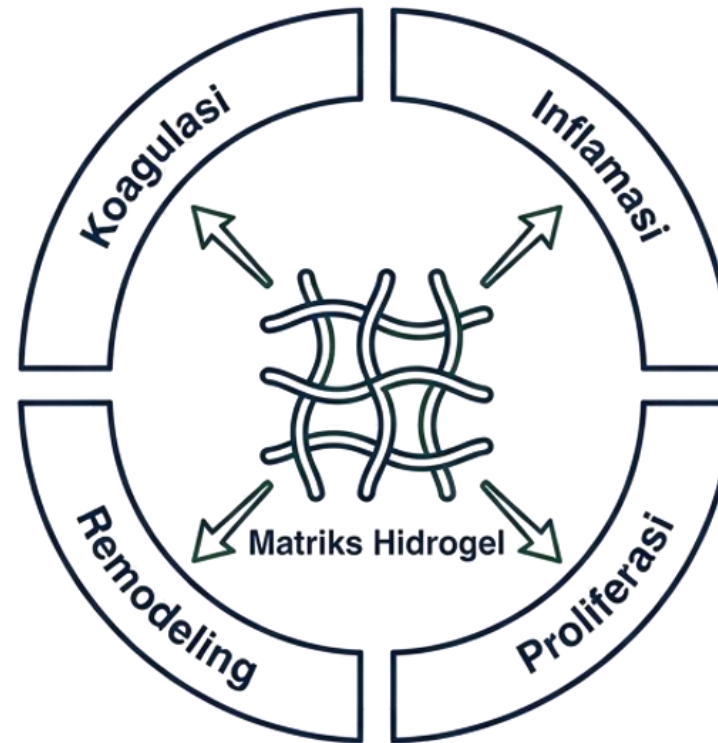
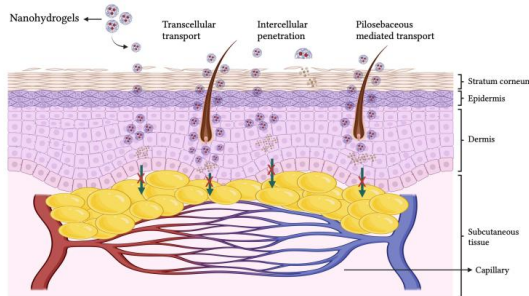
Sistem berlapis, nanohydrogel, dan smart nanocarrier dapat digunakan untuk menyesuaikan pelepasan obat berdasarkan sifat obat, lokasi target, dan kondisi lingkungan biologis

(Herdiana et al., 2022; Meylina et al., 2023; Yuniarsih et al., 2024; Sulastri et al., 2025; Suharyani et al., 2025)

Peran Biomaterial dalam Regenerasi Jaringan

Prinsip

Biomaterial berperan menyediakan lingkungan mikro yang menyerupai jaringan alami agar sel dapat melekat, berkembang, dan membentuk jaringan baru



Inovasi

Hidrogel menjadi biomaterial penting karena mampu menjaga kelembapan luka, menyerap cairan, melindungi dari kontaminasi, dan mendukung migrasi sel

Sacran merupakan contoh polisakarida alami yang potensial karena mampu membentuk hidrogel film, memiliki daya pembengkakan tinggi, elastis, biokompatibel, dan mendukung hidrasi luka

Kombinasi hidrogel sacran dengan agen bioaktif seperti kurkumin dapat memperkuat fungsi terapeutik melalui efek antioksidan, antiinflamasi, dan pelepasan bertahap

(Wathoni et al., 2026; Fitriani et al., 2025)

Scaffold, Hidrogel, dan Film Berbasis Nanopolisakarida

Scaffold



Kerangka tiga dimensi yang mendukung adhesi sel, proliferasi, difusi oksigen, dan pembentukan jaringan baru

Hidrogel



Jaringan terhidrasi yang elastis, mampu menyerap air, menjaga kelembapan, dan menyesuaikan diri dengan jaringan lunak

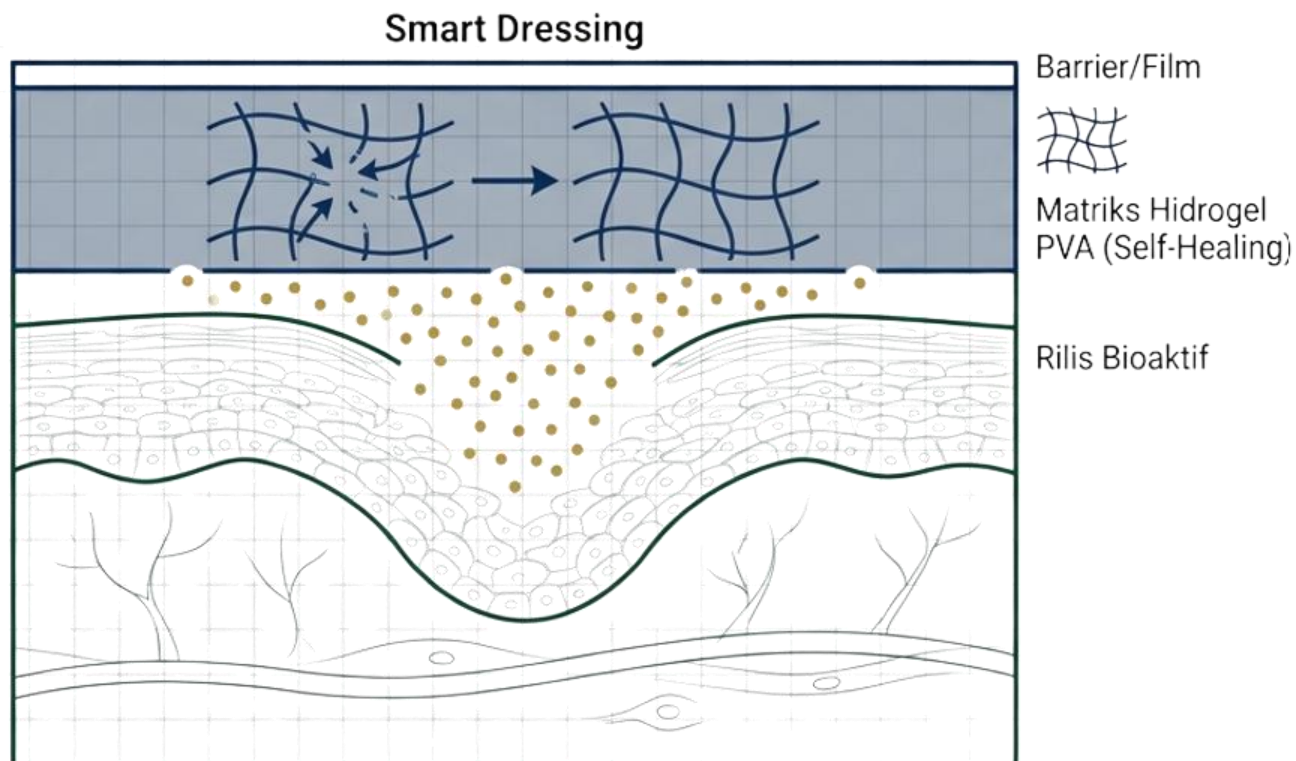
Film



Film berbasis nanopolisakarida berfungsi sebagai balutan luka tipis yang fleksibel, melindungi luka dari kontaminasi, menyerap eksudat, dan tetap memungkinkan pertukaran udara

Ketiga bentuk ini dapat menjadi sistem multifungsi karena tidak hanya memberi dukungan struktural, tetapi juga dapat menghantarkan agen antiinflamasi, antioksidan, antimikroba, dan faktor pertumbuhan

Balutan Luka Modern sebagai Sistem Terapeutik Aktif



Bukan Sekadar Penutup Luka

Balutan tidak lagi pasif. Hidrogel berbasis karboksimetil kitosan membentuk jaringan perbaikan diri (self-healing) yang dinamis terhadap tekanan deformasi luka.

Akselerator Angiogenesis

Menghantarkan gas S-nitrosoglutathione sebagai donor Nitric Oxide (NO), yang meningkatkan perfusi jaringan, aktivitas fibroblas, sekaligus antibakteri.

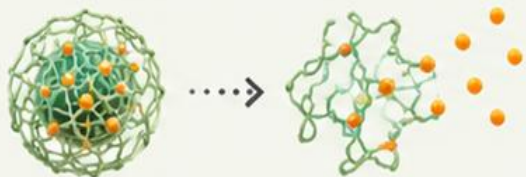
Pelepasan Faktor Pertumbuhan

Hidrogel terprogram melepas Keratinocyte Growth Factor (KGF) secara bertahap. Mendorong migrasi fibroblas dan epitelisasi ulang sempurna demi restorasi kulit tanpa cacat.

(Palungan et al., 2024; Hasan et al., 2023; Firmansyah et al., 2026)

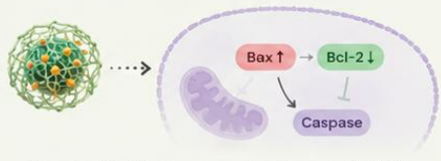
Nanopartikel Berbasis Kitosan sebagai Terapi Cancer

Peningkatan Bioavailabilitas



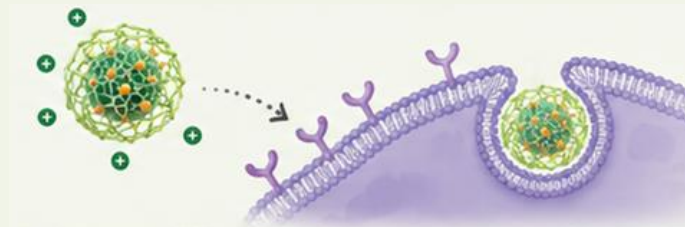
Nanopartikel kitosan mengenkapsulasi obat dari degradasi, meningkatkan stabilitas, dan mengatur pelepasan obat secara terkendali.

Modulasi Jalur Kanker



Nanopartikel kitosan menekan stres oksidatif dan menginduksi apoptosis melalui aktivasi jalur Bax/Bcl-2 dan kaspase, sehingga meningkatkan kematian sel kanker.

Internalisasi Sel Kanker

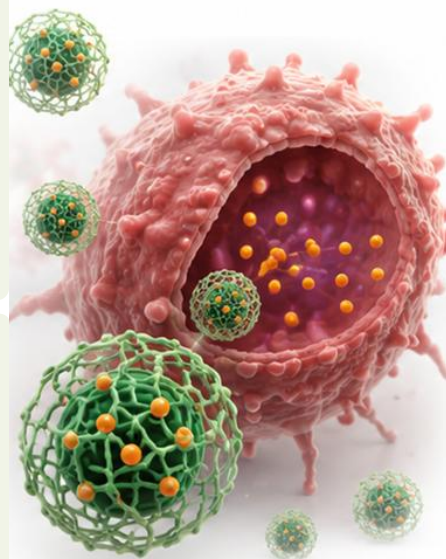


Muatan positif kitosan berinteraksi dengan membran sel kanker yang bermuatan negatif → meningkatkan adsorpsi dan endositosis obat ke dalam sel kanker.

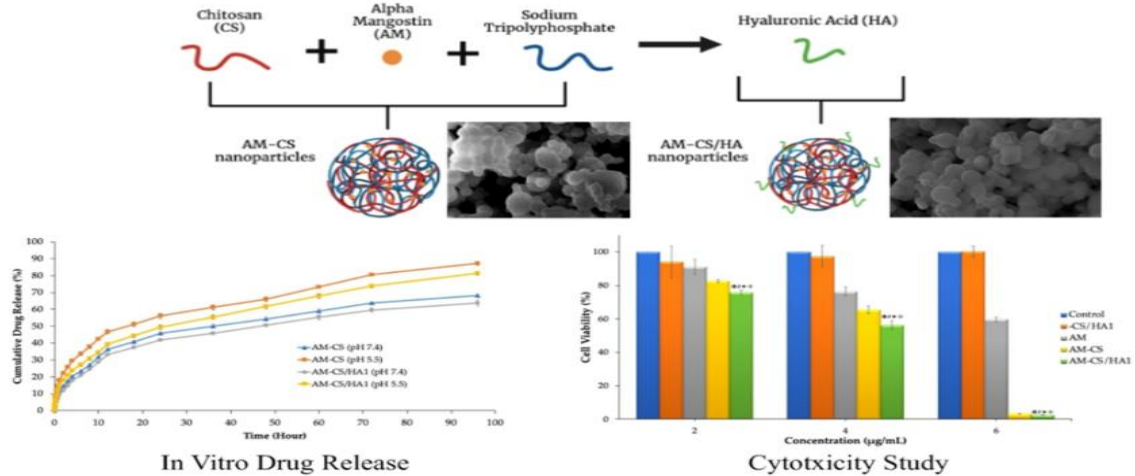
Penargetan Tumor



nanopartikel mengakumulasi jaringan tumor melalui efek EPR dan modifikasi permukaan nanopartikel dapat meningkatkan pengenalan terhadap reseptor sel kanker.

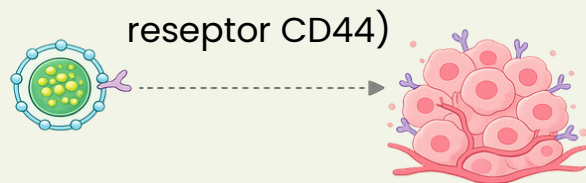


Nanopartikel Kitosan-Asam Hialuronat

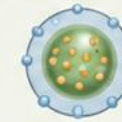


Internalisasi Sel Meningkat

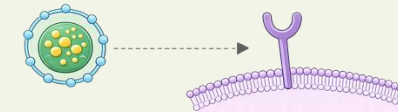
(Nanopartikel lebih mudah masuk melalui endositosis yang dimediasi



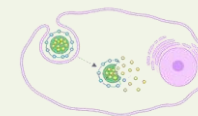
Core-Shell Nanoparticle



Interaksi dengan DC44



Penargetan Sel Kanker



(Akumulasi pada jaringan tumor meningkat)

Pelepasan Obat Terarah

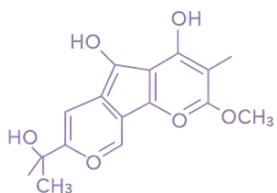
(Efektivitas terapi meningkat)

Tokisitas Sistemik Menurun

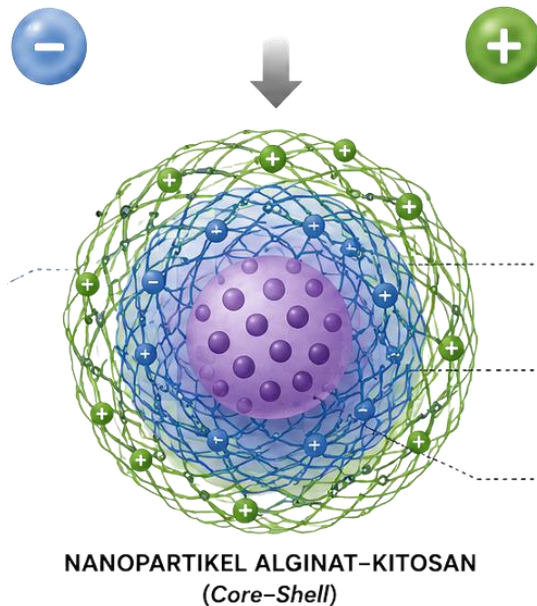
(Meylina et al., 2023; Puluhulawa et al., 2022)

Nanopartikel Kombinasi Alginat + Kitosan

α -mangostin



- Senyawa sitotoksik terhadap sel kanker payudara
- Kelarutan rendah
- Degradasi cepat



Hasil

Aktivitas Antikanker Meningkat
lebih tinggi dibanding α -mangostin bebas

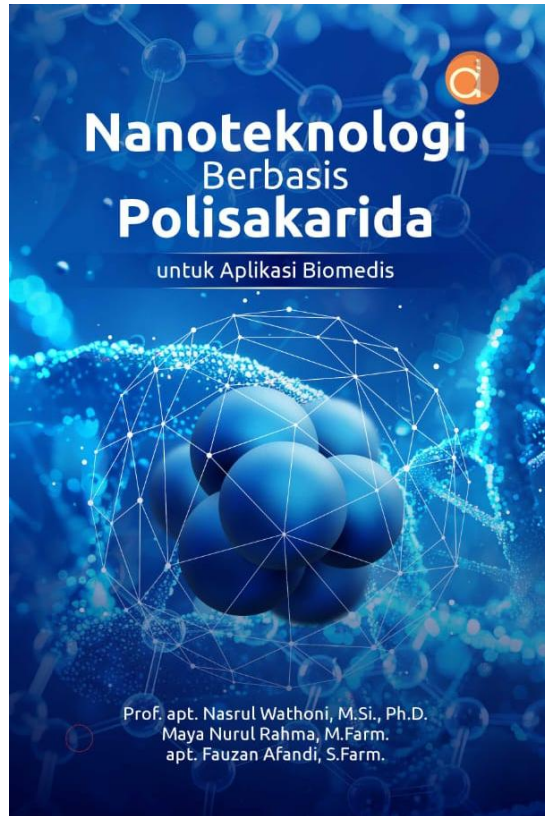
Pertumbuhan Tumor Terhambat
inhibisi tumor lebih efektif

Toksisitas Sistemik Menurun
Profil keamanan lebih baik

- Adhesi sel meningkat
- Pelepasan bertahap
- Responsif pada lingkungan tumor (pH lebih asam)

(Muchtaridi et al., 2023; Herdiana et al., 2022; Milanda et al., 2022)

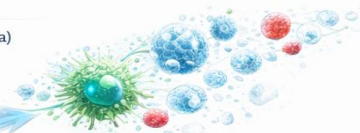
Bagian 4



Bagian 4: TANTANGAN, REGULASI, DAN MASA DEPAN Translasi Nanoteknologi Polisakarida dari Laboratorium ke Klinik

Tantangan Biokompatibilitas

- Transformasi biologis (protein corona)
- Biodistribusi & eliminasi
- Respons imun & inflamasi
- Risiko akumulasi jaringan



Desain yang Lebih Terkontrol

Skalabilitas Produksi

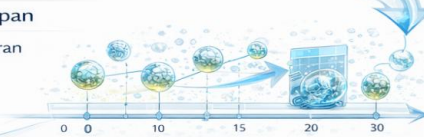
- Variasi bahan baku polisakarida
- Sensitivitas gelasi & kompleksasi ionik
- Kontrol ukuran & muatan permukaan
- Reprodusibilitas antar batch



Quality by Design (QbD)

Stabilitas & Masa Simpan

- Agregasi & perubahan ukuran
- Reorganisasi matriks
- Retensi vs pelepasan obat
- Degradasi kimia muatan



Kontrol Atribut Mutu Kritis (CQA)

Regulasi & Uji Klinik

- Bukti in vivo sistemik
- Konsistensi proses manufaktur
- Standarisasi parameter mutu
- Validasi keselamatan & manfaat



Kesiapan Komersialisasi

Kontrol Struktur + Proses + Regulasi
→ Translasi Klinik Berkelanjutan

Nanoteknologi Berbasis Polisakarida

untuk Aplikasi Biomedis



Berangkat dari ketertarikannya pada hubungan antara struktur molekul dan fungsi biologis, Prof. apt. Nasrul Wathoni, M.Si., Ph.D. beserta tim risetnya mengembangkan keahlian di bidang farmasetika dan nanoteknologi berbasis *biopolymer*. Lulusan Kumamoto University, Jepang, ini merupakan Profesor di Departemen Farmasetika dan Teknologi Farmasi, Fakultas Farmasi, Universitas Padjadjaran dengan fokus riset pada sistem penghantaran obat dan kosmetik berbasis polisakarida.

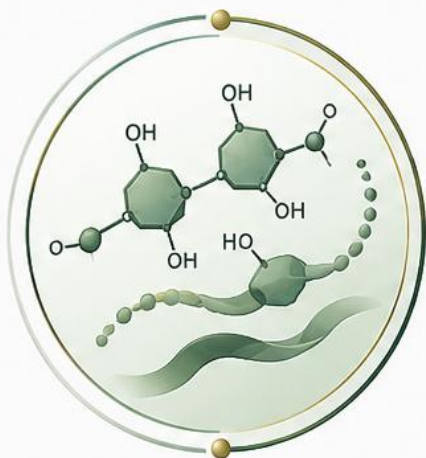
Buku ini merefleksikan bidang keilmuan yang ia tekuni dimulai dari pemahaman struktur dan klasifikasi polisakarida, metode fabrikasi dan karakterisasi nanomaterial, hingga desain sistem penghantaran obat tertarget dan terkontrol. Pembahasan mencakup kitosan, alginat, hialuronat, karagenan, ulvan, pektin dan sacran sebagai platform desain biomaterial dengan pendekatan struktur, proses dan fungsi.

Selain aspek teknis, buku ini juga menyoroti tantangan konsistensi mutu, keamanan biologis, translasi klinis, serta pentingnya integrasi *Quality by Design* dan kesiapan regulatori. Melalui pendekatan ilmiah yang sistematis dan reflektif, penulis mengajak pembaca melihat nanoteknologi polisakarida sebagai bidang yang bergerak dari eksplorasi menuju penerapan yang matang dan berkelanjutan.

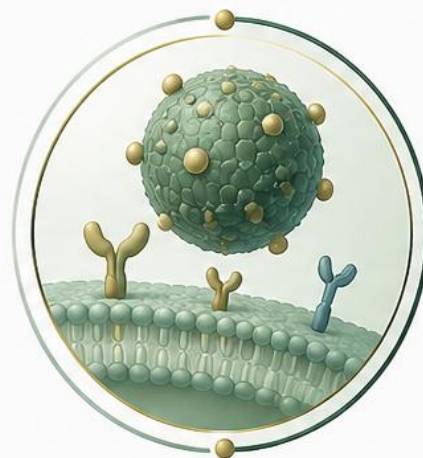
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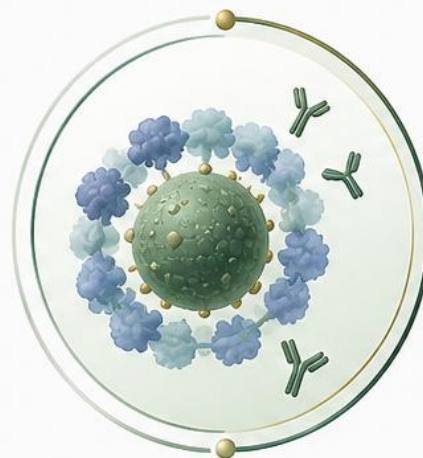
Potensi Toksisitas Nanopartikel Berbasis Polisakarida



Variasi struktur dan sifat polisakarida



Interaksi nanopartikel dengan sistem biologis



Pembentukan protein corona dan respon imun



Evaluasi keamanan jangka panjang sebelum uji klinis

(Salsabila et al., 2025; Wathoni, Herdiana, et al., 2024; Hidayat et al., 2025)

Tantangan Scale up ke Industri

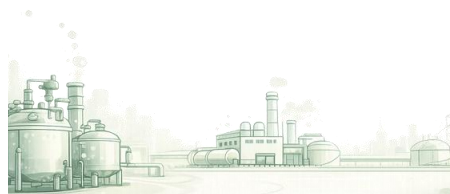
Peningkatan skala produksi ke industri menghadirkan tantangan dalam menjaga konsistensi kualitas nanoteknologi berbasis polisakarida

Perubahan Kondisi

Perbedaan pencampuran, suhu, tekanan dan gaya geser

Variasi Bahan Baku

Kitosan, alginat dan polisakarida lain memiliki variasi berat molekul dan kemurniaan antar batch



Berpengaruh terhadap Kualitas Produk

- Ukuran Partikel tidak seragam
- Reproduksi antar batch sulit
- efisiensi enkapsulasi berubah

Standarisasi bahan baku dan jaminan mutu diperketat

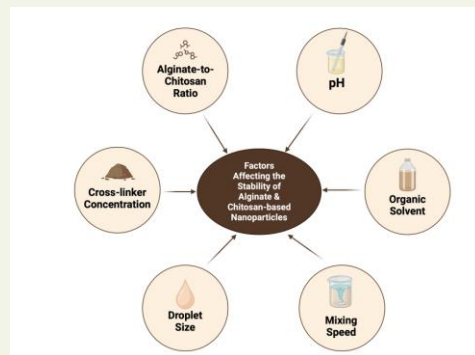
- Proses terkontrol
- Kualitas terjaga
- Produk aman dan efektif

(Herdiana et al., 2022; Hidayat et al., 2025; Herdiana et al., 2024)

Stabilitas Nanopartikel

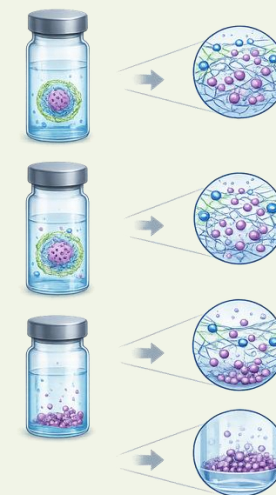
Stabilitas Nanopartikel

- Ketetapan ukuran partikel dan sebarannya,
- Kekuatan muatan permukaan dan integritas matriks polimer
- Retensi zat aktif
- keterulangan profil pelepasan selama penyimpanan



Nanopartikel Kitosan–Alfa Mangostin

- Ikatan polimer sensitif terhadap pH dan kekuatan ion
- Penyimpanan dapat mengubah porositas matriks dan mobilitas molekul
- Reorganisasi matriks menyebabkan migrasi zat aktif ke permukaan
- Memicu presipitasi dan perubahan laju pelepasan obat



Strategi

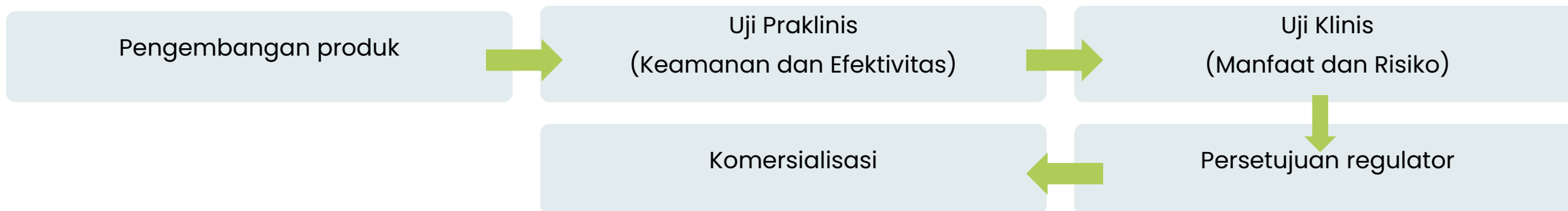
- Pelapisan nanopartikel untuk mempertahankan karakteristik awal
- Pengendalian kondisi penyimpanan

(Wathoni et al., 2024;Herdiana et al., 2022; Sulastri et al., 2025; Meylina et al., 2023)

Regulasi dan Tahapan Pengembangan Nanopartikel Berbasis Polisakarida

Regulasi oleh Badan Otoritas

- Menjamin keamanan, mutu, dan efektivitas produk.
- Menilai konsistensi bahan, proses, dan karakteristik nanosistem.
- Memastikan produk tetap memiliki mutu yang sama pada setiap produksi.

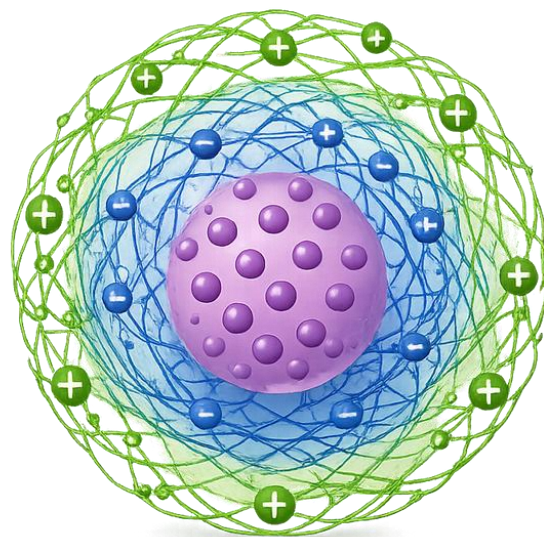


Pengembangan produk nanoteknologi berbasis polisakarida memerlukan evaluasi mutu, keamanan, dan efektivitas secara bertahap sebelum dapat digunakan secara klinis dan dipasarkan.

(Hidayat et al., 2025; Salsabila et al., 2025; Herdiana et al., 2022)

HAKI dalam Pengembangan Nanoteknologi Berbasis Polisakarida

Perlindungan Identitas Teknologi



Kebaruan Struktur dan Proses

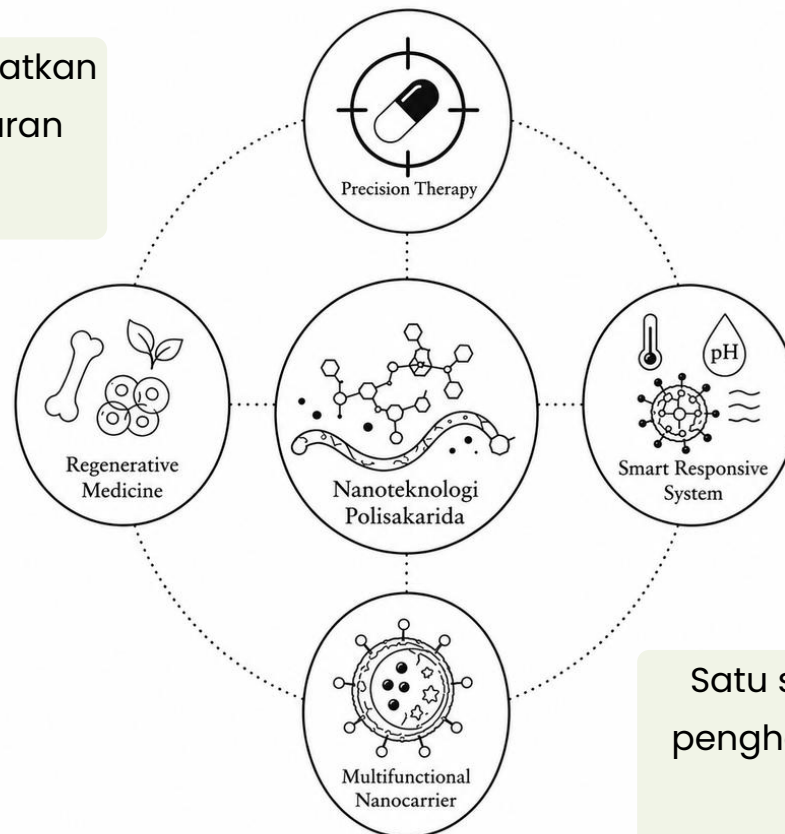
Diferensiasi Performa

Standardisasi dan Reprodusibilitas

(Herdiana et al., 2022)

Tren Terkini Nanopartikel Berbasis Polisakarida

Karakteristik setiap polisakarida dimanfaatkan untuk menghasilkan sistem penghantaran yang lebih spesifik dan efektif.



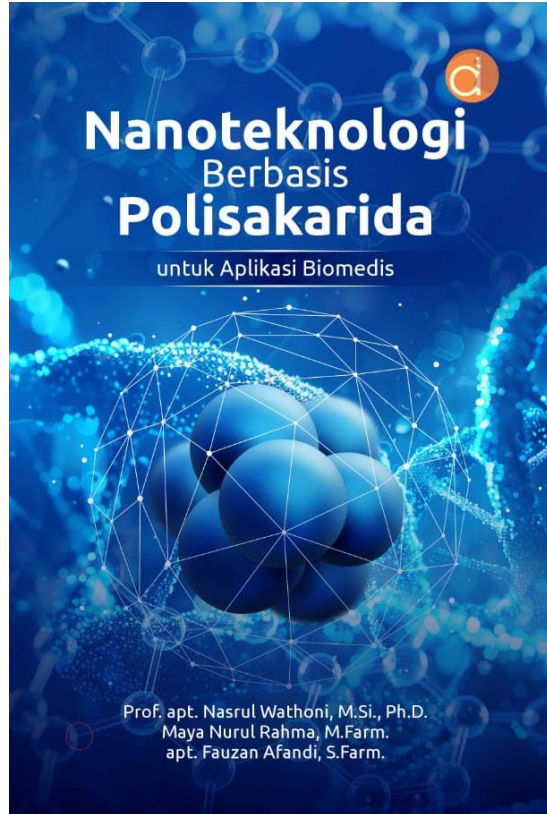
Nanomaterial dirancang untuk merespons perubahan kondisi biologis seperti pH atau stimulus tertentu.

Pengembangan nanopartikel diarahkan untuk meningkatkan selektivitas penghantaran obat ke lokasi target.

Satu sistem dapat menggabungkan fungsi penghantaran, perlindungan, dan pelepasan zat aktif secara bersamaan.

(Herdiana et al., 2024; Yuniarsih et al., 2024; Wathoni, Herdiana, et al., 2024; Akmal et al., 2025).

Bagian 5



Masa Depan Nanoteknologi Berbasis Polisakarida



Menuju Aplikasi Klinis yang Lebih Luas

Masa depan nanoteknologi polisakarida bergantung pada presisi desain, pengendalian mutu, serta integrasi inovasi dan regulasi sejak tahap awal pengembangan.

Polisakarida sebagai Platform Strategis

Polisakarida memiliki sifat biokompatibel, biodegradable, dan mudah dimodifikasi

Integrasi Desain, Mutu, dan Keamanan

Keberhasilan nanoteknologi ditentukan oleh material, fabrikasi, karakterisasi, stabilitas, keselamatan, dan regulasi.

(Wathoni et al., 2026; Hidayat et al., 2025; Herdiana et al., 2022; Salsabila et al., 2025; Yuniarsih et al., 2024)

TIM RISET

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Nanostructured lipid carriers as co-delivery systems for cancer therapy: Prospects and challenges

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ABSTRACT

Keywords: Nanostructured lipid carriers; Co-delivery systems; Combination therapy; cancer therapy

Cancer combination therapy is widely used to address tumor heterogeneity, multidrug resistance, and dose-limiting toxicities associated with conventional monotherapy. However, the clinical benefits of free-drug combinations are often compromised by antimicrobial pharmacokinetics, inconsistent intratumoral drug ratios, and poor solubility or stability of individual agents. Nanostructured lipid carriers (NLCs), composed of a solid-lipid lipid matrix, have emerged as a biocompatible nanoplatform capable of overcoming these limitations through high drug-loading capacity, improved colloidal stability, and tunable release behavior. This review aims to summarize the role of NLCs as co-delivery systems for cancer therapy. A literature search was conducted across databases to identify studies reporting NLC-based co-delivery strategies for anticancer applications. By enabling the co-encapsulation of multiple cargos inside a single carrier, NLCs facilitate synergistic interactions, maintain synchronized bioavailability, and enhance intracellular accumulation at tumor sites. These attributes support the co-delivery of diverse therapeutic modalities, including chemotherapeutics, genetic materials, and stimuli-responsive particles such as photodynamic, photothermal, and magnetic hyperthermia agents. The review briefly examines the structural features, formulation considerations, and preparation techniques of NLCs, followed by discussions of the rationales for co-loading strategy and representative applications across various cancer types. Challenges related to formulation complexity, manufacturing scalability, safety, and regulatory translation remain important considerations, whereas advances in rational formulation design and data-driven development strategies may accelerate the clinical translation of NLC-based co-delivery systems and expand their potential in cancer therapy.

Open Access Full Text Article

REVIEW

Lipid-Based Nanocarriers for Curcumin Delivery: A Promising Strategy in The Management of Inflammatory Diseases

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Abstract: Inflammation is a key pathophysiological process underlying a broad spectrum of chronic disorders, including rheumatoid arthritis, osteoarthritis, inflammatory bowel disease, neurodegenerative diseases, and metabolic syndrome, and is closely linked to obstructive stress, immune dysregulation, and sustained production of pro-inflammatory mediators. Curcumin, a bioactive polyphenol derived from *Curcuma longa*, has been extensively studied because of its pleiotropic anti-inflammatory mechanisms; however, its therapeutic translation is substantially limited by poor aqueous solubility, chemical instability, rapid metabolism, and low systemic bioavailability. In this context, lipid-based nanocarriers, notably liposomes, solid lipid nanoparticles, nanostructured lipid carriers, phytosomes, ethosomes, niosomes, nanemulsions, self-nano-emulsifying drug delivery systems (SNEDDS), transferosomes, lipid nanoparticles, lipid micelles, and cubosomes, have emerged as promising formulation strategies to improve curcumin delivery. These platforms can enhance the solubility, stability, absorption, and pharmacokinetic performance of curcumin and, in selected cases, facilitate more efficient accumulation at inflamed sites. This review critically appraises recent advances in lipid-based nanocarrier systems for curcumin delivery in inflammatory diseases and addresses the principal formulation, translational, and clinical challenges that remain to be resolved.

Keywords: phytosome, SLN, prostanin, alzheimer

Drug Design, Development and Therapy

ORIGINAL RESEARCH

Nanoencapsulated α -Mangostin Loaded Chitosan-Alginate Hydrogel Films for Enhanced Topical Anti Acne Therapy

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Background: α -Mangostin (α -M) is a natural antimicrobial and anti-inflammatory compound with promising anti-acne potential; however, its poor solubility and instability limit its topical use. This study developed and evaluated chitosan-alginate hydrogel films incorporating nanoencapsulated α -M (HF α -M NPs) to enhance stability, skin penetration, and therapeutic efficacy against *Propionibacterium acnes*.

Methods: α -M NPs were produced by ionic gelation using chitosan and sodium tripolyphosphate, followed by alginate coating, and subsequently incorporated into chitosan-alginate hydrogel films. Nanoparticles and films were characterized using SEM, FTIR, mechanical testing, swelling behavior, degradability analysis, and in vitro drug-release studies. The anti-acne performance was assessed in a *P. acnes* mouse model using total plate count, histopathological evaluation, and measurement of edema and erythema.

Results: The nanoparticles exhibited a mean size of 120.7 ± 18.15 nm, PDI of 0.450 ± 0.104, and zeta potential of -40.9 ± 1.91 mV, indicating strong colloidal stability. SEM confirmed the uniform distribution of nanoparticles in the hydrogel matrix, while FTIR revealed molecular interactions between the polymers and α -M. HF α -M NPs showed improved mechanical strength, controlled swelling, and a sustained release profile compared with free α -M films. In vivo, the HF α -M NPs achieved the greatest reduction in *P. acnes* load (4.5×10^7 CFU/g), significant epidermal restoration, and the lowest edema and erythema scores, which were superior to those of free α -M and comparable to those of clindamycin gel.

Conclusion: Nanoencapsulation of α -M within a chitosan-alginate hydrogel matrix significantly enhanced its stability, release behavior, and antimicrobial and anti-inflammatory effects. HF α -M NPs represents a promising antibiotic-free topical therapy for acne and merits further optimization and clinical investigation.

Drug Design, Development and Therapy

REVIEW

Film-Forming Gels for Topical Drug Delivery: A Systematic Review of the Effects of Formulation on Film Performance, Drug Release, and Skin Permeation

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Abstract: Film-forming gels (FFGs) are increasingly recognized as a medium for topical drug delivery. However, existing evidence correlating specific formulation characteristics with drug delivery efficacy remains fragmented across many studies and is only partially organized. This systematic review aimed to consolidate these findings into a single framework and evaluate how important formulation variables affect three main outcome domains: film characteristics, drug release behavior, and skin permeation. A systematic search of PubMed and Scopus was conducted until October 2023, adhering to the PRISMA criteria. Studies were included if they included topical FFG formulations and reported at least one of the predetermined outcomes. A total of 27 studies fulfilled the inclusion criteria, with solvent evaporation identified as the predominant method for FFG preparation. Across this body of research, the selection and relative ratio of polymers and plasticizers have consistently emerged as critical determinants influencing drug time (t_{50}), mechanical strength, flexibility, and bioadhesive properties of the film on the skin. Most formulations released the drug slowly over approximately 8–48 hours. In studies that measured permeation, FFGs usually exhibited a higher flux and/or better drug retention in the skin than regular topical formulations. The film's ability to block the skin and the use of penetration enhancers in the matrix are thought to cause these effects. In summary, these results show that FFGs are a flexible and customizable formulation platform, where the film's characteristics, release rate, and skin permeation are all strongly linked to the composition's design. To obtain this technology with clearer therapeutic benefits, we need to employ Quality by Design principles more widely and

Nanotechnology, Science and Applications

REVIEW

Nanostructured Lipid Carrier-Gels for Wound Healing: A Narrative Review of Formulation Strategies, Mechanisms, and Translational Potential

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Abstract: Wound healing is a complex process involving hemostasis, inflammation, proliferation, and remodeling of tissues or cells. In chronic conditions, such as diabetic wounds, this process is often disrupted. Nanostructured lipid carriers (NLCs) are advantageous topical drug delivery systems because of their ability to improve stability, bioavailability, and controlled drug release. The incorporation of NLCs into a gel matrix (NLC-gel) enhances the formulation with bioadhesive properties, skin hydration, and drug retention in the wound area. This accelerates healing and reduces the risk of infection. While these findings highlight the potential of NLC-gel systems to improve local drug bioavailability and promote tissue regeneration, most available evidence is derived from in vitro and animal studies, and clinical data remain limited. This review critically summarizes recent advances in NLC-gel formulations for wound healing, with particular emphasis on the relationship between formulation strategies and biological mechanisms, including modulation of inflammation, angiogenesis, fibroblast and keratinocyte proliferation, collagen deposition, and antimicrobial and analgesic activities. Additionally, translational considerations such as long-term safety, formulation stability, and clinical prospects are discussed. Recent in vivo and in vitro studies have shown that NLC gels containing active ingredients, such as curcumin, curcumin, quercetin, melatonin, or other therapeutic proteins, can accelerate wound healing, particularly in wounds caused by metabolic disorders. These results suggest that NLC gels have great potential as therapeutic platforms for wound care. However, further research is required to optimize its formulation and clinical translation.

Keywords: nanostructured lipid carriers, gel, hydrogel, wound healing

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REVIEW

Liposome-Based Drug Delivery for Diabetes: Therapeutic Applications and a Nanomedicine Perspective on Diabetic Complications

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Abstract: Diabetes mellitus (DM) affects approximately 537 million adults worldwide and remains inadequately controlled in a substantial proportion of patients despite the availability of various pharmacological therapies. Conventional antidiabetic treatments are often limited by poor bioavailability, rapid degradation of peptide-based drugs, insufficient tissue targeting, and systemic adverse effects. Liposomes, phospholipid bilayer-based nanocarriers, provide a versatile structural platform capable of simultaneously encapsulating hydrophilic and lipophilic agents, thereby addressing key pharmacokinetic limitations of conventional therapies. Their advantages include enhanced drug stability, improved bioavailability, and controlled release properties, resulting in more favorable pharmacokinetic performance. Surface modifications, such as PEGylation and ligand functionalization, further extend circulation time and enable targeted delivery, enhancing therapeutic efficacy in both type 1 and type 2 diabetes compared with conventional formulations. The evidence synthesized in this review indicates that liposomal systems consistently demonstrate improved pharmacokinetic profiles, enhanced tissue-specific accumulation, and reduced systemic toxicity in preclinical models of diabetes, although high-quality clinical validation remains limited. This review summarizes recent advances in liposome design, fabrication strategies, and therapeutic mechanisms in diabetes and its complications, providing a critical evaluation of their therapeutic benefits and translational barriers. Despite their clear potential, major challenges persist, including gastrointestinal instability, enzymatic degradation of encapsulated peptides, large-scale manufacturing complexity, and regulatory standardization. Addressing these limitations through formulation optimization, advanced targeting strategies, and rigorous clinical validation will be essential for successful clinical translation. Overall, liposomes represent a strategic and evolving nanomedicine platform for precision diabetes therapy.

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WILEY

Review Article

Advancements in Alginate-Based Biomaterials for Enhanced Skin Regeneration: A Comprehensive Review

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Alginate, a naturally occurring polysaccharide composed of β -D-mannuronic (M) and α -L-gulonic (G), has attracted widespread attention for skin regeneration applications due to its exceptional biocompatibility, biodegradability, and tunable physicochemical properties. Beyond its traditional role in maintaining a moist wound environment and providing a protective



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