
A REFERENCE VOLUME

FIRST EDITION · 2026



The Chitosan Handbook

The molecule, its derivatives, and their industrial applications.

EDITED BY STEVE NICE · CHUCK COLLINS, PhD

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The Chitosan Handbook

The molecule, its derivatives, and their industrial applications.

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Foreword.

This handbook is written as a scientific reference for the industries confronting antimicrobial resistance, plastic pollution, and the reconstruction of modern agriculture. Chitosan is a powerful new tool that can solve problems with chemical pollution in all its forms. These chemicals can weaken our bodies and create premature limitations if left unchecked. Toxic load from forever chemicals, microplastics, heavy metals, etc., found in water, soil, and air, can be addressed with chitosan.

This work is presented as an introduction to the ways chitosan will be used to detoxify the environment, products, and our bodies. *Chitosan is something so good for us and the planet that, within ten years, we predict it will be on or in most products that go on or into pets and people.*

— *Steve Nice*

SHIELD NUTRACEUTICALS / CHITOSAN GLOBAL

A NOTE ON GLOBAL SUPPLY

As demand for chitosan explodes in late 2027, the worldwide supply of shellfish waste will be consumed very quickly unless a sustainable method of meeting that demand emerges. We believe we have seen that solution. Green-manufactured, well-characterized chitosan from mushrooms or insect shells makes possible a transition from a world using toxic ingredients to one that is safe, clean, and environmentally sound.

A NOTE ON FEEDSTOCK QUALITY

The majority of world chitosan production still originates from shellfish waste. That feedstock is variable, largely uncharacterized, and carries documented risk of residual heavy metals and mercury. Bulk imports from China and India require third-party characterization before they can be used for feed, dietary supplements, or medical applications.

THIS HANDBOOK IS A REFERENCE

After years of reading and research about chitosan and its uses, varieties, and sources, we decided to help shorten the path for anyone in this space. Enjoy the discovery and pass it on.

ACKNOWLEDGMENTS

With thanks.

This handbook is the product of contributions from a distributed team of scientists, agronomists, veterinarians, engineers, and operators working across the United States, India, and Latin America. We thank the growers, herdsman, plant managers, and municipal water engineers who let us test insect- and mushroom-derived chitosan against the working problems of their industries.



Promecens Entosystems Pvt. Ltd., Pune, India, is the manufacturer of Chitosan FG, AG, IG, WS, AS and Native Chitosan from mushrooms and black soldier flies.

“Love is the only engine of survival.”

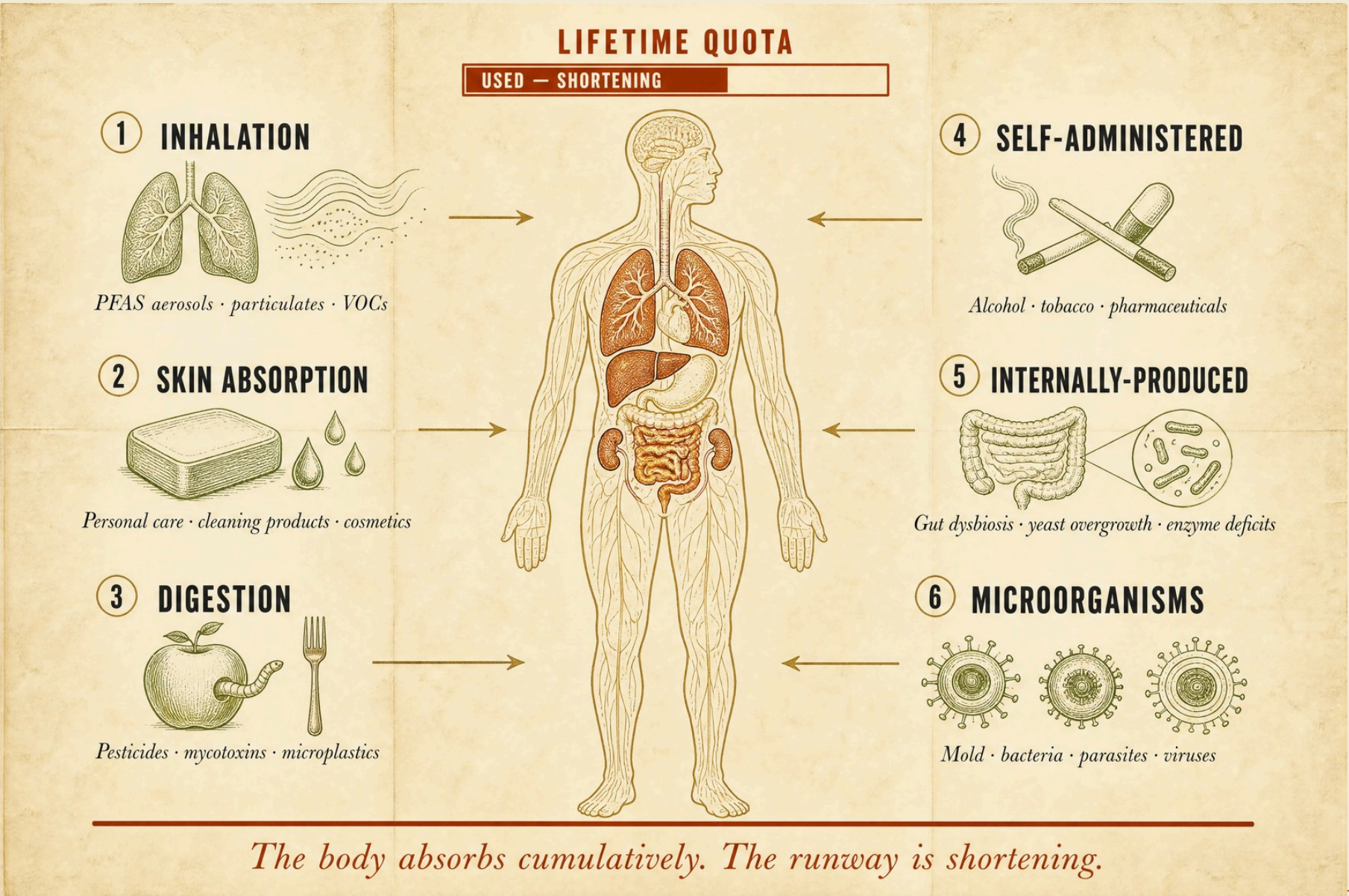
— LEONARD COHEN

ETSU Innovation Lab

We are especially grateful to **East Tennessee State University** and the **ETSU Innovation Lab** for their sustained support of Shield Nutraceuticals and Chitosan Global, from the earliest characterization work on insect derived chitosan through the applied research programs that shaped the derivatives catalogue.

Their willingness to host a small biotech company inside a working academic environment provided the scientific foundation for this work.

A fixed quota. A shortening runway.



Every human body absorbs toxicants across its lifetime through the air we breathe, the water we drink, the food we eat, the skin we touch, and the medicines and habits we adopt.

The load is **cumulative**. PFAS, microplastics, pesticides, mycotoxins, heavy metals, industrial chemicals, and pathogenic microbes **stay in tissue** long after the exposure ends. Modern life is shortening the runway to overload.

THE CHITOSAN THROUGH-LINE

Chitosan binds and removes these cumulative toxins from **water, soil, and air** before they reach the body. Additionally, inside the body, it binds ingested microplastics, dietary fat, bile, acid-bound cholesterol, and heavy metals to make them ready for excretion.

It is the primary antimicrobial and adsorbent that closes the loop across every industry that touches humans and animals. *That is why we are in this business.*

AN INTRODUCTION · WHAT CHITOSAN IS, WHERE IT COMES FROM, WHY IT MATTERS

Chitosan — Wow.

Where chitosan comes from, why it carries a positive charge, and how that single property can lower environmental toxic load in people and pets.



SOURCES

Where chitosan comes from.

Chitosan (pronounced *KITE-o-san*) is made from **chitin** (pronounced *KITE-n*), the **second most abundant biopolymer on Earth**. Chitin forms the exoskeletons of insects and crustaceans and the cell walls of fungi. Enzymatic deacetylation of chitin yields chitosan.

SOURCE 01

Insects



Black soldier fly exoskeletons. Year-round biomass, farmed in controlled bioreactors on organic waste streams.

SOURCE 02

Fungi



Mushroom cell walls — especially *Agaricus* and *Lenzites betulina*. Vegan, kosher, halal, no shellfish allergens.

SOURCE 03

Crustaceans



Shrimp, crab, lobster shells — the traditional source. Widely used for industrial and agricultural grades.

SOURCE 04

Algae



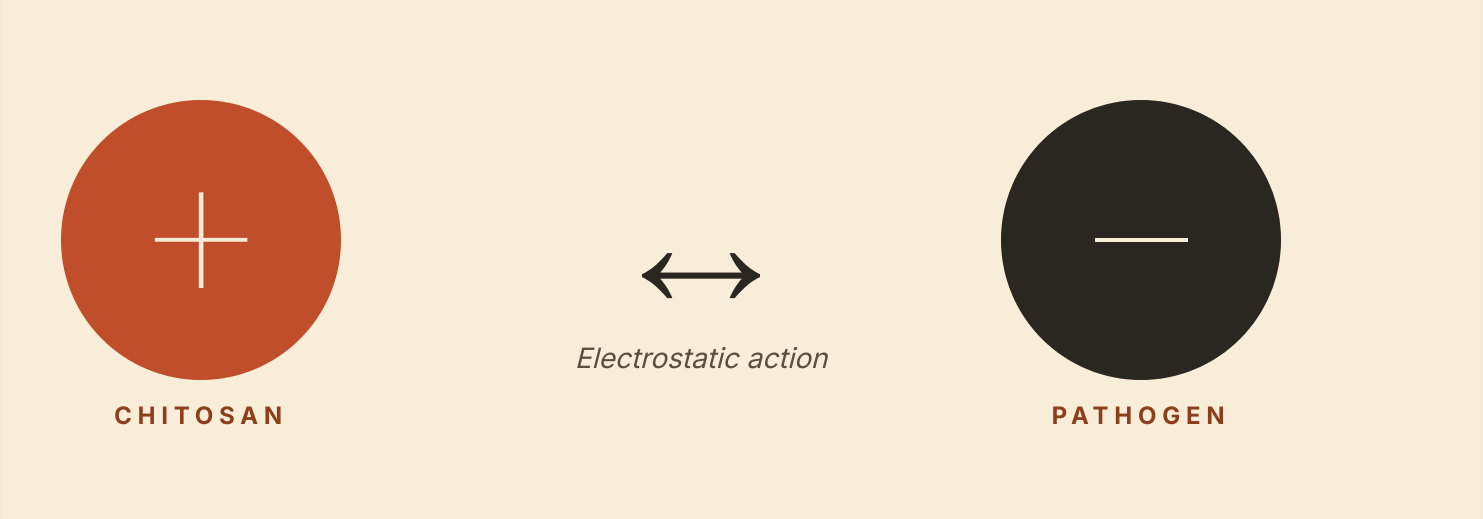
Certain green and brown algae also contain chitin. An emerging, marine-friendly source under active research.

Chitin — exoskeletons of crustaceans, insects, fungi, and algae

Opposite charges attract.

Disease-causing microbes carry a **negative (-) charge** on the outside of their cells. Chitosan carries a **positive (+) charge**.

Opposite charges attract. The positive chitosan binds to the negative microbial surface and disrupts the cell wall through **electrostatic action**.



Most disease-causing microbes carry a negative surface charge.

<i>E. coli</i> gut infections, food poisoning	<i>Salmonella</i> poultry, eggs, produce	<i>Listeria</i> deli meats, cheese, fridge cold-tolerant	<i>MRSA</i> hospital & skin infections
<i>Pseudomonas</i> biofilm, wound infections	<i>Shigella</i> dysentery, waterborne	<i>Candida</i> yeast infections, oral thrush	Many more Gram-negative and Gram-positive bacteria, yeasts, and fungi.

Chitosan vs. Quats.

The traditional industry uses **quaternary compounds** — “Quats” — to kill microbes. They work, but they come with real trade-offs. Chitosan is the biopolymer replacement.

COMPARISON	TRADITIONAL QUATS · SYNTHETIC CHEMICALS	CHITOSAN · BIODEGRADABLE · BIOCOMPATIBLE · NON-TOXIC
Source <i>Where it comes from.</i>	Petrochemical feedstocks. Manufactured in industrial reactors from synthetic precursors.	Shells, mushrooms, or insect exoskeletons — produced by simple enzymatic deacetylation.
Health impact <i>Effect over time.</i>	Skin, lung, and long-term exposure concerns are documented. Rinsed residues persist.	Biocompatible and non-toxic. Safe for direct food, feed, and medical contact.
Resistance <i>Can microbes adapt.</i>	Yes. Bacteria mutate around chemical modes of action, and Quat resistance is now widespread.	No. The action is electrostatic; there is no biochemical target to mutate around.

KEY BENEFITS · FOUR REASONS CHITOSAN REPLACES QUATS

01 Selective binding.

Pathogens carry a negative surface charge. Positively charged chitosan binds them electrostatically, ignoring neutral tissue.

02 Physical mode of action.

The mechanism is electrostatic, not biochemical. The positive charge disrupts the microbial cell wall on contact.

03 No resistance pathway.

Because the action is electrostatic rather than biochemical, microbes have no target to mutate around and cannot develop resistance.

04 Biocompatible source.

Derived from shellfish, insects, fungi, and algae. GRAS-notified for food; biocompatible for medical use.

Regulatory clearances.

Chitosan comes in many forms and has many applications. **Most of those applications are already approved** under the food, feed, cosmetic, water-treatment, and biopesticide frameworks of major markets. Some, however, still depend on **use-specific or product-specific** clearances — for example, an EPA-exempt biopesticide may still need brand-name registration in individual U.S. states.

It is **the customer’s responsibility** to confirm and, where required, obtain the appropriate clearances for their finished product, use pattern, and territory. Chitosan Global supplies the raw material and its Certificate of Analysis; the buyer owns the finished-product registration.

DIVISION OF RESPONSIBILITY

Chitosan Global provides

Certificate of Analysis, technical data, GRAS-notified raw material, safety documentation, and formulation guidance.

Customer obtains

Finished-product registration, label review, brand-name state approvals, and any use-specific clearance for the target application and territory.

WHERE CHITOSAN IS ALREADY CLEARED · AND WHERE PRODUCT-SPECIFIC WORK MAY BE NEEDED

Food & feed

CLEARED FRAMEWORKS

U.S. FDA GRAS (GRN 170, GRN 397, GRN 443 for fungal chitosan); EU EFSA opinion on shrimp chitosan; OIV Resolution 336-2009 for wine fining; feed-additive listings in several jurisdictions.

CUSTOMER’S WORK

Finished-product label review, allergen statement, and any state-level food-contact filings.

Agricultural biopesticide

CLEARED FRAMEWORKS

U.S. EPA 25(b) minimum-risk exemption for chitosan and poly-D-glucosamine (40 CFR 152.25); EU biocontrol basic-substance status; approved plant defence elicitor in Japan and Korea.

CUSTOMER’S WORK

Brand-name state registrations (CA, NY, and others), efficacy dossier, label copy.

Cosmetics & personal care

CLEARED FRAMEWORKS

INCI-listed as “Chitosan” and its salts; EU CosIng entry; U.S. MoCRA cosmetic-facility framework applies to finished products.

CUSTOMER’S WORK

MoCRA facility registration, safety substantiation file, INCI-compliant labelling.

Water, medical, and novel uses

CLEARED FRAMEWORKS

NSF/ANSI 60 potable-water coagulant listings for qualifying grades; FDA 510(k) precedent for chitosan hemostatic dressings; drinking-water and swimming-pool clarifier allowances in most jurisdictions.

CUSTOMER’S WORK

Product-specific NSF or medical-device submission, novel-use consultation with regulator.

Introduction.

Chitosan is a global industrial asset. It is derived from shellfish, insects, fungi, and certain types of algae, and its measurable impact now runs from agriculture and water treatment through food safety, animal health, and medicine. This handbook is written for the CEOs, formulators, and investors who need actionable, scientific, and commercial intelligence.

- Real-world use cases, not laboratory abstractions.
- CAS-certified derivatives with batch-linked Certificates of Analysis.
- Regulatory alignment: GRAS, FDA, EFSA, REACH, ISO.
- Pilot-backed protocols from Shield Nutraceuticals and Promecens Entosystems.

- I** **THE MOLECULE**
Origins, sourcing, derivatives, analytical methods. Chapters 1–5.
- II** **APPLICATIONS**
Agriculture, food, animal health, mycotoxin. Chapters 6–8.
- III** **WATER, ENVIRONMENT, INDUSTRY**
Water, supplement, oral care, industrial. Chapters 9–12.
- IV–VI** **MANUFACTURING, FRONTIER, REFERENCE**
Pilot studies, compliance, market outlook, glossary, index, references.

Editors and team.

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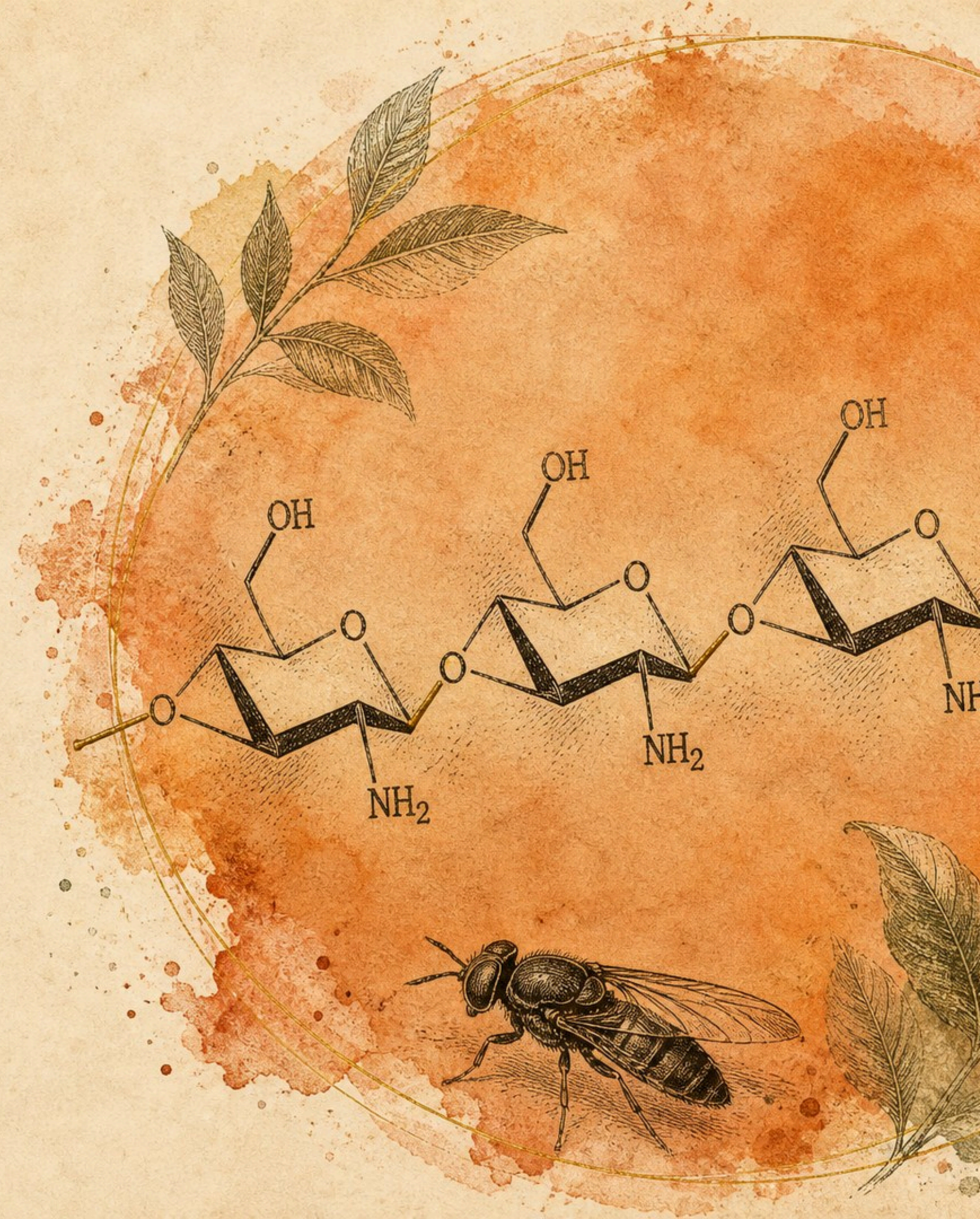
Acronyms.

ACP	Amorphous calcium phosphate
AFB₁	Aflatoxin B ₁
BRD	Bovine respiratory disease
BSF	Black soldier fly (<i>Hermetia illucens</i>)
CAS	Chemical Abstracts Service registry number
CMC / CMCS	Carboxymethyl chitosan
CoA / COA	Certificate of Analysis
COS	Chitosan oligosaccharide
DDA	Degree of deacetylation
DoQ	Degree of quaternization
DS	Degree of substitution
EFSA	European Food Safety Authority
ETEC	Enterotoxigenic <i>Escherichia coli</i>
FCR	Feed conversion ratio
FG	Food grade (Chitosan Global product tier)
FHB	Fusarium head blight
GRAS	Generally Recognized As Safe (US FDA)
GRN	GRAS Notice (FDA docket)

HCl	Hydrochloric acid / hydrochloride salt
IG	Industrial grade (Chitosan Global product tier)
kDa	Kilodalton (1000 daltons)
LMW	Low molecular weight
MBC	Minimum bactericidal concentration
MIC	Minimum inhibitory concentration
MW	Molecular weight
NAHMS	USDA National Animal Health Monitoring System
OIV	International Organisation of Vine and Wine
PFAS	Per- and polyfluoroalkyl substances
PFOA / PFOS	Perfluorooctanoic / perfluorooctanesulfonic acid
Q_{max}	Maximum adsorption capacity (mg/g)
RCT	Randomised controlled trial
TMC	Trimethyl chitosan (N,N,N-trimethylated)
TVC / TPC	Total viable count / total plate count
USDA	United States Department of Agriculture
w/v	Weight per volume (concentration)
pK_a	Acid dissociation constant

PART ONE

What chitosan is.

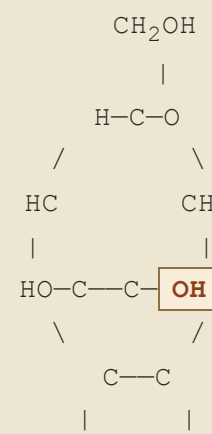


One amine group away from cellulose.

SIDE-BY-SIDE · THE ONE SUBSTITUTION THAT CHANGES EVERYTHING

CELLULOSE

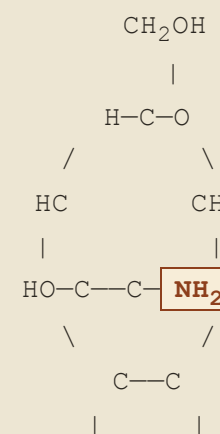
Poly β -1,4-D-glucose



Neutral. Structural. The C-2 hydroxyl group makes cellulose inert — the scaffolding polymer of all plant life.

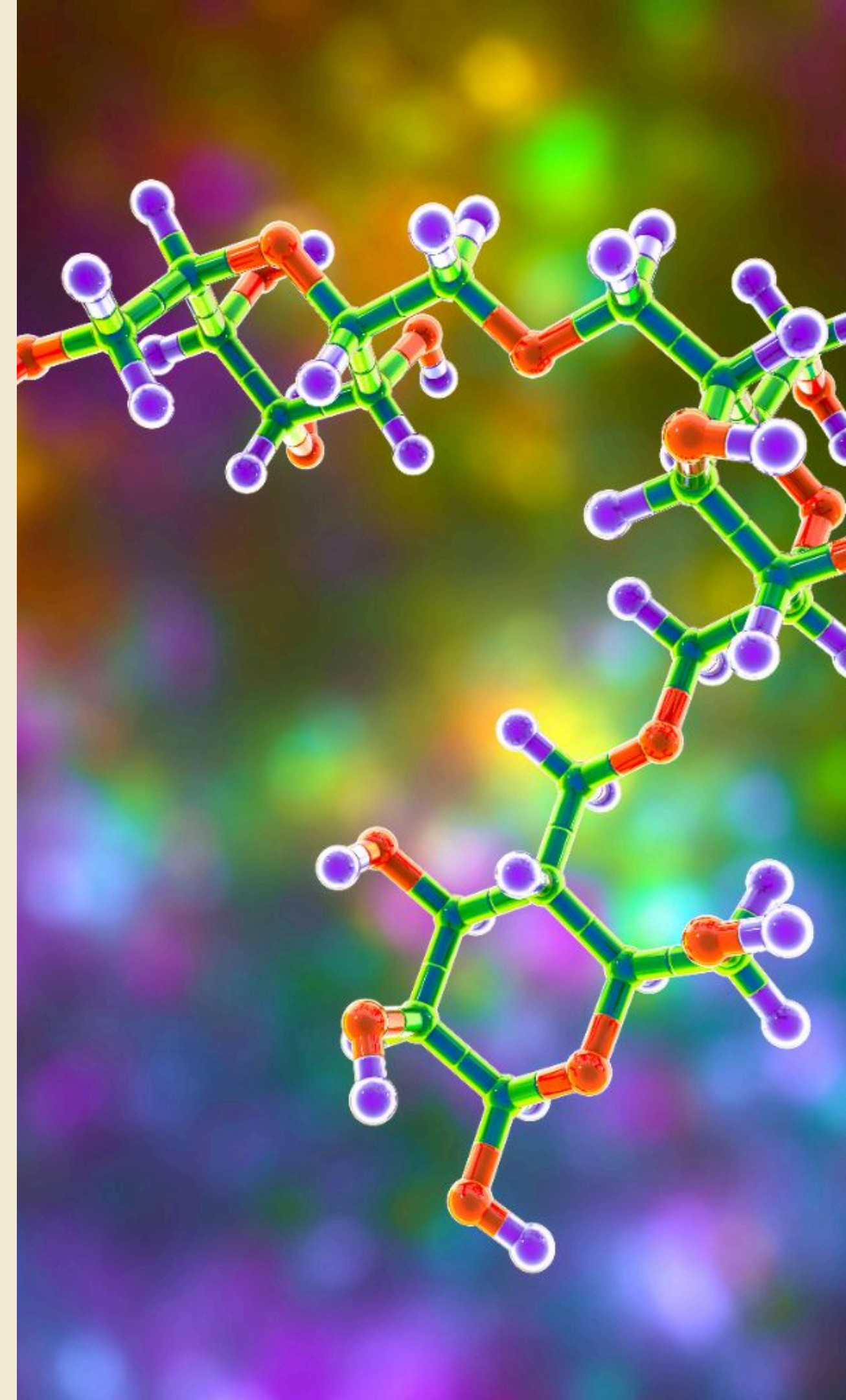
CHITOSAN

Poly β -1,4-D-glucosamine



Positively charged. Reactive. The amine (—NH_2) at C-2 is what lets chitosan bind pathogens, metals, and PFAS.

Cellulose and chitosan share almost the same backbone. Where cellulose carries a hydroxyl (—OH), chitosan carries an amine (—NH_2). That one substitution at C-2 turns an inert structural sugar into the only positively charged polymer in nature.



CHITOSAN

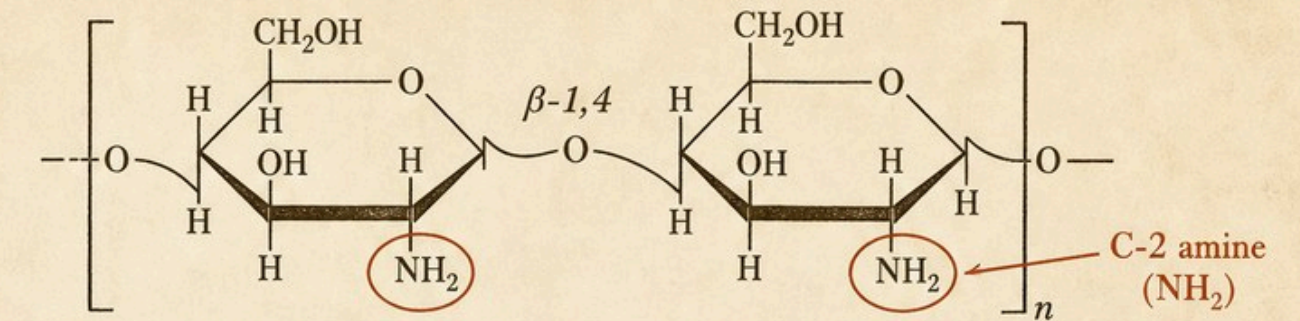
Naturally derived. Positively charged.

Chitosan is a naturally derived polysaccharide that carries a positive electrical charge. That charge is the origin of every functional application that follows — direct interaction with negatively charged microbial surfaces, contaminant particles, and plant, animal, and human tissue.

It is produced from chitin — one of the most abundant natural biopolymers on Earth, present in crustaceans, fungi, insects, and certain algae — through a deacetylation reaction that converts each acetyl group into a primary amine.

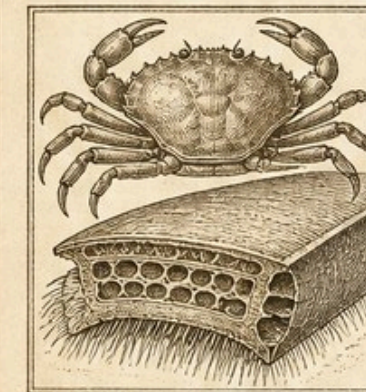
Chitosan is valued as a naturally derived, biocompatible alternative to harsher synthetic chemical approaches. Its versatile functional properties span R&D, biomedical and healthcare, food and agriculture, and environmental remediation.

1. WHAT IS CHITOSAN

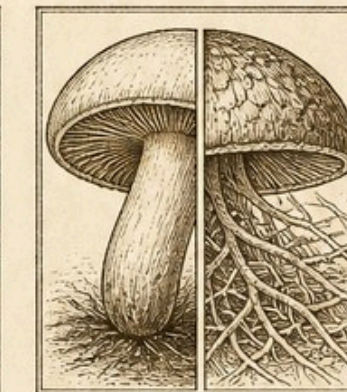


The only naturally occurring positively charged biopolymer.

2. FOUR NATURAL SOURCES



Carcinus maenas



Agaricus bisporus

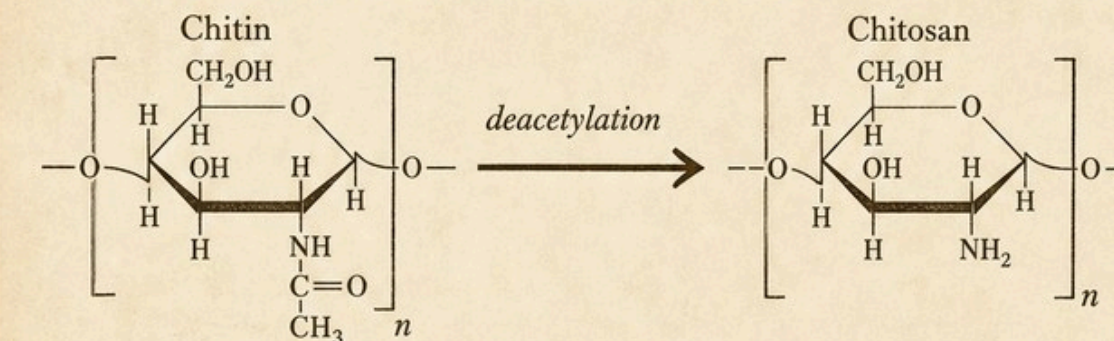


Hermetia illucens

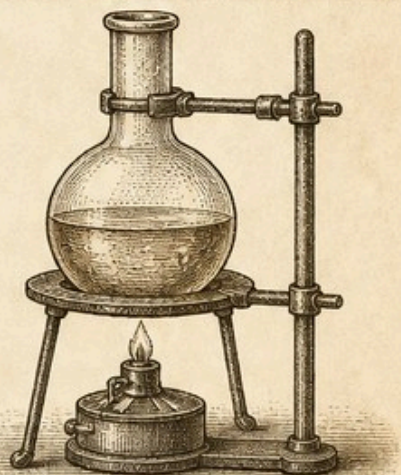


Ulva lactuca

3. PRODUCTION FROM CHITIN



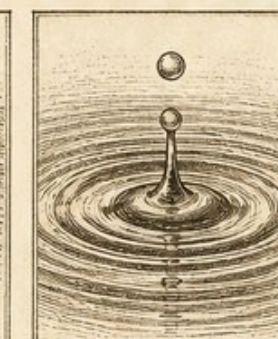
Enzymatic deacetylation converts acetyl groups into primary amines.



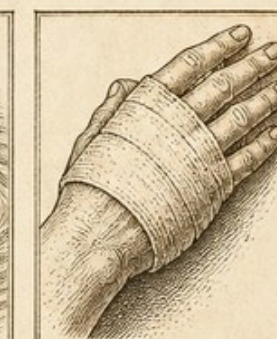
4. WHERE IT WORKS



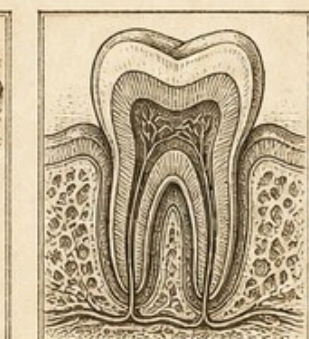
Food & agriculture



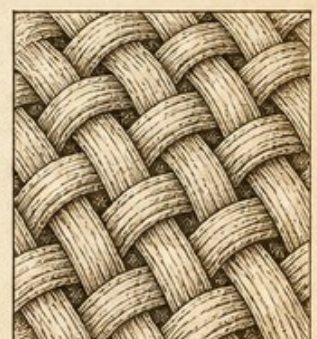
Water treatment



Wound care



Oral care



Textiles

Discovered in 1811. Industrialised in 2026.

1811	Henri Braconnot isolates fungin from mushroom cell walls — the first published record of chitin.
1859	Charles Rouget discovers that heating chitin in alkali produces chitosan — a soluble, positively charged polymer.
1878	The name <i>chitosan</i> is formally adopted; its structural relationship to cellulose is established.
1930s	First industrial-scale extraction from crustacean shells; early textile and water-treatment work.
1970s	Antimicrobial activity documented; wound-care applications begin in Japan and Scandinavia.
2003	Chitosan hemostatic dressings deployed by US military forces; battlefield use begins.
2009	OIV approves fungal-source chitosan for wine fining — first clean-label deployment in a regulated food category.
2013	FDA GRAS Notice 443 for shrimp chitosan (Primex ChitoClear) accepted for human food use.
2023	FDA GRAS Notice 997 for <i>Agaricus</i> mushroom chitosan + β -glucan — the first fully-vegan chitosan food-use pathway.
2026	Chitosan Global launches Chitosan FG (food), Chitosan IG (mycotoxin), and crown-ether lithium chemistry.

Nine categories, nine incumbents being replaced.

APPLICATION	INCUMBENT	WHY CHITOSAN WINS
Bakery preservative	Calcium propionate, sorbates, benzoates	Clean label
Wine fining	Isinglass, gelatin, casein, egg white	Vegan, no allergen
Water-treatment coagulant	Alum, ferric sulfate, PAC	No aluminium residual
PFAS remediation	Granular activated carbon	Higher capacity, lower cost
Poultry feed additive	Sub-therapeutic antibiotics	No AMR pathway
Wound dressing hemostat	Gauze + fibrin sealants	Bio-absorbable, non-animal
Antimicrobial textile finish	Silver nanoparticles, triclosan	No metal leaching
Lithium recovery	Evaporation ponds, DLE resins	Selectivity, water footprint
Mycotoxin binder	Bentonite, activated charcoal	Targeted charge affinity

SOURCE BIOMASS · FIGURE 2.1

Chitin. The second-most abundant polymer on Earth.

Chitin forms the structural component of crustacean shells, insect exoskeletons, and fungal cell walls. Only cellulose is more abundant. Removal of the acetyl group from each glucosamine unit yields chitosan — the same polymer backbone, now bearing a primary amine and, in acidic media, a cationic charge.

Shellfish chitosan accounts for roughly 95 % of all chitosan made in the world — on the order of 50,000 metric tons annually.



Black soldier fly. Year-round biomass. Non-shellfish.

Black soldier fly larvae are cultivated on organic waste streams in controlled bioreactors and harvested year-round. Their exoskeletons yield chitin at consistent purity, free of shellfish-allergen protein and independent of marine harvest cycles.



Six parameters define chitosan quality.

Before comparing sources, fix the vocabulary. These six attributes, measured on the batch Certificate of Analysis, determine how the polymer behaves in the formulation and in the body.

01 DDA · DEGREE OF DEACETYLATION

How much is actually chitosan.

Fraction of deacetylated units along the chain. Below ~60% the polymer behaves like chitin; between 85% and 99% is high-quality chitosan. DDA determines how much positive charge the polymer can develop in acidic solution.

04 ZETA POTENTIAL

How much cationic charge in solution.

Direct measure of net surface charge in mV at a given pH. A potential of +30 mV or higher is the colloidal-stability threshold; grades running +60 to +70 mV are the ones driving pathogen binding, flocculation, and contaminant adsorption.

02 MOLECULAR WEIGHT · MW / M_v

How long the chain is.

Reported as M_v (viscometric) or M_w (weight-average), typically between <3 kDa (oligosaccharides) and >1 MDa (full-chain). Long chains form films; short chains cross membranes and act as prebiotics and plant-defense elicitors.

05 BIOACTIVITY

What it actually does in an assay.

Quantified in functional tests: minimum inhibitory concentration against pathogens, adsorption capacity for metals or PFAS (Q_{max}, mg/g), upregulation of plant-defense genes. DDA and charge are necessary but not sufficient — bioactivity is proven in the assay.

03 PURITY · RESIDUALS

What else is in the powder.

Water-insoluble matter, ash, residual protein, heavy metals (Pb, Cd, Hg, As), and bio-burden (total count, *Salmonella*, coliforms). Food and pharmaceutical grades require <10 ppm heavy metals and <100 CFU/g microbial count.

06 BIOAVAILABILITY · SOLUBILITY

Where in the body it can reach.

Salt form (HCl, lactate, acetate) and molecular weight set the pH range of solubility. Low-MW COS crosses mucosal linings and cell walls; full-chain chitosan stays on the surface. Bioavailability is tuned with the derivative, not the dose.

*Every Chitosan Global batch is characterised on all six parameters. The batch Certificate of Analysis documents each value for every shipment — see **Chapter 4** for the full COA verification checklist.*

Crustacean, mushroom, or black soldier fly. Same molecule, three feedstocks.



CRUSTACEAN



MUSHROOM · BUTTON & OYSTER



BLACK SOLDIER FLY

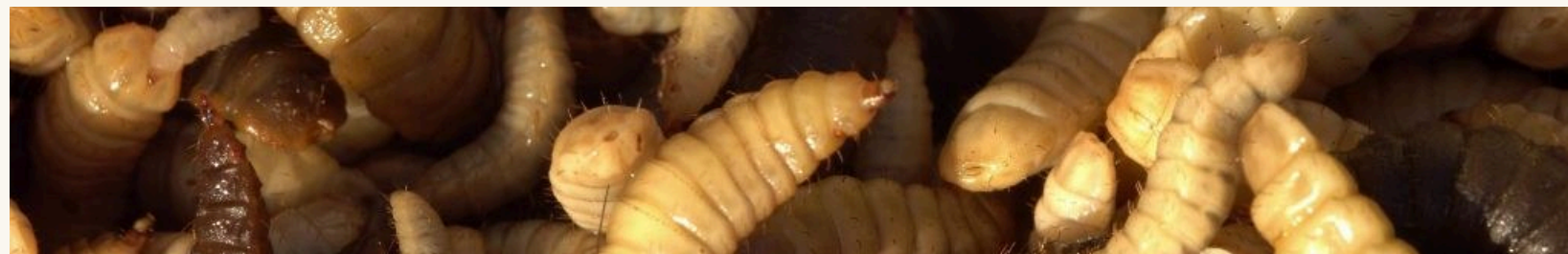
ATTRIBUTE	CRUSTACEAN	MUSHROOM	BLACK SOLDIER FLY
Source organism	Shrimp, crab, lobster shells	<i>Agaricus bisporus</i> , <i>Lenzites betulina</i> , oyster mushroom	<i>Hermetia illucens</i> larvae exoskeleton
Typical DDA	80–95 %	95–99 %	85–95 %
Typical MW range	50 kDa – 1 MDa	2 kDa – 300 kDa	10 kDa – 400 kDa
Shellfish allergen risk	Requires tropomyosin removal	None	None
Vegan / kosher / halal	Not vegan; kosher/halal review needed	All three	Not vegan; kosher/halal review needed
FDA GRAS pathway	GRN 443 (Primex, 2013)	GRN 997 (<i>Agaricus</i> , 2023)	In progress
OIV wine fining approval	Not approved	Approved 2009 (fungal only)	Not approved
Best for	High-MW film-forming, cost-sensitive volumes	Food, cosmetics, oral care, clean-label	Continuous supply, circular feedstock, industrial scale

Sources: FDA GRAS Notices 443 and 997. OIV Resolution 336-2009. Kaya et al. 2015, Zool Sci 32:397. Waśko et al. 2016, Nova Biotechnol Chim 15:213. Chitosan Global product data 2026.

Farmed indoors. Fed on spent brewers' grain and other agricultural waste.

Black soldier fly larvae (*Hermetia illucens*) eat organic waste and produce two things: an oily, protein-rich feed for other animals, and an exoskeleton rich in chitin.

Unlike shrimp fisheries, BSF farming is continuous, indoor, and completely uncoupled from marine ecosystems. The chitin yield is consistent from batch to batch. The exoskeleton is free of the marine heavy-metal exposure that food-grade shellfish chitosan producers spend money to remove. And the byproduct feed helps make the whole system economically viable. BSF chitosan can help meet worldwide demand by building biorefineries that valorise agricultural waste as feedstock.



Sources: Kaya et al. 2015, Zool Sci 32:397. Waško et al. 2016, Nova Biotechnol Chim 15:213. Promecens Entosystems process documentation 2026.

Consistent supply. No fisheries dependence, no seasonal price swings.

Circular feedstock. Farms convert organic waste into chitin at industrial scale.

Lower heavy-metal load than marine shell. Indoor rearing on controlled substrate; no marine bioaccumulation.

No shellfish allergen risk. Insect tropomyosin is antigenically distinct from crustacean tropomyosin in most allergy panels.

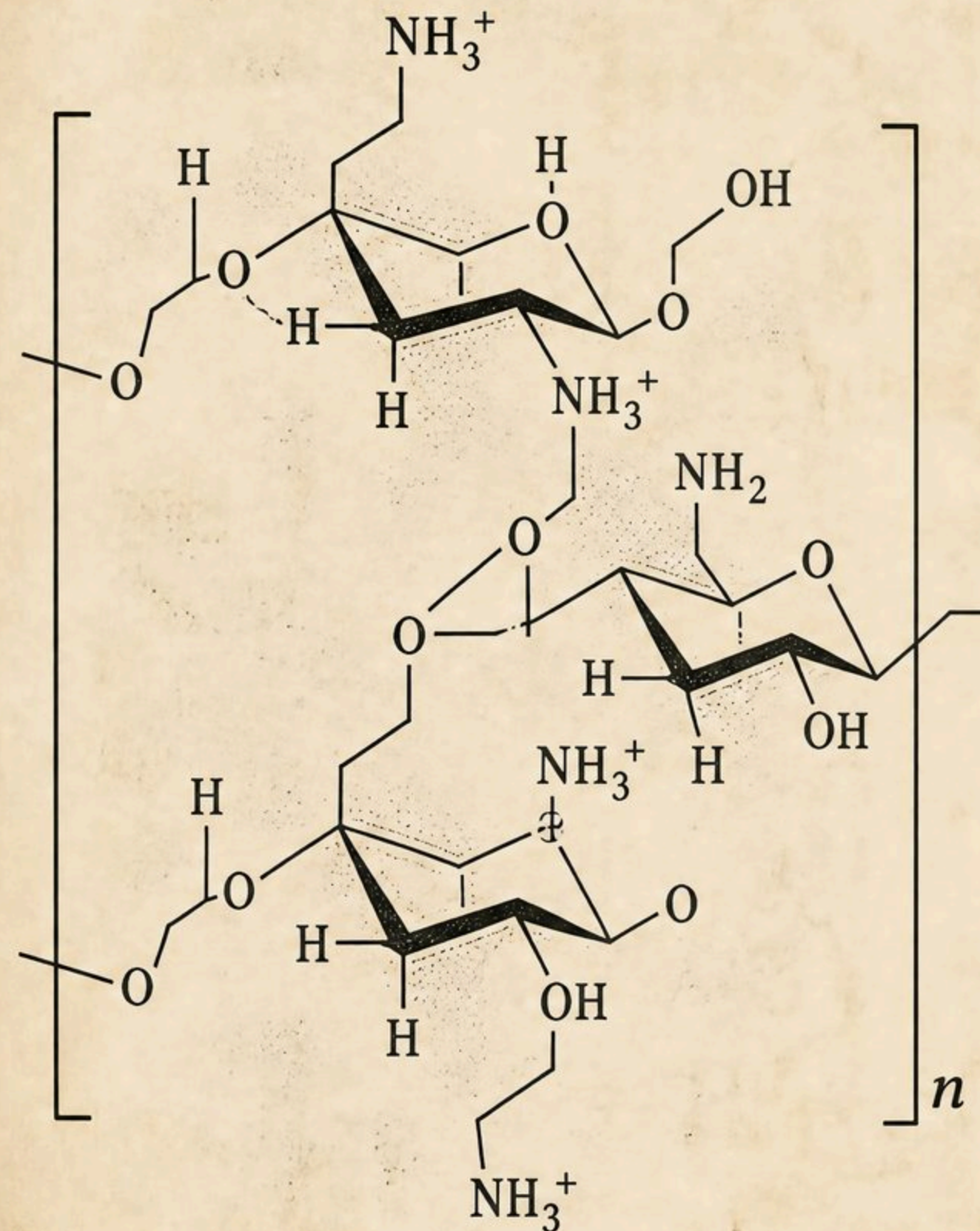
THE CHARGE LADDER

Nine grades of Chitosan Global chitosan, ordered by COA-verified zeta potential (mV) at pH 3.5-5.0.

All zeta values verified by third-party analytical lab at Venture Center, Pune.
Chitosan Global / Promecens Entosystems batch COAs, 2025-2026.

- 1 **+71.04 mV — CHITOSAN 70 AG / 70 IG (COS-HCl)** COA
98.67% DDA · lot PRM/CHT-70AG/01-2026 · water/PFAS/mycotoxin
- 2 **+59.77 mV — CHITOSAN 60 FG (COS-Lactate)** COA
98.67% DDA · lot PRM/CHT-60FG/01-2026 · food preservation, produce coatings
- 3 **+45 to +55 mV — QUATERNARY CHITOSAN**
86.5% DDA · MW 145 kDa · lot QCh/01/2025 · oral care, medical films
- 4 **+40 to +55 mV — TRIMETHYL CHITOSAN (TMC)**
58.6% DS · MW 296 kDa · lot TMC/01/2025 · pharma mucosal delivery
- 5 **+37.45 mV — CHITOSAN AS (Acid-Soluble)** COA
92.54% DA · MW 170 kDa · lot PRM/CHT-AS/01-2026
- 6 **+37.34 mV — CHITOSAN WS (Water-Soluble)** COA
93.23% DA · MW 45 kDa · lot PRM/CHT-WS/01-2026
- 7 **+25 to +45 mV — CHITOSAN OLIGOSACCHARIDE (COS)**
nutraceuticals, plant elicitor, calf nutrition
- 8 **+15 to +35 mV — CARBOXYMETHYL CHITOSAN (CMC)**
amphoteric · MW 249 kDa · lot CMCS/01/2025 · cosmetics, remineralization
- 9 **+15 to +40 mV — CHITOSAN ACETATE**
literature range · agricultural spray, seed coating

● COA VERIFIED ○ LITERATURE RANGE



The higher the surface charge, the broader the electrostatic action.



The positive charge survives only below pK_a .

Chitosan carries its cationic charge on the primary amine at C2 of each glucosamine unit. The amine accepts a proton and becomes —NH_3^+ only below its acid-dissociation constant, pK_a — unless it is **Chitosan FG, IG, or AG from Chitosan Global**, which is antimicrobial from pH 2 to 12. It is the only chitosan, besides quaternized derivatives, that can make that claim. For native chitosan, pK_a is 6.3–6.5.

Above pK_a , the amine deprotonates. Solubility, cationic binding, membrane disruption, and flocculation performance drop with it. Because municipal water runs pH 7–8, seawater pH 8.1, blood pH 7.4, and most industrial effluent above 7, standard chitosan is inactive in the systems where it is most needed.

Sources: Wang et al. 2006, Int. J. Biol. Macromol. 40(1):24–29. Rinaudo 2006, Prog. Polym. Sci. 31:603–632. Chang et al. 2015, Carbohydr. Polym. 134:74–81.

NATIVE CHITOSAN · CHARGE VS. PH

pH 3.0 (acetic acid solution)	> 90 % protonated
pH 5.0 (produce surface)	~ 80 % protonated
pH 6.5 (pK_a)	50 % protonated
pH 7.0 (drinking water)	~ 20 % protonated
pH 8.0 (seawater)	< 5 % protonated
pH 9.0 and above	Effectively neutral

Cationic through pH 12. The first chitosan that holds its charge in alkaline media.

Three Chitosan Global grades manufactured by Promecens Entosystems — **Chitosan 60 FG** (COS-Lactate, food grade), **Chitosan 70 AG** (COS-HCl, agriculture grade), and **Chitosan 70 IG** (COS-HCl, industrial grade) — retain measurable cationic charge across the entire pH range from 3 to 12.

This is a first in the industry. It removes the pK_a ceiling that has limited chitosan for four decades and opens applications previously inaccessible to the polymer: alkaline wash water, hard-water clarification, seawater lithium extraction, cementitious systems, and physiological-pH drug delivery.

Source: Promecens Entosystems Pvt. Ltd. technical data. Third-party zeta-potential characterisation, Venture Center, Pune, India. COA lots PRM/CHT-60FG, PRM/CHT-70AG, PRM/CHT-70IG (01/01-2026).

CHARGE RETENTION ACROSS THE PH RANGE

PH	NATIVE CHITOSAN	PROMECENS FG / AG / IG
3	> 90 %	+70 mV
5	~ 80 %	+68 mV
7	~ 20 %	+62 mV
8	< 5 %	+58 mV
10	Neutral	+50 mV
12	Neutral	+40 mV

FG, AG, and IG grades are available at industrial scale from four biomass origins — *Agaricus bisporus*, *Lenzites betulina*, oyster mushroom, and black soldier fly — at parity pricing across all four. Procurement teams can specify origin (vegan, kosher/halal, allergen-free, or upcycled insect) without a cost differential.

AGARICUS · LENZITES · OYSTER · BSF

Chitosan 70 AG & IG

(COS-HCl)

Chitosan Oligosaccharide Hydrochloride · Agaricus bisporus mushroom source · CAS 70694-72-3

The HCl salt of a low-molecular-weight, high-DDA chitosan oligosaccharide, sourced from *Agaricus bisporus* mushroom mycelium. The batch COA reports a zeta potential of **+71.04 mV** at pH 4.48 — the highest charge measurement in the Chitosan Global catalog.

That charge underpins the primary applications of both grades. The AG (agricultural) grade elicits plant defense response and adsorbs mycotoxins in stored grain. The IG (industrial) grade removes PFAS from municipal water and binds heavy metals.



Chitosan 70 AG — low-molecular-weight, high-DDA oligosaccharide hydrochloride sourced from Agaricus bisporus mycelium. Sold as fine off-white powder; water-soluble at neutral pH.

Click the photo → shop this product on [chitosanglobal.com](#)

CERTIFICATE OF ANALYSIS

Batch specifications

Lot PRM|CHT-70AG|01|01-2026 · Promecens Entosystems Pvt. Ltd. · Mfg. January 2026 · Exp. December 2028

CAS number	70694-72-3
Source material	Agaricus bisporus
Molecular weight	< 3 kDa
Deacetylation degree	98.67 %
Purity	99.13 %
Zeta potential (1% aq.)	+71.04 mV
pH (1% solution, 25°C)	4.48
Viscosity (1% aq., 30°C)	6.59 cSt
Heavy metals (as Pb)	Nil
Water-insoluble fraction	0.01 %

Figure 3.1

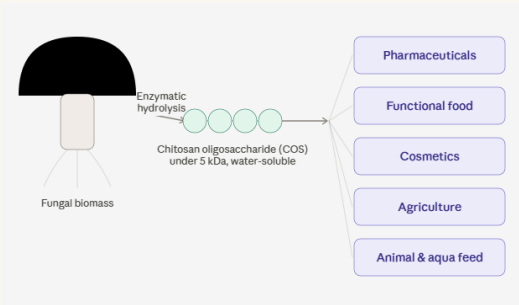
Chitosan 60 FG

(COS-Lactate)

Chitosan Oligosaccharide Lactate · Agaricus bisporus mushroom source · CAS 148411-57-8

The lactate salt of a low-molecular-weight, mushroom-derived chitosan oligosaccharide. The batch COA reports a zeta potential of **+59.77 mV** at pH 4.48 — a high cationic charge in a food-grade salt form.

The lactate anion is food-grade and GRAS-pathway compatible. That combination — high cationic charge in a food-safe salt form — is why Chitosan FG has become the anchor grade for produce coatings, natural food preservation, and bakery shelf-life extension.



Chitosan 60 FG (COS-Lactate) — food-grade cationic oligosaccharide. Sold as free-flowing off-white powder; used in produce coatings, bakery shelf-life, and cut-flower vase treatments.

Click the photo → shop this product on chitosanglobal.com

CERTIFICATE OF ANALYSIS

Batch specifications

Lot PRM|CHT-60FG|01|01-2026 · Promecens Entosystems Pvt. Ltd. · Mfg. January 2026 · Exp. December 2028

CAS number	148411-57-8
Source material	Agaricus bisporus
Molecular weight	Low MW oligo
Deacetylation degree	98.67 %
Purity	99.13 %
Zeta potential (1% aq.)	+59.77 mV
pH (1% solution, 25°C)	4.48
Viscosity (1% aq., 30°C)	6.59 cSt
Heavy metals (as Pb)	Nil
Water-insoluble fraction	0.01 %

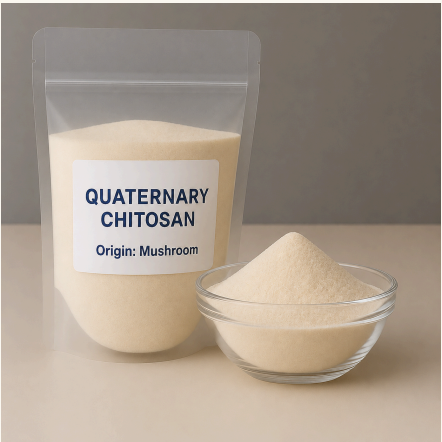
Figure 3.2

Quaternary Chitosan

Quaternary ammonium chitosan derivative (HTCC) · Origin CAS 9012-76-4 · MW 145 kDa

Every other chitosan depends on protonation. Take the pH above 6 and the positive charge disappears. Quaternary chitosan does not. A permanent quaternary ammonium group is chemically grafted to the polymer — the charge is built in and cannot be turned off by pH.

That single property makes it the strongest broad-pH antimicrobial platform in the family. It is where the peer-reviewed literature points for dental-device coatings, mucosal drug delivery, and biocide films that need to work in neutral or alkaline environments.



Quaternary Chitosan (HTCC) — permanent cationic charge, water-soluble across the full pH range. Supplied as pale off-white powder from mushroom or shellfish source.

Click the photo → shop this product on chitosanglobal.com

CERTIFICATE OF ANALYSIS

Batch specifications

Lot QCh/01/2025 · Promecens Entosystems Pvt. Ltd. · Mfg. April 2026 · Exp. March 2028

CAS number (origin)	9012-76-4
Molecular weight (avg.)	145 kDa
Deacetylation degree	86.54 %
Degree of quaternization	0.42
Zeta potential (literature)	+40 – +55 mV
Purity (dry basis)	99.23 %
Viscosity (1% aq., 25°C)	2.3 cS
pH (1% aqueous)	4.2
Heavy metals (as Pb)	Nil

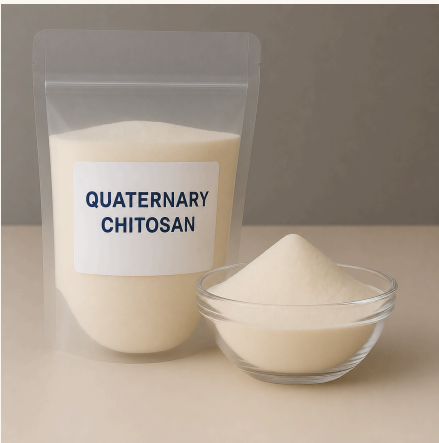
Figure 3.3 · Zeta not published on this COA; range from Sahariah & Másson 2017.

Trimethyl Chitosan

TMC · N,N,N-trimethyl chitosan · CAS 52349-26-5 · MW ~296 kDa

Trimethyl chitosan (TMC) is a specific member of the quaternary chitosan family — three methyl groups on the amine nitrogen, producing a permanent trimethylammonium cation. It has become the workhorse of chitosan pharmaceutical development.

TMC dissolves cleanly across the full physiological pH range. It opens tight junctions in mucosal epithelium, briefly and reversibly, which is what lets nasally-delivered vaccines and peptide drugs cross into the bloodstream. Insulin, calcitonin, and several influenza and hepatitis B vaccine candidates have been formulated on TMC.



Trimethyl Chitosan (TMC) — a specific member of the quaternary chitosan family. Supplied to pharmaceutical formulators for nasal vaccine adjuvants, mucosal drug carriers, and peptide-drug delivery.

Click the photo → shop this product on chitosanglobal.com

CERTIFICATE OF ANALYSIS

Batch specifications

Lot TMC|01|2025 · Promecens Entosystems Pvt. Ltd.

CAS number	52349-26-5
Molecular weight (avg.)	295.67 kDa
Degree of substitution	58.6 %
Purity (dry basis)	99.09 %
Zeta potential (literature)	+35 – +55 mV
Viscosity (1% aq., 25°C)	3.1 cP
pH (1% aqueous)	6.1
Heavy metals (as Pb)	Nil
Total viable count	< 100 CFU/g

Figure 3.4 · Zeta not published on this COA; range from Amidi 2010.

Chitosan Hydrochloride

HCl salt of chitosan · the regulatory-clean anion · 98% DDA, 3 kDa

Where COS-HCl is the highest-charge, lowest-molecular-weight variant used in water and mycotoxin work, plain chitosan hydrochloride is the pharma-and-agriculture workhorse. The chloride counter-ion is regulatory-clean — no confounding organic acids, no residual acetate, no lactate to interfere with a downstream assay.

It is the grade a formulator reaches for when the finished product will face FDA, EMA, or ICH review. It is also the grade that dominates the agricultural biostimulant category, where 98% DDA and 3 kDa molecular weight give the most bioavailable elicitor of plant defense response.

Chitosan hydrochloride, 98% DDA, 3 kDa — grams of powder per gallon:

Volume	Seed soak 0.3%	Foliar 0.4%
1 gal	11.4 g	15.1 g
5 gal	56.8 g	75.7 g
10 gal	114 g	151 g
50 gal	568 g	757 g
100 gal	1,136 g	1,514 g
300 gal	3,407 g	4,542 g

Slurry small volume first, expand, agitate 10 min. Warm water (40–50 °C) accelerates dissolution. Use within 24–48 h.

Source: Chitosan Hydrochloride Mixing Guide for Agricultural Applications, Chitosan Global 2026. Full 8×10 table in Chapter 8, page 72.

Chitosan AS & WS. Same molecule. Two salt behaviours.

CHITOSAN AS · ACID-SOLUBLE

Higher MW. Heavier film.

Native chitosan, 170 kDa, dissolved in mild acetic acid at pH 3.5. The higher molecular weight builds a mechanically stronger film on produce, meat, and wound surfaces — the reference grade for edible-coating literature.

Zeta potential	+37.45 mV
Degree of acetylation	92.54 %
Molecular weight	170 kDa
Batch	PRM/CHT-AS/01/01-2026

CHITOSAN WS · WATER-SOLUBLE

Lower MW. Neutral pH.

Native chitosan, 45 kDa, hydrolysed to full water solubility. Same zeta, lower viscosity, no acid needed. The grade formulators reach for when the product must dissolve at neutral pH, in cold water, without acid.

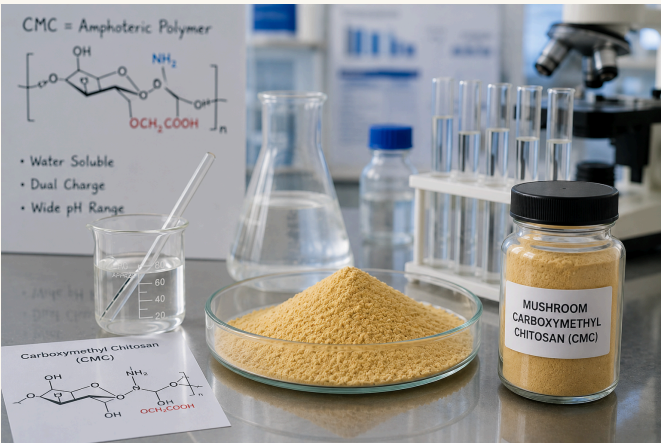
Zeta potential	+37.34 mV
Degree of acetylation	93.23 %
Molecular weight	45 kDa
Batch	PRM/CHT-WS/01/01-2026

Carboxymethyl Chitosan

CMC · CMCS · CAS 83512-85-0 · the amphoteric derivative

Grafting a carboxymethyl group onto chitosan makes the polymer amphoteric and freely soluble at near-neutral pH. This solubility enables use in the cosmetics and personal-care formulation category, which typically operates at pH 5–7.

In oral care, CMC is where the strongest peer-reviewed signals concentrate. It reduces *Streptococcus mutans* adherence, and its complexes with amorphous calcium phosphate template the intrafibrillar remineralization of dentin and enamel.



Carboxymethyl Chitosan (CMC) — the amphoteric derivative. Sold as pale yellow-to-tan powder from mushroom, shellfish, or BSF source.

Click the photo → [shop this product on chitosanglobal.com](https://chitosanglobal.com)

CERTIFICATE OF ANALYSIS

Batch specifications

Lot CMCS|01|2025 · Promecens Entosystems Pvt. Ltd.

CAS number83512-85-0

Molecular weight (avg.)249.12 kDa

Purity (dry basis)99.23 %

Viscosity (1% aq., 25°C)2.3 cS

Zeta potential (literature)+15 – +35 mV

pH (1% aq., acidic)4.2

pH (1% aq., alkaline)8.5

Heavy metals (as Pb)Nil

Insoluble substances0.12 %

Figure 3.6 · Zeta not published on this COA; range from Qu et al. 2023, PMC10570529.

Chitosan Oligosaccharide (COS)

COS is chitosan reduced to its short-chain form, typically under 3 kDa. Where full-chain chitosan sits on a surface, COS moves through it — small enough to cross cell walls and interact with intracellular targets.

In the soil, COS at 0.3% w/v is one of the most reliable elicitors of plant defense response, triggering a roughly three-fold upregulation of the pathogenesis-related defense genes TaPAL, TaPR1, and TaPR2. In the calf gut, it functions as a prebiotic amino sugar that shifts the microbial balance and shortens diarrhea recovery. In the nutraceutical aisle, it is the immune-support ingredient that anchors dozens of clean-label supplement lines.

Plant elicitor. 0.3–0.4% w/v foliar / seed treatment activates systemic acquired resistance in wheat, corn, tomato, cucumber, coffee.

Calf nutrition. Prebiotic fibre; supports gut barrier function and reduces neonatal diarrhea recovery time.

Dietary supplements. Immune modulation, gut-microbiome support, cholesterol management via bile-acid binding.

Cosmeceuticals. Low-molecular-weight, water-soluble; penetrates the stratum corneum where high-MW chitosan cannot.

Sources: Gunupuru et al. 2019, *Plant Sci* 285:110–120. Alam et al. 2012, *Vet Med Czech* 57(8):400. Shah et al. 2022, *Fermentation* 8(10):549.

Chitosan Lactate

Full-chain chitosan in its lactate salt form · GRAS-pathway counter-ion

Full-chain chitosan (typically 50–300 kDa) dissolved into its lactate salt. The lactate counter-ion sits inside the GRAS-pathway envelope for food and personal-care use, and it dissolves cleanly at pH 4–5 without leaving an acetic-acid odor.

The molecular weight matters. Where COS-lactate creates a thin, penetrating film, chitosan lactate builds a heavier, more mechanically resilient coating — the grade of choice for meat surface treatments, dairy interior packaging, and film-forming personal-care leave-ons.

Meat surface treatments. Film-forming coating on cured meats and poultry, extending refrigerated shelf life through moisture control and surface pathogen interference.

Dairy packaging interiors. Interior linings for yoghurt cups and cheese wraps that inhibit mold at the film surface.

Leave-on personal care. Hair conditioners, hand creams, film-forming serums — where the higher-MW variant gives substantivity.

Film-and-coating research. Standard reference grade in edible-film literature.

Chitosan Acetate

Full-chain chitosan dissolved in dilute acetic acid · the agricultural default

The oldest and most common agricultural form. Chitosan dissolved in 0.5–1% acetic acid, adjusted to pH 5–6, and diluted into tank mix. It has been the workhorse of chitosan crop-protection literature for three decades — the grade behind most of the published foliar-spray field trials.

The acetate counter-ion makes it inexpensive and reliable in the field. The tradeoff is a mild acetic-acid odor at concentration, and slightly lower shelf life in the sprayer once mixed. For most agricultural applications, those tradeoffs are acceptable in exchange for a lower cost per acre.

Foliar sprays. Sugarcane red rot, coffee rust, tomato smut — the reference literature grade.

Seed treatments. Coats seed with a thin elicitor film that pre-primes systemic defense response before germination.

Post-harvest dips. Fruit and vegetable surface treatments in the packing shed.

Chitosan-nanoparticle research. Standard starting material for nano-formulation development.

Which grade goes in your formula.

APPLICATION	WHY THIS GRADE	GRADE
PFAS, heavy-metal water treatment	Highest charge; low MW for pore access	COS-HCl
Mycotoxin adsorption in grain	High-charge cation binds anionic aflatoxin B ₁	COS-HCl (IG)
Produce coatings, food preservation	GRAS-pathway; high charge in food-safe form	COS-Lactate (FG)
Broad-pH oral rinse, dental coating	Charge does not fade with pH swing	Quaternary
Nasal vaccine, oral peptide delivery	Opens tight junctions; broad-pH solubility	TMC
Medical-device coating, ag elicitor	Regulatory-clean chloride counter-ion	Chitosan HCl
Toothpaste, wound hydrogel, cosmetics	Water-soluble at neutral pH; amphoteric	CMC
Plant elicitor, dietary supplement	Crosses cell walls; high bioactivity	COS
Meat films, dairy packaging	Higher MW gives mechanical film strength	Chitosan Lactate
Foliar spray, seed coat, post-harvest dip	Lowest cost/acre; three decades of field data	Chitosan Acetate

Every grade, every origin, one page.

Green-manufactured, batch-COA characterized, and available in Mushroom, Shellfish, and Black Soldier Fly (BSF) origins. Click any product name to view its shop page and order samples.

PRODUCT · GRADE		ORIGIN		PRIMARY APPLICATIONS			PROCESS
NATIVE CHITOSAN				CARBOXYMETHYL CHITOSAN (CMCS)			
Native Chitosan	Mushroom	Industrial	GREEN	CMCS	Mushroom	Food, Pharma, Cosmetics	GREEN
Native Chitosan	Shellfish	Food, Agriculture	GREEN	CMCS	Shellfish	Food	ORIGINAL
CHITOSAN OLIGOSACCHARIDE · HCL				CMCS	BSF	Food	GREEN
Chitosan AG	Mushroom / BSF	Agriculture	GREEN	QUATERNARY CHITOSAN			
Chitosan IG	Mushroom / BSF	Industrial	GREEN	Promecens Quaternary	Mushroom	Industrial, Medical, Pharma	GREEN
CHITOSAN OLIGOSACCHARIDE · LACTATE				Quaternary	Shellfish	Industrial, Medical, Pharma	ORIGINAL
Chitosan FG	Mushroom / BSF	Food	GREEN	Quaternary	BSF	Industrial, Medical, Pharma	GREEN
CHITOSAN HYDROCHLORIDE				ADVANCED DERIVATIVES			
Chitosan HCl	Mushroom	Multi-industry	ORIGINAL	Trimethyl (TMC)	Mushroom / Insect	Medical, Pharma	GREEN
Chitosan HCl	Shellfish	Multi-industry	ORIGINAL	Sulphonated	Mushroom / Insect	Medical, Pharma	GREEN
Chitosan HCl	Mushroom / BSF	Multi-industry	GREEN	Phosphorylated	Mushroom / Insect	Medical, Pharma	GREEN
CHITOSAN OLIGOSACCHARIDE · SOLUBILITY GRADES				FEED & SPECIALTY COS			
Chitosan-36 AS · acid-soluble	Mushroom / Insect	Industrial, Agriculture	GREEN	Feed & cosmetic COS RX-H10, H85 · RY-COS90 · NUGLY LB/IM	Sea source	Feed, Cosmetic, Food	ORIGINAL
Chitosan-36 WS · water-soluble	Mushroom / Insect	Industrial, Agriculture	GREEN	Alginate Oligo RY-AOS	Sea source	Agriculture	ORIGINAL

BULK PRICING · COA · MSDS — For current bulk pricing, tender documentation, and technical support, use the [Contact Us](#) page at chitosanglobal.com or write to info@chitosanglobal.com.

SAMPLES — Analytical samples are available directly through the [Shop](#) at chitosanglobal.com.

What to look for on a Certificate of Analysis.

CHEMISTRY

Six numbers to check.

1. Deacetylation degree (DDA / DS / DoQ)
2. Molecular weight or oligosaccharide range
3. Purity on dry basis
4. pH of 1% aqueous solution
5. Viscosity of 1% aqueous solution
6. Water solubility / insoluble fraction

PROVENANCE

Three lines to insist on.

1. Source material named (species and derivative)
2. CAS number
3. Batch / lot number tied to the shipment

Reference: All Chitosan Global product CoAs at chitosanglobal.com follow this schema. Zeta measurement is available on request.

CONTAMINANTS

Four things that must be present.

1. Heavy metals (as Pb) ≤ 10 ppm
2. Arsenic ≤ 2 ppm
3. Total viable count ≤ 100 CFU/g
4. Absence of pathogenic bacteria (*Salmonella*, coliforms)

ZETA POTENTIAL

Nice to have, rarely required.

Zeta measurement is not standard on every CoA. When it is present, it should carry the pH condition of the measurement. Chitosan zeta is highly pH-dependent, and a value quoted without a pH is not a meaningful specification.

PART TWO

Applications.



A biopolymer, sprayed on the leaves.

Chitosan works on plants in two ways at once. It forms a thin antimicrobial film on the leaf surface, and it triggers the plant's own defense pathways — systemic acquired resistance. Field trials in tomato, coffee, and sugarcane have documented both effects together.



Imperial & Metric mixing charts.

All concentrations expressed as % w/v (weight/volume). Highlighted columns show the two most-common field concentrations: seed soak (0.20%) and foliar / plant defense (0.30–0.50%).

IMPERIAL · OUNCES & POUNDS PER GALLON

CONCENTRATION	RATE	1 GAL	5 GAL	10 GAL	25 GAL	50 GAL	100 GAL
0.025% Drip	0.03 oz/gal	0.03 oz	0.17 oz	0.33 oz	0.84 oz	1.67 oz	3.34 oz
0.05% Drip	0.07 oz/gal	0.07 oz	0.34 oz	0.67 oz	1.67 oz	3.34 oz	6.68 oz
0.10% Drip	0.13 oz/gal	0.13 oz	0.67 oz	1.34 oz	3.34 oz	6.68 oz	0.83 lb
0.20% Seed soak	0.27 oz/gal	0.27 oz	1.34 oz	2.67 oz	6.68 oz	0.83 lb	1.67 lb
0.30% Plant defense	0.40 oz/gal	0.40 oz	2.00 oz	4.01 oz	10.01 oz	1.25 lb	2.50 lb
0.40% Plant defense	0.53 oz/gal	0.53 oz	2.67 oz	5.34 oz	13.35 oz	1.67 lb	3.34 lb
0.50% Plant defense	0.67 oz/gal	0.67 oz	3.34 oz	6.68 oz	1.04 lb	2.09 lb	4.17 lb
0.80% Pathogen	1.07 oz/gal	1.07 oz	5.34 oz	10.68 oz	1.67 lb	3.34 lb	6.68 lb
1.00% Pathogen	1.34 oz/gal	1.34 oz	6.68 oz	13.35 oz	2.09 lb	4.17 lb	8.35 lb

METRIC · GRAMS PER LITER OF SOLUTION

CONCENTRATION	RATE	1 L	5 L	10 L	20 L	100 L
0.025% Drip	0.25 g/L	0.25 g	1.25 g	2.5 g	5 g	25 g
0.05% Drip	0.5 g/L	0.5 g	2.5 g	5 g	10 g	50 g
0.10% Drip	1 g/L	1 g	5 g	10 g	20 g	100 g
0.20% Seed soak	2 g/L	2 g	10 g	20 g	40 g	200 g
0.30% Plant defense	3 g/L	3 g	15 g	30 g	60 g	300 g
0.40% Plant defense	4 g/L	4 g	20 g	40 g	80 g	400 g
0.50% Plant defense	5 g/L	5 g	25 g	50 g	100 g	500 g
0.80% Pathogen	8 g/L	8 g	40 g	80 g	160 g	800 g
1.00% Pathogen	10 g/L	10 g	50 g	100 g	200 g	1 kg

APPLICATION KEY

Seed soak 0.20% · 30–60 min pre-planting
Drip irrigation 0.025–0.10% during irrigation cycles
Plant defense 0.30–0.50% foliar during stress
Pathogen mitigation 0.80–1.00% only when needed

PREPARATION

Most water-soluble chitosans take about an hour to dissolve. The high-charge chitosans — **Chitosan FG, AG, and IG** — dissolve in 15 minutes at room temperature and in under 5 minutes at 110 °F (43 °C). Slurry the powder in a small bucket first, then add to the main tank while stirring.

CAUTION · DO NOT MIX WITH

Chitosan HCl is cationic (+). **Do NOT mix** with anionic polymers — xanthan gum, alginate, carrageenan, or pectin. Immediate clumping and precipitation will ruin the batch. PPE: dust mask, glasses, gloves.

Systemic resistance · and in-vitro proof against *Fusarium*.

Chitosan mimics a fungal cell-wall fragment. When a plant leaf senses it on the surface, the plant reads that signal as an incoming pathogen and turns on its systemic acquired resistance pathway — before any real pathogen actually shows up. Within 24 hours, pathogenesis-related genes are upregulated three-fold or more; phytoalexin production increases; callose is deposited at the cell wall.

UVG PLANT PROTECTION LABORATORY · REPORT FI-26-179 (2026)

Chitosan 70 mV in-vitro efficacy at 8 g/L (0.8 %).

PATHOGEN (SAMPLE)	EFFECTIVENESS A / B	READING VS. CONTROL
<i>Fusarium</i> sp. (LPV-26-779)	100 % / 100 %	Equivalent to sterile-water negative control.
<i>Alternaria</i> sp. (LPV-26-780)	90 % / 90 %	Agronomically meaningful; fits IPM protocols.
<i>Colletotrichum</i> sp. (LPV-26-781)	0 % / 0 %	Indistinguishable from untreated positive control.

Method: 1×10⁶ CFU/mL spore suspension combined with 8 g/L (0.8 %) Chitosan 70 mV for 24 h; 100 µL plated on PDA; incubated 28 °C; read at 5 & 6 days.

MOLECULAR SIGNATURE OF THE ELICITOR RESPONSE

TaPAL. Phenylalanine ammonia lyase — the entry point to phenylpropanoid defense metabolism.

TaPR1. Pathogenesis-related protein 1 — broadly antifungal.

TaPR2. β-1,3-glucanase — degrades fungal cell walls.

Chitinase induction. The plant produces its own chitosan-degrading enzyme.

Trichothecene suppression. Downregulates the biosynthesis pathway for *Fusarium* mycotoxins including DON.

Sources: Gunupuru et al. 2019, Plant Sci 285:110. El Hadrami et al. 2010, Marine Drugs 8:968. Iriti & Faoro 2009, Environ Sci Pollut Res 16:191. UVG Plant Protection Laboratory (CEAA), Universidad del Valle de Guatemala, Report FI-26-179 · Samples LPV-26-779 to 781 · issued July 2026 · submitted by Shield Nutraceutical Inc.

Same molecule, every stage of the crop.

SEED TREATMENT

Priming before germination.

Seeds soaked at 0.3% w/v chitosan HCl for 4–12 hours emerge with the systemic defense pathway pre-activated. Germination rates improve 8–15% under stress; seedling vigor is measurably higher.

Cotton, wheat, soybean, tomato, cucumber, pepper.

FOLIAR SPRAY

Defense on demand.

A 0.4% foliar application at seven-to-fourteen day intervals maintains the systemic acquired resistance signal through the vegetative growth stage. Deployed as a stand-alone product or tank-mixed with fertilisers.

Standard rate: 15 g / gal in the sprayer.

POST-HARVEST DIP

The last treatment.

A 0.5–1.0% dip in the packing shed forms the thin surface film that carries produce through cold-chain distribution. Extends refrigerated shelf-life without any pesticide-residue tolerance.

Citrus, stone fruit, berries, capsicum.

Agricultural protocol. At 15 g of Chitosan AG per foliar gallon and 20 gal per acre, combined with a 5–15 % post-harvest shrink reduction and a modest yield uplift, payback is typically inside a single growing season. For current pricing, contact chitosanglobal.com/contact-us.

On the plant. On the shelf. On the plate.

The mechanism against foodborne pathogens is identical to that in water treatment: electrostatic binding to the negatively charged microbial surface. Applied as a wash or a coating, chitosan inactivates *Salmonella*, *Listeria*, and *E. coli* at concentrations well below those required by chlorine or quaternary ammonium.

Chitosan FG at 0.1% concentration is ideal for spraying vegetables to help maintain freshness.

[MORE INFO →](#) · [GROCERY SHELF-LIFE ARTICLE →](#)



Produce loses value between pack-out and the shelf edge.

Moisture loss, surface dulling, and uneven appearance during handling, transit, and store-level rotation all erode what buyers and shoppers see at the shelf. Today's options are typically heavier processing chemistries or label-driven fungicide programs.

Buyers are asking for a gentler, cleaner-label quality-support option that fits inside an existing pack line. Chitosan FG is one answer.

01

Visual quality slipping between pack and shelf.

02

Pressure for cleaner-label, surface-based options.

03

Limited pack-line minutes to add a new step.

How the coating anchors, forms, breathes.



01 · ANCHOR

Opposite charges attract.

Chitosan is a cationic biopolymer. Produce surfaces — including natural cuticles — contain negatively associated carboxyl and hydroxyl groups. That difference in charge creates electrostatic attraction, allowing the polymer to anchor closely to the produce surface rather than sit loosely on top.

02 · FORM

Water leaves; a network arrives.

After application, the water phase begins to evaporate. As this occurs, chitosan molecules self-organize into a thin, continuous polymer network on the surface of the fruit or vegetable. The film is flexible, uniform, and adherent.

03 · BREATHE

It moderates. It does not seal.

Chitosan films allow oxygen, carbon dioxide, and water vapor to pass through at moderated rates. Because the coating is semi-permeable, it does not trap the produce in a closed environment. It slows exchange rather than blocking it.

Many spoilage organisms have negatively charged surfaces, so chitosan’s positive charge can interfere with their ability to adhere.

This document presents that mechanism as an operational discussion point only, not as a validated process claim.

Spray before pack-out. Coat. Pack. Ship.

01

LAY OUT

Lay out produce on the existing pack line.

02

SPRAY

Apply an even, light spray of Chitosan FG using standard spray hardware.

03

COAT & PACK

Allow film to form as moisture evaporates, then pack normally.

04

SHIP

Ship to store following standard cold-chain procedures.



Chitosan FG (*Chitosan Oligosaccharide-Lactate*) is positioned only on the surface-quality and physical-coating story. One should be conservative about regulated claim categories: no kill, no log-reduction, no sanitizer language. This is a quality-support tool, not a food-safety intervention.

Replacing benzoates, sorbates, propionates.

Baked goods remain a major category for synthetic preservatives — sodium benzoate, potassium sorbate, and calcium propionate. Consumer demand for clean-label alternatives has grown over the past decade, but until recently no natural preservative matched their broad-spectrum activity at commercially viable dosage.

Chitosan FG (COS-Lactate, +60 mV) enters that gap at 0.3% w/w. It targets the same organisms the synthetics target: *Aspergillus*, *Penicillium*, and *Bacillus subtilis* rope spoilage in bread; surface molds on tortillas and flatbreads.



Standard loaf (700 g)	2.1 g
Tortilla pack (500 g)	1.5 g
Recommended dose	0.3% w/w

Application: Dry blend into flour mix before hydration for breads and dough. Aqueous dispersion (spray/brush) for tortillas and flatbreads.

For current pricing, contact chitosanglobal.com/contact-us.

Sources: Chitosan Global Bread & Tortillas Product Sheet, 2026. Coma 2008, Meat Sci 78:90–103. No et al. 2002, Int J Food Microbiol 74:65–72.

Identify candidate categories, together.

Chitosan FG is not one product for every produce category. It is a family of application approaches — spray, dip, wash — matched to the physiology of the specific commodity.

Our approach with a produce buyer is to shortlist categories where surface-coating support is most relevant to that retailer’s shopper experience. From there, we work backward to a small trial: one category, one distribution centre, a defined observation window, and standard quality metrics tracked against baseline. **Vegetables are a good fit, as are cut flowers.**

No claim of shrink reduction. No sanitizer language. What we measure is what the buyer already measures.

Source: Chitosan FG Grocery Buyer Presentation, Chitosan Global 2026.

Berries. Strawberries, blueberries, raspberries. High moisture loss, visible surface dulling.

Leafy greens. Spinach, kale, romaine hearts. Wilting between DC and shelf.

Tomatoes & peppers. Firmness and skin gloss are the visual signals shoppers use.

Stone fruit. Peaches, nectarines, plums. Bruising and surface abrasion during handling.

Cut flowers. Roses, tulips, lilies. Petal quality and vase-life extension.

Post-harvest citrus. Oranges, lemons, mandarins. Surface finish for merchandising.

One bouquet. One misting. Ten days of extended shelf-life.

Bouquet purchased **Jan 8, 2024**, misted **once** with 0.25% chitosan oligosaccharide from oyster mushrooms (DDA 98%, MW ~3 kDa, ζ +36 mV). Still in good shape on Jan 18. Single-sample anecdote, not a controlled trial.



JAN 8, 2024
Day 0 · misted



JAN 8, 2024
Day 0



JAN 8, 2024
Day 0



JAN 13, 2024
Day 5



JAN 18, 2024
Day 10



JAN 18, 2024
Day 10

FORMULATION			
0.25% mist · single application		DEACETYLATION	MOLECULAR WEIGHT
chitosan oligosaccharide · oyster mushroom source		DDA 98%	~3 kDa
			ZETA POTENTIAL
			ζ +36 mV

Single-sample anecdote — not a controlled trial. Not a Chitosan FG® performance claim.

Added to the feed, not to the animal.

At feed-additive concentrations, chitosan binds pathogens in the gut, improves feed conversion, and modulates immunity — without residues in the meat, milk, or egg. It is one of the few candidates that has held up as a broad-spectrum antibiotic alternative under peer review.



A non-antibiotic tool at the teat.

Mastitis is the most common disease of dairy cows, and the largest single reason for antibiotic use on a modern dairy farm. Each clinical case costs an estimated \$250–\$400 in milk discard, treatment, and labour.

Chitosan-based teat dips and intramammary formulations are now in peer-reviewed evaluation as a non-antibiotic tool for subclinical mastitis. Bovine mammary epithelial cell studies show CMC- and low-MW chitosan reduce inflammatory cytokine response to lipopolysaccharide challenge — the same signalling pathway that drives clinical mastitis.

TNF- α reduction. Significant downregulation in bovine mammary epithelial cells challenged with lipopolysaccharide.

IL-6 and IL-8 reduction. Same mechanism; supports the anti-inflammatory hypothesis.

Oxidative stress markers. Reduced malondialdehyde and elevated superoxide dismutase in treated cells.

Note: The cell-model data are supportive but not equivalent to an in-vivo clinical mastitis field trial. Regulatory positioning for on-farm use is currently as a teat-dip aid, not a therapeutic replacement.

Sources: Wang et al. 2025, *Mar Drugs* 23(1):31 (PMID 39852532). Ruegg 2017, *J Dairy Sci* 100:10381. Ma et al. 2024, in-vitro bovine mammary work.

A prebiotic amino sugar for the first ninety days.

Calf mortality, neonatal diarrhea, bovine respiratory disease, and delayed rumen development are among the largest economic losses in modern dairy and beef operations. As antibiotic stewardship becomes a global priority, the veterinary community is seeking non-antibiotic tools that support calf health from birth.

Mushroom-derived chitosan oligosaccharide (COS) is a prebiotic fibre — also known as an amino sugar. Chitosan Global's three-phase protocol matches calf physiology from birth through weaning.

FOR MORE INFORMATION, CONTACT INFO@CHITOSANGLOBAL.COM



Photo · chitosanglobal.com · Chitosan's new role in calf development and nutrition

Match the derivative to the physiology.



Photo · chitosanglobal.com · Newborn calf, birth-window support

PHASE 01 · BIRTH – 8 WEEKS

COS-Lactate

Food-grade, gentle on the neonatal gut

Supplied 5–10 g/day in milk replacer. The lactate salt is GRAS-pathway compatible and matches the calf’s early acidic abomasal environment.

Focus: gut barrier support, scours prevention, immune development.

PHASE 02 · 6 – 12 WEEKS

COS-HCl

Higher charge, regulatory-clean anion

Supplied 3–5 g/day during transition. The +70 mV grade supports respiratory and pathogen-challenge phases as the calf shifts to solid feed.

Focus: respiratory support, pathogen suppression, transition-diet stability.

PHASE 03 · 10 WEEKS +

Plain COS

Slow-release rumen prebiotic

Supplied 5–10 g/day. Shifts rumen fermentation toward propionate (energy-efficient) and supports papillae development.

Focus: rumen microbiota, feed conversion, methane modulation.

Two verified calf trials.

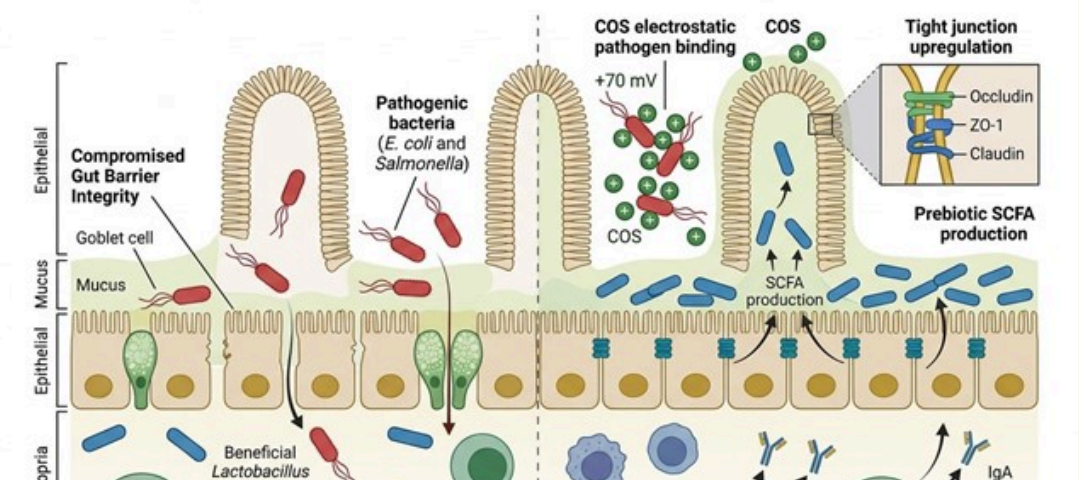


Figure 7.2 · chitosanglobal.com · Mechanism of action of COS in the neonatal calf intestine

ALAM ET AL. 2012 · HANWOO CALVES

Complete recovery of ETEC-challenged calves.

86 calves — 40 control, 46 treated with COS in milk over five days.

89% complete recovery (41/46) in the COS-treated group.

12% spontaneous recovery (5/40) in the untreated control group.

Fecal-consistency scoring, hydration status, and plasma-protein profiles all improved in the treated group.

Vet Med – Czech, 57(8):400–407. DOI vet-201208-0001.

LI ET AL. 2024 · DAIRY CALVES, 67-DAY TRIAL

Roughly half the diarrhea incidence.

48 Holstein calves, four dietary groups compared over 67 days.

4.82% diarrhea incidence in the attapulgit + COS group (ACO).

9.65% incidence in the untreated control — a roughly 50% relative reduction attributable to the COS-containing combination.

Serum IgA, IgG, IgM, and IL-6 markers all shifted favorably in the COS-supplemented groups.

Frontiers in Veterinary Science 11:1376758. PMC11128685.

Dose protocol. Chitosan FG at 4 g[calf]/day for 5 days = 20 g total per calf — against a US pre-weaning mortality baseline of 5% and morbidity of 34%. For current pricing, contact chitosanglobal.com/contact-us.

Note: earlier compilations cite a 62.9% diarrhea reduction; that number traces to Maodong et al. 2010 (Feed Research), not PubMed-indexed.

A quiet workhorse in the pet aisle.

Cats and dogs share our homes, our air, our microplastics, and our aging bones. The pet-supplement category has grown into a **\$2.9 billion U.S. market** as owners seek natural, functional ingredients that do real work.

Chitosan is already inside that market — binding phosphate in feline chronic kidney disease, disrupting oral biofilm on canine teeth, and supporting joints in senior formulas. Chitosan FG, produced from mushroom and Black Soldier Fly sources, offers a green, well-characterized alternative to shellfish-derived material for every category on the next page.

FOR MORE INFORMATION, CONTACT INFO@CHITOSANGLOBAL.COM



Photo · Chitosan formats used in companion-animal products

\$2.9B U.S. pet supplements · 2025 · **8** categories using chitosan

Where chitosan already works in cats and dogs.

Every card below represents a category where chitosan is either (a) already on shelves in named branded products, or (b) supported by peer-reviewed veterinary research. Chitosan FG from Chitosan Global is a drop-in ingredient for each.

01 · FELINE CKD Phosphate binder Chitosan + calcium carbonate binds dietary phosphate in the gut. Sold as Epakitin / Ipakitine (Vétoquinol) and Renakitin for cats and dogs. Source · PubMed 29582226	02 · ORAL CARE Dental chews & gels Cationic chitosan disrupts oral biofilm. Chitosan jelly has been compared favorably to chlorhexidine for canine periodontal disease in peer-reviewed work. Source · Comparative Efficacy of Chitosan Jelly & Chlorhexidine, 2022	03 · JOINT & SENIOR Mobility supplements Listed by Virbac alongside glucosamine and chondroitin as a joint-support ingredient for senior dogs. Chitosan supports the connective tissue matrix. Source · Virbac veterinary advice	04 · GUT HEALTH Probiotic formulas Chitosan oligosaccharide (COS) is a prebiotic amino sugar that selectively feeds beneficial gut flora. Doubles as a matrix for microencapsulated probiotics. Grade · Chitosan FG (COS-Lactate)
05 · SKIN & COAT Shampoo & topical Cationic film-former that binds to anionic hair-shaft damage. Antimicrobial for hot-spot-prone coats.	06 · WOUND CARE Hot-spot gels Hemostatic, film-forming, antimicrobial. Used in veterinary wound gels to accelerate closure and reduce infection risk.	07 · LITTER BOX Cat litter Chitosan binds feline and urease-derived malodor and improves clump integrity in bentonite and plant-based litters.	08 · FRESH PET FOOD Preservation Natural antimicrobial that extends refrigerated shelf life of raw and gently-cooked pet meals — a clean-label alternative to synthetic preservatives.

Two chances to reduce one expensive risk.



Chitosan IG is a dual-action platform designed to suppress selected toxigenic fungi and adsorb aflatoxin B₁ at two critical risk windows: pre-harvest, and during processing and storage.

For grain producers, elevators, storage operators, and feed processors, the same chemistry addresses both risk points — field infection before harvest, and recontamination during handling.

\$52M – \$1.68B

Annual aflatoxin contamination cost to the US corn industry under warmer conditions.

Mitchell et al. 2016

\$6 – \$18B

Global losses per year, all mycotoxins combined.

FAO industry estimate

Aflatoxins are highly heat-stable. Routine cooking is insufficient to break them down; full decomposition requires temperatures above 237 °C. Once formed, they persist through processing.

Field-level prevention is required.

Field infection. Storage recontamination. Same tool.

TOUCHPOINT 01 · PRE-HARVEST

Three mechanisms in the field.

Direct antifungal action. The cationic polymer disrupts fungal cell walls and membranes, inhibiting hyphal growth of *Aspergillus flavus* and *A. parasiticus*.

Plant defense elicitation. Roughly three-fold upregulation of the pathogenesis-related defense genes TaPAL, TaPR1, and TaPR2.

Mycotoxin pathway suppression. Downregulates trichothecene biosynthesis genes at the transcript level.

Francesconi 2020; Gunupuru 2019; Gong 2024.

TOUCHPOINT 02 · STORAGE & PROCESSING

Adsorption after the fact.

Spore germination inhibition. Chitosan IG applied to stored grain inhibits *A. flavus* spore germination, hyphal development, and conidia production.

Aflatoxin B₁ adsorption. The +70 mV cationic amino groups bind anionic aflatoxin at grain surfaces, sequestering already-formed toxin.

pH-responsive activity. The polymer is most active in acidic grain environments — the same conditions in which mycotoxin risk is highest.

Wieczorek 2024; Gijiu 2022.

Four studies. Two touchpoints. One tool.



FRANCESCONI ET AL. 2020

Fusarium head blight in wheat.

Chitosan seed treatment reduced **FHB severity from 20% to 6%** in field trials. Deoxynivalenol contamination in harvested grain dropped in parallel.

Food Chem Toxicol 137:111162.

GONG ET AL. 2024

Post-harvest corn suppression.

Chitosan-treated stored corn showed **~75% inhibition of mycelial growth** of *A. flavus* compared with untreated controls over 21 days.

Journal of Stored Products Research 108:102372.

GUNUPURU ET AL. 2019

Field-scale wheat elicitation.

Foliar chitosan produced an **80% reduction in infection area** from *F. graminearum* and an **84% reduction in conidia** on wheat spikes.

Plant Sci 285:110–120.

WIECZOREK ET AL. 2024

Chitosan-ZnO active films.

Chitosan–ZnO composite films achieved **complete inhibition of spore germination** for *A. flavus* on grain-contact surfaces.

Food Packag Shelf Life 41:101210.

Additional context: Mitchell et al. 2016, World Mycotoxin J 9(2):145 (US corn economic model). Gjiu et al. 2022, *Toxins* 14(2):138 (mycotoxin detoxification in swine).

Four mycotoxin reduction strategies.



GRAIN PRODUCER

Pre-harvest field application.

Foliar or seed-treatment application to the growing crop. Priorities: reducing pre-harvest infection risk in high-warmth seasons, protecting yield in *Aspergillus*-prone regions.

FEED PROCESSOR

Inclusion in finished feed.

Included at 0.1–0.5% w/w in the finished feed mix. Priorities: adsorbing residual mycotoxins in incoming grain, supporting animal performance without antibiotics.

GRAIN ELEVATOR

In-bin storage application.

Applied to grain in silo or bin as a surface dust or fumigant-adjunct. Priorities: preventing storage-mold development, adsorbing already-formed aflatoxin, avoiding load rejection at rail-out.

EXPORTER

Meeting EU / Asia import limits.

Applied at consolidation and containerisation. Priorities: staying below the EU 2 µg/kg aflatoxin B₁ limit, avoiding rejected shipments at the port of entry.

Application rates depend on crop, moisture, and matrix. Efficacy is trial-validated per site. Chitosan IG is positioned as a risk-reduction tool, not a guaranteed detoxification agent.

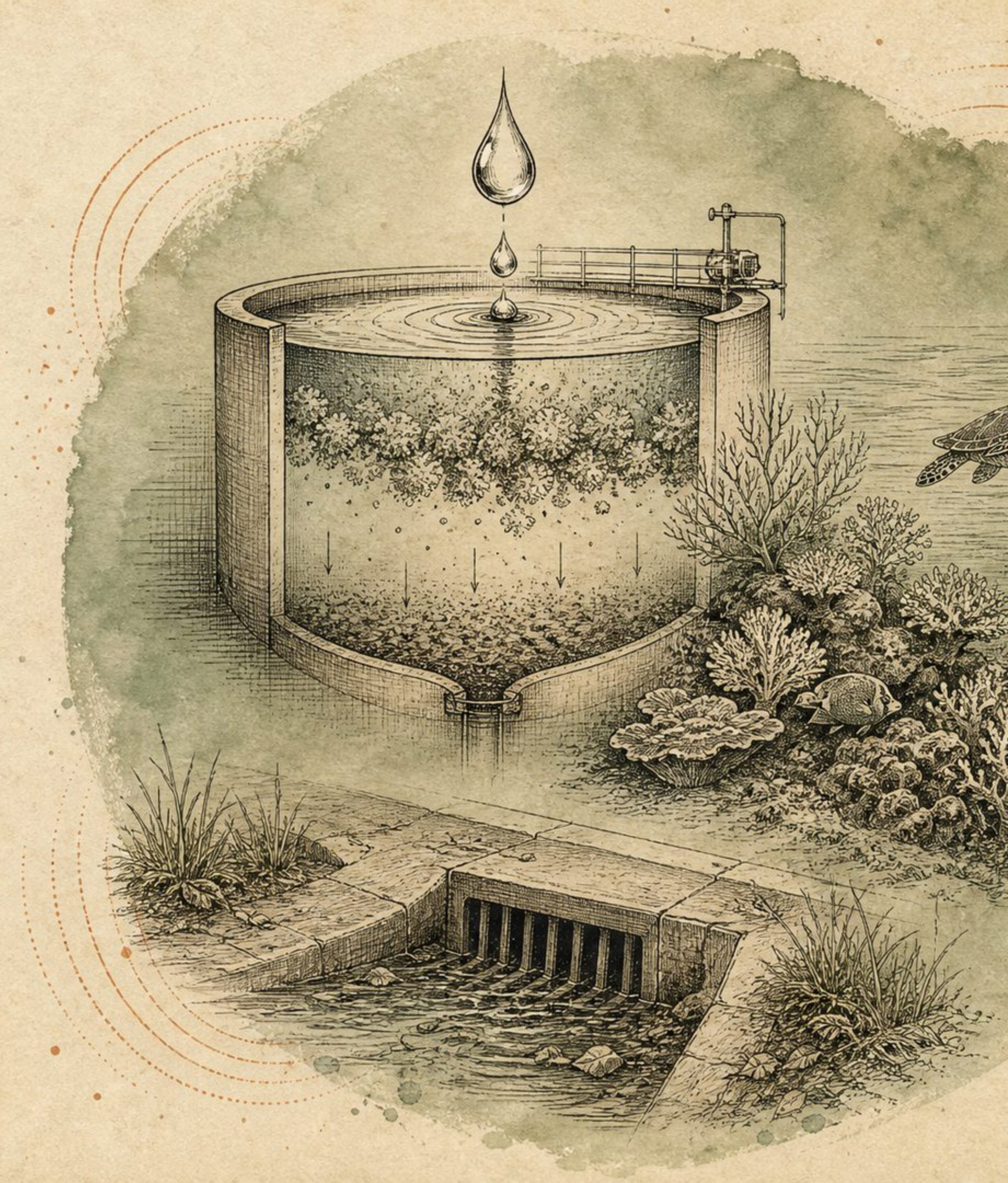
Cleared for use on the human body.

Hemostatic dressings, drug-delivery matrices, and tissue-engineering scaffolds. Chitosan is cleared for medical use because it stops bleeding, holds active ingredients, and degrades safely inside the body.



PART THREE

Water & industrial.



What falls out of water ends up on chitosan.

Heavy metals, dyes, oils, pesticides, microplastics, and pathogens share a common property: a negative surface charge. Cationic chitosan aggregates them into flocs that settle out of solution.



A biodegradable coagulant, at scale.

A US municipal drinking-water plant treating 10 MGD (million gallons per day) uses roughly 3 metric tons of alum daily. The residual aluminium in finished water is small — but growing evidence links long-term exposure to neurological outcomes, and sludge from alum plants requires special handling.

Chitosan IG at 2–5 mg/L achieves equivalent turbidity removal to alum at 15–40 mg/L — a **5–10× lower** effective dose. At 3 mg/L a 10 MGD plant uses roughly 114 kg/day. Sludge is biodegradable, the aluminium residual disappears, and soft-water plants no longer need supplemental alkali.

Effective dose (alum)	15–40 mg/L
Effective dose (chitosan)	2–5 mg/L
Turbidity removal, both	>95 %
Al ³⁺ residual, alum	0.1–0.2 mg/L
Al ³⁺ residual, chitosan	none
Sludge biodegradable	yes

For current pricing, contact chitosanglobal.com/contact-us.

Sources: Yang et al. 2016, Chem Eng J 296:157. Renault et al. 2009, Eur Polym J 45:1337. WHO Guidelines for Drinking-Water Quality, 4th ed. 2022.

Beating granular activated carbon — and everything else.

Granular activated carbon (GAC) has been the workhorse of municipal PFAS removal for two decades. Its problems are well known: high regeneration cost, short-chain PFAS pass-through, and disposal of the spent carbon itself as a PFAS-laden waste.

Chitosan-based adsorbents, such as **Chitosan AG**, can be used to inoculate biochar — sprayed on directly or introduced through a pond. The combination can lift adsorptive capacity by up to **40%**, making it the most powerful combination tool yet for remediating **PFAS, phosphates, heavy metals such as cadmium and mercury, and microplastics** from water and soil.

Chitosan-based adsorbents outperform GAC on the two most-regulated PFAS at neutral pH, and the spent form is biodegradable rather than a persistent waste. For water utilities facing the 2024 EPA maximum contaminant levels for PFOA and PFOS, chitosan is under active evaluation as a compliance technology.

[FULL ARTICLE · BIOCHAR · CHITOSAN · MICROBES →](#)

Sources: Zhang et al. 2011, Water Res 45:4645. Ateia et al. 2019, Chemosphere 220:866. US EPA 2024 final PFOA/PFOS drinking-water MCLs. Shield Nutraceuticals 2026 white paper · Biochar-Chitosan-Microbes.

THE 3-PRONG SYNERGY

Biochar · Chitosan · Microbes

- B** **BIOCHAR · THE POROUS HOST**
300–2,000 m²/g surface area. Micropore entrapment, electrostatic adsorption, and surface complexation with metal ions.
- C** **CHITOSAN · THE BINDER**
Cationic amine groups chelate heavy metals and PFAS anions. Films inoculate biochar, hold microbes, and stabilize both.
- M** **MICROBES · THE METABOLIZER**
Biodegrade organic contaminants; bio-immobilize mobile metals into stable, less-bioavailable forms; sheltered inside the biochar habitat.

COMBINED LIFT

Increased up to **40%** adsorptive capacity · **90–99%** heavy-metal immobilization

Cationic flocculation of colloidal suspensions.

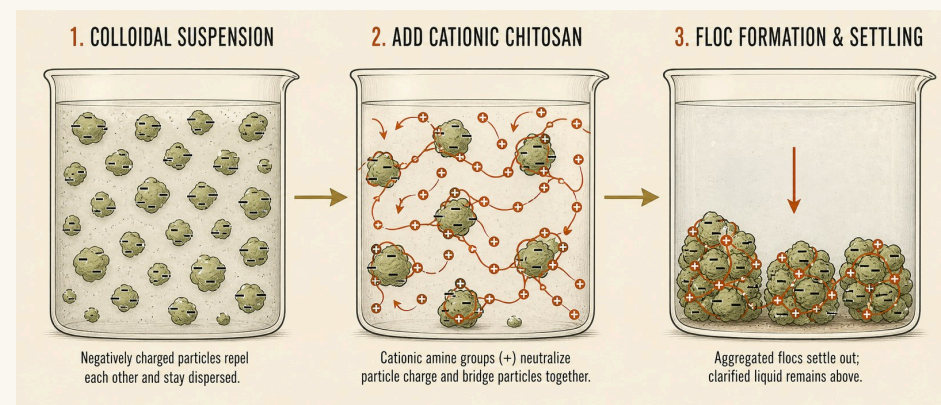


Figure 10B.1 · Cationic flocculation mechanism · Chitosan neutralizes anionic colloids, bridges them into flocs, and drops them to the bottom.

Wine, whiskey, beer, milk, drinking water, swimming pools, ornamental ponds. All of them are colloidal suspensions — small negatively charged particles (proteins, tannins, silt, algae) that refuse to settle out.

Add a cationic polymer, and the particles neutralize, aggregate, and drop. That is flocculation. Chitosan — the only naturally occurring cationic polymer — is used as a clarifier across all of these categories.

TO ORDER A CUSTOM-DESIGNED CHITOSAN FLOCCULANT FOR MILK SOLIDS, POOLS, SPIRITS, OR PROCESSED WATER, CONTACT STEVE@CHITOSANGLOBAL.COM

Sources: Renault et al. 2009, European Polymer J 45(5):1337–48. Yang et al. 2016, Chem Eng J 296:157–66. OIV Code of Oenological Practices, chitosan (fungal-source) approved 2009.

Wine. Fining agent for tannin, protein, and yeast haze; vegan alternative to isinglass, gelatin, and casein.

Whiskey & spirits. Chill-haze removal and cold-stabilization of finished distillates.

Milk & dairy. Cheese-whey clarification; recovery of milk proteins from process wastewater.

Municipal water. Primary coagulant replacing alum in surface-water treatment plants.

Swimming pools. Weekly-dose clarifier that drops fine debris to the filter.

Ornamental ponds & koi. Non-toxic to fish; clears algal and colloidal turbidity.

Fining without animal proteins.

WINE

The OIV-approved vegan fining agent.

Chitosan (fungal-source, from *Aspergillus niger*) was formally added to the OIV Code of Oenological Practices in 2009. It replaces isinglass (fish bladder), gelatin, casein, and egg white as a protein-haze and yeast-cell fining agent.

Dose: 20–500 mg/L, depending on wine style. Removes *Brettanomyces* spoilage yeast populations without allergen labelling concerns.

OIV Resolution 336-2009; Bornet & Teissedre 2008, Eur Food Res Technol 226(4):681–9.



WHISKEY AND BEER

Chill-haze without chill-proofing enzymes.

Whiskey and beer both develop chill haze — the milky cloudiness that appears when cold protein-tannin complexes precipitate. Chitosan removes these complexes during pre-bottling fining, without the use of papain, silica gel, or PVPP.

Beer dose: 5–40 mg/L in the finished bright beer.

Whiskey: 10–100 mg/L on the finished spirit, contact 24 h, then racked off.

Gassara et al. 2015, LWT 61(2):613–9. Van Nierop et al. 2004, J Am Soc Brew Chem 62(3).

The coagulant that replaces alum.



MUNICIPAL WATER TREATMENT

A biodegradable primary coagulant.

Chitosan at 1–10 mg/L destabilises colloidal particles in surface-water treatment plants. It equals or beats alum on turbidity removal at a fraction of the residual-aluminium load in finished water.

Advantages: biodegradable sludge, no aluminium residual, effective across pH 5–8.

Yang et al. 2016, Chem Eng J 296:157. Renault 2009.

SWIMMING POOLS

Weekly-dose clarifier.

Applied at 1–3 fl oz per 10,000 gal, chitosan aggregates the sub-micron particles that pool filters cannot catch alone, dropping them to the floor for vacuum removal.

Advantages: works with chlorine or bromine; non-irritating to skin and eyes; safe for saltwater systems.

APSP consumer pool guidance; multiple commercial formulations.

ORNAMENTAL PONDS & KOI

Non-toxic to fish.

Chitosan applied to ornamental ponds at 0.5–2 mg/L clears algal and colloidal turbidity without killing fish or beneficial bacteria in the biofilter. It also binds phosphate, limiting the nutrient supply for the next algal bloom.

Advantages: compatible with koi and goldfish; supports downstream irrigation reuse.

Divakaran & Pillai 2002, J Appl Phycol 14(5):419–22.

Recovering protein from process water.

Cheese production generates enormous volumes of whey and rinse water. Both carry dissolved milk proteins (whey proteins, caseinomacropeptide) that were once dumped to drain — a waste stream that would fail every modern effluent standard.

Chitosan added at 100–500 mg/L flocculates those proteins out of solution within minutes. The recovered protein cake is food-grade and can be dried into a whey-protein concentrate. The clarified water can be reused as process water or safely discharged.

The same chemistry — cationic polymer, negative protein — makes chitosan the accepted alternative to isinglass (fish bladder) fining in vegan wine and beer.

FOR MORE INFORMATION, GO TO: CHITOSANGLOBAL.COM/CONTACT-US

Cheese whey protein recovery	85–95 %
Chitosan dose	100–500 mg/L
Working pH	5.0–6.5
Turbidity reduction	>95 %
Contact time	3–15 min

Recovered protein passes into whey-protein concentrate. Clarified water can be recycled to the plant, cutting fresh-water intake.

Sources: Fernández et al. 2018, J Dairy Sci 101(11):9769. Casal et al. 2006, J Dairy Res 73(2):143. Casal et al. 2014, Food Chem 154:271.

Four things it binds on the way through.



Chitosan is one of the few dietary polymers that carries a positive charge in the acidic stomach. Anything with a negative surface — dietary fat, bile acids, microplastic particles, PFAS, heavy metal ions — will bind to it electrostatically and be carried out of the body without absorption.

This binding is the mechanism behind every supplement use in this chapter. The action is non-metabolic: chitosan does not enter the bloodstream. Bound complexes are excreted in stool.

- 01 Dietary fat.** Binds triglycerides and cholesterol in the small intestine; ~10 g/day supports LDL reduction across meta-analyses.
- 02 Microplastics.** Adsorbs polyethylene, polystyrene, and PET particles onto the cationic polymer surface; excreted in stool.
- 03 PFAS.** Cationic amino groups bind the anionic sulfonate and carboxylate head-groups of PFOA and PFOS.
- 04 Heavy metals.** Chelates Pb^{2+} , Cd^{2+} , Hg^{2+} , As^{3+} via lone-pair donation from the amino nitrogen.

The lipid-binding polymer.

In the acidic stomach, protonated chitosan carries a strong positive charge. It binds emulsified dietary fat droplets and bile-acid anions before they reach the absorptive surface of the small intestine. The bound fat is carried out in stool rather than absorbed.

Meta-analyses of randomised placebo-controlled human trials show modest but statistically significant reductions in total cholesterol and LDL at 1–3 g/day doses over 4–12 week periods. Body-weight effects are smaller and more heterogeneous.

Total cholesterol: –5.9 to –15.1 mg/dL vs placebo (meta-analysis, 14 RCTs, n=1223).

LDL cholesterol: –3.5 to –10.2 mg/dL vs placebo.

Effective dose: 1.2–3.0 g/day, taken with meals containing fat.

Mechanism: Chitosan-fat complex forms in the stomach; the polymer also binds bile-acid anions in the small intestine, upregulating hepatic bile-acid synthesis from cholesterol.

Regulatory: EFSA Article 13.1 health claim reviewed 2011; not authorised. FDA does not review dietary-supplement structure-function claims pre-market.

Adsorbing the plastic we swallow.

Microplastic particles enter the gut every day — from bottled water, seafood, salt, and processed foods. Most are polyethylene, polystyrene, or PET. Their surfaces carry a slight negative charge in aqueous suspension.

Cationic chitosan adsorbs those particles onto its polymer backbone through a combination of electrostatic and hydrogen-bonding interactions. The bound particles are then carried out of the body in stool, unable to translocate across the gut wall.

This mechanism is now the subject of active in-vivo research in animal models.

CONSUMER PRODUCT · [MICROPLASTIC PROTECT · SHIELDNUTRA.COM](#) →

Sources: Zhang et al. 2021, J Hazard Mater 407:124713. Sun et al. 2020, Water Res 176:115722. Ma et al. 2019, Chemosphere 235:1104–12.

Polystyrene (100 nm)	92 %
Polyethylene (0.5 µm)	78 %
PET fibres (1–5 µm)	65 %
Sim. gastric fluid	pH 1.5–3.0

Extension to oral supplementation is under active investigation.



Shield Nutraceuticals Microplastic Protect · 99% pure chitosan capsules

Binding forever chemicals.

PFOA and PFOS — the most-regulated members of the per- and polyfluoroalkyl (PFAS) family — both terminate in a negatively-charged sulfonate or carboxylate head group. That anionic head is what makes them water-soluble, mobile in soil, and persistent in the human bloodstream.

It is also what makes them bindable. The cationic amino groups on chitosan attach to the PFAS head group electrostatically, forming an insoluble complex. In water-treatment applications, chitosan-based adsorbents now match or exceed granular activated carbon in PFOA removal at lower cost.

In dietary supplementation, the same mechanism is proposed to reduce gastrointestinal uptake of ingested PFAS from drinking water and food.

[FULL ARTICLE · CHITOSAN FOR PFAS REMOVAL →](#)

Sources: Zhang et al. 2011, *Water Res* 45(15):4645. US EPA 2022, *PFAS Lifetime Health Advisories*, EPA-822-P-22-002. Ateia et al. 2019, *Chemosphere* 220:866.

PFOA on chitosan bead	Q_{max} 322 mg/g
PFOS on chitosan bead	Q_{max} 385 mg/g
GAC benchmark	Q_{max} ~250 mg/g
US EPA lifetime health advisory	PFOA 0.004 ppt

Chitosan-based adsorbents outperform granular activated carbon for the most-regulated PFAS by a meaningful margin at neutral pH.

Chelating lead, cadmium, mercury, arsenic.

The amine nitrogen on the chitosan backbone is a natural lone-pair donor. It coordinates with divalent and trivalent heavy-metal cations — Pb^{2+} , Cd^{2+} , Hg^{2+} , Ni^{2+} , Cu^{2+} , and As^{3+} — forming stable chelate complexes that resist reabsorption.

This mechanism is the basis of decades of published research on chitosan as a water-treatment sorbent for heavy metals. In dietary supplementation, the same chemistry sequesters ingested metals in the gut lumen and excretes them.

MAXIMUM ADSORPTION CAPACITIES (Q_{MAX})

Lead (Pb^{2+})	398 mg/g
Cadmium (Cd^{2+})	250 mg/g
Mercury (Hg^{2+})	815 mg/g
Nickel (Ni^{2+})	167 mg/g
Copper (Cu^{2+})	222 mg/g
Arsenic (As^{3+})	145 mg/g

Values are cross-linked chitosan bead maximum uptake at optimal pH per adsorbent chemistry.

Sources: Bhatnagar & Sillanpää 2009, Adv Colloid Interface Sci 152:26. Wang & Chen 2014, Bioresour Technol 160:129. Miretzky & Cirelli 2009, J Hazard Mater 167(1–3):10.

Dose. Form. Timing.

CAPSULE · POWDER

Full-chain chitosan for fat and bile binding.

Typical dose: 500–1500 mg per capsule, 2–4 capsules per meal. Taken 15 minutes before food, in the stomach’s acidic phase where the polymer protonates and begins binding.

Best for: cholesterol support, dietary-fat management.

CHEWABLE · GUMMY

Low-molecular-weight COS for daily use.

Typical dose: 200–500 mg per chewable. COS is water-soluble in the mouth and reaches the stomach pre-dispersed. Best matched to nutraceutical positioning: immune, gut-microbiome, general wellness.

Best for: daily wellness routine, gut support.

BEVERAGE STICK PACK

Water-soluble grade for daily hydration.

Typical dose: 500–1000 mg per stick, dissolved in 250 mL of water. Positioning: environmental adsorption (microplastics, heavy metals, PFAS from tap water) plus fibre benefit.

Best for: environmental exposure reduction.

Chitosan is a dietary supplement ingredient in the US under DSHEA, and a novel food or food supplement across most EU member states depending on source. Product-specific label claims are the formulator’s responsibility — this handbook does not endorse specific structure-function claims. **Shellfish-allergic consumers should use mushroom-source chitosan only.**

The mouth is a tricky formulation.

Toothpaste is alkaline. Coffee is acidic. Bacteria colonise a wet surface that shifts pH every hour. The strongest peer-reviewed signals for chitosan in the mouth concentrate on carboxymethyl chitosan (CMCS) driven biofilm interference and enamel/dentin remineralization.

Chitosan is not one ingredient in oral care. It is four ingredients, and the salt form determines where each grade actually belongs in a formula.

CMCS	→ gel · paste
Chitosan HCl	→ rinse
COS-Lactate	→ mild-acid clean-label
Quaternary Chitosan	→ durable cationic surface

Source: Chitosan Global Oral Care White Paper, 2026. PMC10570529, PMC12537699, PubMed 38003281, PMC9014838.

Templating enamel and dentin, one crystal at a time.

Carboxymethyl chitosan (CMCS) does two things at once, in a mouth that is otherwise hostile to both.

First, it stabilises amorphous calcium phosphate (ACP) — a metastable precursor of hydroxyapatite — and templates its transformation into intrafibrillar mineral deposits on demineralised dentin and early-caries enamel. Second, it interferes with *S. mutans* adherence to enamel, reducing acid production at the biofilm level.

Every peer-reviewed dental review of chitosan in the last decade returns to CMCS as the derivative with the strongest signal.

01 • Remineralization

CMCS–ACP nanocomplexes deliver Ca^{2+} and PO_4^{3-} ions to early-caries lesions and template intrafibrillar deposition of hydroxyapatite into the demineralised collagen matrix — the pattern of remineralization that natural tooth structure requires.

02 • Biofilm interference

The same amphoteric surface reduces *Streptococcus mutans* adherence to enamel. Less adherence means fewer acid-producing colonies means less demineralisation to begin with.

Position CMCS in toothpaste gels and paste vehicles; use HCl for rinses; use quaternary for durable coatings on prosthetics and orthodontic appliances.

Minimum inhibitory concentration against oral pathogens.

ORGANISM	DERIVATIVE	MIC	MBC
<i>Streptococcus mutans</i> (cariogenic)	Chitosan HCl, LMW	0.156 mg/mL	0.625 mg/mL
<i>Porphyromonas gingivalis</i> (periodontal)	Quaternary chitosan	0.125 mg/mL	0.500 mg/mL
<i>Aggregatibacter actinomycetemcomitans</i>	Quaternary chitosan	0.250 mg/mL	1.000 mg/mL
<i>Candida albicans</i> (denture stomatitis)	COS-Lactate	0.500 mg/mL	2.000 mg/mL
<i>Fusobacterium nucleatum</i> (halitosis)	CMCS	0.312 mg/mL	1.250 mg/mL
<i>Streptococcus sobrinus</i>	Chitosan HCl, LMW	0.156 mg/mL	0.625 mg/mL

[FULL PAPER · CHITOSAN IN ORAL CARE & DENTAL PRODUCTS →](#)

Sources: Ikinici et al. 2002, Int J Pharm 235:121. Costa et al. 2013, J Appl Oral Sci 21:565. Sahariah & Måsson 2017, Biomacromolecules 18:3846.

A charge that doesn't rinse away.

The pH of the mouth swings from acidic (meals, coffee, wine) to alkaline (sleep, after brushing) many times a day. Older literature says chitosan is antimicrobial only in acidic conditions — because generic native chitosan loses its protonated charge above pH 6.

That limitation no longer applies to modern chitosans. **Chitosan FG (COS-Lactate)** and **Chitosan AG / IG (COS-HCl)** from Chitosan Global are high-charge oligosaccharides that stay antimicrobial across pH 2–12. **Quaternary chitosan** holds its permanent positive charge across the same range. Together they are the modern broad-pH toolkit for oral care.

The peer-reviewed literature identifies these grades for extended-wear applications: prosthetic coatings, retainers, dental implants, chewing-gum systems, and other appliances retained in the mouth for long periods.

Sources: Sahariah & Måsson 2017, *Biomacromolecules* 18:3846. Andreica et al. 2020, *Polymers* 13:2514. Sensoy et al. 2022, *J Prosthodont* 31:e97.

Denture coatings. Reduces *Candida albicans* colonisation without daily replacement.

Retainer & aligner films. Overnight-wear appliances stay lower-bioburden.

Titanium implants. Reduces peri-implantitis pathogen load in laboratory models.

Chewing gum vehicle. Sustained-release antimicrobial delivery.

Orthodontic bracket adhesive. Anti-cariogenic barrier around the bracket.



Medical Quaternary Chitosan ·
chitosanglobal.com

Antimicrobial Treatment of Woven and Non-Woven Fiber with Chitosan.

Cotton and cellulose fibres carry a slight negative charge in wet processing. Cationic chitosan binds those surfaces electrostatically and, when cross-linked with citric acid or glutaraldehyde, resists twenty or more household wash cycles.

The result is a permanent-antimicrobial finish on medical textiles, hospital scrubs, sports fabrics, and food-service uniforms. Where silver-nanoparticle finishes carry a heavy-metal disposal problem, chitosan-finished fabric is biodegradable at end-of-life.



BOUND TO FIBRE, INVISIBLE IN HAND-
FEEL

[FULL ARTICLE · ENHANCED BI-COMPONENT FIBERS WITH QUATERNARY CHITOSAN →](#)

Sources: Shahid-ul-Islam & Butola 2019, Carbohydr Polym 224:115152. Elshaarawy et al. 2021, J Environ Chem Eng 9(5):106090.

Reduction <i>S. aureus</i> (AATCC 100)	>99.9 %
Reduction <i>K. pneumoniae</i>	>99 %
Wash cycles retained	20–30
Add-on to fabric	1–3 % w/w

The finish is invisible, does not affect hand-feel, and unlike silver nanoparticles, releases no metal residues into wastewater during laundering.

The film-former that behaves.

Formulators evaluating film-forming polymers face three constraints: residual tack on the skin, low substantivity through washing, and consumer preference for non-petrochemical sources.

Carboxymethyl chitosan and low-molecular-weight COS address all three. They form a breathable, moisturising film at pH 5–7, the natural range of skin and hair. They are substantive on protein surfaces. Mushroom- and crustacean-sourced chitosan qualify as clean-label in EU and North American markets.



SKIN-PH RANGE 5-7 · BREATHABLE FILM

[FULL ARTICLE · CHITOSAN IN COSMETICS →](#)

Sources: Aranaz et al. 2018, *Cosmetics* 5(1):11. Güzel & Akpınar 2019, *Adv Polym Technol* 2019:9843472. Chitosan Global Cosmetics Application Notes, 2026.

Moisturiser. Binds water to the stratum corneum without occluding.

Film-former. Substantive hair conditioner, hand cream body, mascara film.

Rheology modifier. Suspension stability in serums and lotions.

Anti-aging support. Templates collagen support in wound-healing and cosmeceutical hydrogels.

Preservation booster. Cationic charge reduces bio-burden, extending formulation shelf-life.

Six markets opening at once.

ANTIMICROBIAL TEXTILES

Silver-nanoparticle replacement.

Hospitals, sportswear, and food-service uniforms want a biodegradable alternative to Ag⁰. Chitosan-treated fabric is now certified under Oeko-Tex.

CONCRETE ADMIXTURES

Superplasticiser and self-healing agent.

Chitosan-based superplasticisers reduce concrete water demand and improve workability. Encapsulated variants trigger microcapsule healing of hairline cracks.

3D-PRINT BIO-INKS

Tissue-engineering scaffolds.

Chitosan-alginate blend inks now support commercial tissue-engineering research systems in scaffold printing.

PACKAGING FILMS

Bio-based active packaging.

Chitosan-blend films with ZnO or plant-extract actives are being trialled as replacements for polyethylene liners in bakery and produce packs.

BATTERY SEPARATORS

Bio-based Li-ion membrane.

Chitosan-based separators are under academic study for lithium-ion cells — a natural pairing with the crown-ether lithium recovery chemistry described in Ch 16.

CORROSION INHIBITOR

Metals in mildly acidic service.

Chitosan films protect mild steel and copper in acidic industrial service, replacing chromate and phosphate inhibitor formulations.

PART FOUR

Manufacturing.



Gentler chemistry, higher purity.

Producing chitosan from mushroom or insect biomass allows milder deproteinization and demineralization than shellfish routes. The plant runs on food-grade acids and bases, in continuous batches, with in-line testing at every step.



Every batch, every spec, before it ships.

Every batch produced at the Pune facility is characterised on the same seven-parameter panel that appears on the Certificate of Analysis: deacetylation degree, molecular weight, purity, viscosity, solution pH, water solubility, and heavy-metal load.

The panel is run at three separate points in the process — on the incoming raw material, at the deacetylation checkpoint, and on the finished dried powder before packaging. A failed measurement at any point stops the batch and triggers rework.

Zeta potential is available on request for orders where surface charge is a critical formulation parameter.

ISO 9001, ISO 14001, GMP, and HACCP certified. Third-party audit available on request.



DDA / DoS / DoQ. Elemental analysis with confirmation by ^1H NMR.

Molecular weight. Gel permeation chromatography with light-scattering detection.

Purity. Loss on drying + total ash + insoluble matter.

Viscosity. 1% solution at 25 °C on Brookfield or capillary viscometer.

Heavy metals. ICP-MS panel: Pb, As, Cd, Hg.

Microbial. TVC, yeast & mould, coliforms, *Salmonella*.

PART FIVE

The frontier.



Crown Ether Chitosan: A new Mega-opportunity in Lithium Capture from Processed Water.

Grafting a 12-crown-4 ether ring onto the chitosan amine backbone creates a chelating polymer whose cavity is sized specifically to accommodate Li^+ ions — not the Na^+ , K^+ , Mg^{2+} , or Ca^{2+} ions that outnumber lithium 1000-to-1 in brine.

Selectivity is the defining challenge. Evaporation ponds, direct-lithium-extraction resins, and membrane separations all face the same problem: separating lithium from cations of nearly identical ionic radius. Crown-ether chitosan achieves this separation in a single pass.

[FULL ARTICLE · CROWN ETHER CHITOSAN FOR LITHIUM CAPTURE →](#)

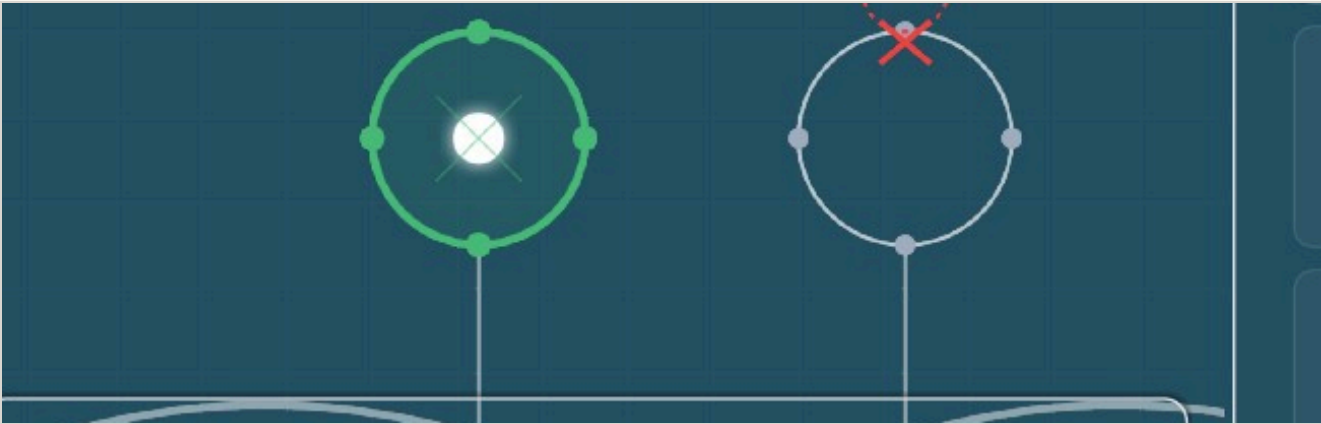


Figure · The 12-Crown-4 ether's molecular lock: binds Li^+ , rejects Na^+ , K^+ , Mg^{2+} . Source: Crown Lithium pitch deck.

Li^+ selectivity (K_d)	15,000
Li^+/Na^+ separation factor	~350
Li^+/K^+ separation factor	~180
$\text{Li}^+/\text{Mg}^{2+}$ separation factor	>500
Working pH	6–9

The crown ether ring is 2.6 Å across — a near-perfect fit for a 1.36 Å lithium cation, too small for anything else.

Sources: Pedersen 1988 (Nobel Prize crown ether chemistry). Yaftian et al. 2019, Chem Papers 73:1837. Multiple emerging DLE technology reviews 2022–2025.

A quarter of US demand from brine and produced water.

The US consumes roughly 5% of global lithium production but produces less than 1% domestically. That gap is what the Inflation Reduction Act and the DOE Critical Minerals strategy are both designed to close.

Crown-ether chitosan applied to Smackover Formation brines in Arkansas, geothermal brines in California, and produced water from Permian oil fields could recover an estimated 25% of U.S. lithium demand from existing brine sources.

Smackover brine Li concentration	100–500 ppm
Salton Sea geothermal Li	~200 ppm
Permian produced-water Li	50–300 ppm
Global Li carbonate price (2025)	~\$14,000/t
US lithium reserve estimate	>5 Mt LCE

Crown-ether chitosan reduces the fresh-water footprint of lithium recovery by 90% versus evaporation ponds. For pricing on carrier chitosan and ether functionalisation, contact chitosanglobal.com/contact-us.

Sources: USGS Mineral Commodity Summaries 2025. DOE Critical Materials Strategy 2023. Vulcan Energy Resources Salton Sea DLE project data 2024.

Three regions, one domestic lithium future.

SMACKOVER FORMATION

Arkansas • Louisiana

Legacy brominated brines, existing surface infrastructure from decades of bromine production. Lithium concentration: 100–500 ppm. Major partners include ExxonMobil (Standard Lithium licensee), Tetra Technologies, and Albemarle.

SALTON SEA GEOTHERMAL

Imperial County, California

Geothermal power-plant brine at 200 ppm Li, existing plants producing electricity. Berkshire Hathaway Energy Renewables, Controlled Thermal Resources, and Energy Source Minerals all active.

PERMIAN PRODUCED WATER

West Texas • New Mexico

Oil-and-gas byproduct water, high volume, 50–300 ppm Li depending on formation. Converts a disposal cost into a revenue stream. Emerging partnerships across the majors.

Crown-ether chitosan applied to all three regions could realistically supply 25% of US lithium demand by 2030 without opening a new hard-rock mine, cutting the water footprint of lithium recovery by roughly 90% versus evaporation, and creating an entirely domestic supply chain.

PART SIX

Reference.



Chitosan by 2030.

Global chitosan production is projected to exceed **250,000 metric tons** by 2030, driven by clean-label food formulation, antibiotic replacement in animal agriculture, PFAS remediation, and direct lithium extraction from brine.

Sustainable-source chitosan — mushroom and black-soldier-fly derived — is projected to reach parity with shellfish-derived material on price and volume by 2028, and to exceed it on both by 2030 as marine harvest constraints tighten.

The time for this industry to plan for that increase in demand is now. This work is designed to steer producers toward green manufacturing practice, and to consider alternatives to shellfish chitin.

Sources: Fortune Business Insights, Chitosan Market Report 2026–2034 (CAGR 20.56 %). Grand View Research, Chitosan Market Outlook 2030. Compiled with Chitosan Global 2026 production data.

- 2027

Commercial offtake. Chitosan FG on a top-10 US produce line; Chitosan IG at a mid-size grain elevator.
- 2028

Regulatory alignment. EU and USDA harmonise chitosan GRAS & feed-material registration; mushroom / BSF supply reaches shellfish parity on price.
- 2029

Domestic lithium. First US commercial deployment of chitosan-based DLE at a producing brine facility.
- 2030

Antibiotic replacement. Three of five largest US poultry integrators eliminate routine feed antibiotics; chitosan-based additives at commercial scale.

Four inflection points to watch.

01 **Three pilots convert to commercial offtake by Q4 2027.**
Chitosan FG on a top-10 US grocery buyer’s produce line. Chitosan IG at a mid-sized US grain elevator. Crown-ether chitosan installed at a US lithium DLE facility.

02 **EPA validates crown-ether chitosan under the Critical Minerals pathway.**
Domestic lithium recovery is a bipartisan policy priority. A validated cleaner alternative to evaporation ponds would move rapidly.

03 **EU and USDA harmonise chitosan GRAS & feed-material registration.**
Cross-Atlantic regulatory alignment removes the largest friction to global scale-up. Target date: 2028.

04 **Three of the five largest US poultry integrators eliminate routine antibiotic use in feed.**
Chitosan-based feed additives are one of the few validated non-antibiotic alternatives available at commercial scale.

Reference points for tracking commercial adoption between 2027 and 2030.

Chitosan — the industrial super-sugar that can detoxify our world.

Chitosan comes in more than 30 derivatives, all of which play a new or ongoing role in a variety of the most common industries.

We have just introduced you to the 9 most popular forms of chitosan and explained how they are characterized according to surface charge (Zeta Potential), molecular weight, degree of deacetylation, water solubility, purity, microbiology, heavy metals, viscosity and pH, each addressing a defined industrial application. Established uses include municipal water clarification, wine and dairy fining, produce coating, personal care products, dietary supplements, agricultural elicitation and pathogen remediation, ruminant and monogastric nutrition, wound hemostasis, and cosmetic formulation.

Emerging applications include antimicrobial non-woven fabrics, plastics, antimicrobial stretch film and packaging, green concrete, soil and water remediation from farming toxicants, regenerative agriculture, Brownfields remediation, PFAS remediation, mycotoxin binding, and direct lithium extraction from brine. Global production is projected to exceed 250,000 metric tons by 2030, driven by clean-label food formulation, antibiotic replacement in animal agriculture, and battery-metal recovery.

Chitosan and the opportunities it creates are more exciting than anything we have seen in any industry. We believe reducing one's personal toxic load, and slowing antibiotic resistance, are among the most important problems we all face. There is a solution.

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Glossary.

Amphoteric

A molecule that can act as both acid and base depending on pH.

ACP

Amorphous calcium phosphate; the metastable precursor of hydroxyapatite.

Aflatoxin B₁

The most toxic member of the aflatoxin family, produced by *Aspergillus flavus*.

BSF

Black soldier fly (*Hermetia illucens*); an insect chitin source.

Cationic

Carrying a positive charge, typically at acidic pH.

Chelation

The binding of a metal ion by an organic ligand at two or more coordination sites.

Chitin

The parent polysaccharide of chitosan; N-acetylglucosamine polymer.

Chitosan

Deacetylated chitin; glucosamine polymer, the only naturally-occurring cationic biopolymer.

CMC / CMCS

Carboxymethyl chitosan; water-soluble at neutral pH, amphoteric.

COS

Chitosan oligosaccharide; low molecular weight (typically <3 kDa) form of chitosan.

DDA

Degree of deacetylation; the percentage of amine groups relative to N-acetylamine on the polymer chain.

DS

Degree of substitution; the fraction of amine groups modified with a functional group.

DoQ

Degree of quaternization; the fraction of amines converted to quaternary ammonium.

Elicitor

A molecule that triggers plant defense response without being pathogenic itself.

ETEC

Enterotoxigenic *Escherichia coli*; a leading cause of neonatal calf diarrhea.

Flocculation

The aggregation of dispersed particles into larger clusters that settle out.

GRAS

Generally Recognized As Safe; US FDA regulatory pathway for food ingredients.

Hydroxyapatite

Ca₅(PO₄)₃(OH); the mineral component of enamel, dentin, and bone.

Kilodalton (kDa)

1000 daltons; the unit used to describe polymer molecular weight.

Agaricus bisporus

The mushroom species used as the default reference source for Chitosan 60 FG, 70 AG, and 70 IG; associated with FDA GRAS Notice 997. Also available at parity pricing from *Lenzites betulina*, oyster mushroom, and black soldier fly.

MIC

Minimum inhibitory concentration; lowest antimicrobial concentration that visibly inhibits growth.

MBC

Minimum bactericidal concentration; lowest concentration that kills 99.9% of the inoculum.

MW

Molecular weight; expressed in daltons or kilodaltons.

Mycotoxin

A toxic secondary metabolite produced by a fungus (mold).

PFAS

Per- and polyfluoroalkyl substances; persistent synthetic fluorochemicals.

PFOA / PFOS

Perfluorooctanoic acid and perfluorooctanesulfonic acid; the two most-regulated PFAS.

Prebiotic

A substrate selectively used by beneficial host microorganisms.

Promecens

Proprietary enzymatic deacetylation process for mushroom-source chitin.

Propionate:acetate ratio

The ratio of two short-chain fatty acids in the rumen; higher values indicate more energy-efficient fermentation.

Q_{max}

Maximum adsorption capacity of a sorbent; expressed in mg of adsorbate per g of adsorbent.

Quaternary ammonium

A permanently positively-charged nitrogen with four substituents; retains charge at all pH values.

Rumen papillae

Finger-like projections of the rumen wall that absorb volatile fatty acids.

Salt form

The counter-ion paired with the cationic amine; e.g. HCl, lactate, acetate.

Systemic acquired resistance

Whole-plant defense state induced by an elicitor at one site and expressed throughout the plant.

TMC

Trimethyl chitosan; N,N,N-trimethylated derivative used in pharmaceutical formulation.

TPC / TVC

Total plate count / total viable count; general measure of microbial contamination.

Trichothecene

Class of mycotoxins produced by *Fusarium* species; includes DON and T-2 toxin.

Zeta potential

The electric potential at the slipping plane of a colloidal particle; a measure of surface charge in solution.

Zeta (positive)

By convention, chitosan zeta values are reported at typical acidic application pH (3.5–5.0). Values decay toward zero as pH rises above the amine pKa (~6.5).

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