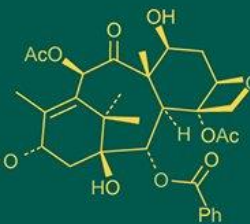
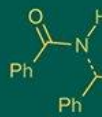


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; 10(8): 695-701
www.biochemjournal.com
Received: 12-06-2026
Accepted: 17-07-2026

Dr. R Umayya Suganthi
Principal Scientist,
Department of Biochemistry,
NIANP, Bengaluru, India

Dr. A Sai Chanakya
Postgraduate Scholar, NIANP,
Bengaluru, India

Chitosan-based active coatings enriched with plant essential oils for preservation of chicken meat: A review

R Umayya Suganthi and A Sai Chanakya

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8i.9741>

Abstract

Chicken meat is a nutritionally valuable but highly perishable food because its high moisture content, nutrient availability and unsaturated lipid fraction favour microbial growth and oxidative deterioration. Postmortem glycolysis is an early biochemical event that contributes to lactate accumulation, pH decline and subsequent changes in colour, water-holding capacity and texture. During refrigerated storage, microbial proliferation, lipid oxidation and protein oxidation progressively compromise quality and shelf life. Edible coatings based on chitosan have attracted considerable interest because of their film-forming, antimicrobial, antioxidant, biodegradable and barrier properties. Plant essential oils can further increase the functionality of these coatings by providing volatile phytochemicals with antimicrobial and antioxidant activity. *Murraya koenigii* (Curry Leaf) Essential Oil (CLEO) is a promising but comparatively underexplored natural bioactive because of its diverse terpenoid-rich composition and reported antimicrobial and antioxidant properties. This mini-review synthesizes literature on postmortem biochemical changes in chicken meat, major deterioration pathways, chitosan-based coatings, plant essential oils and chitosan-essential-oil systems, with particular emphasis on CLEO. The review also identifies a specific research gap concerning the influence of chitosan-CLEO coatings on postmortem glycolytic enzyme dynamics and integrated biochemical quality. Current evidence supports chitosan-CLEO coatings as a promising multifunctional preservation strategy, while formulation optimization, sensory evaluation, mechanistic validation and commercial-scale assessment remain necessary.

Keywords: Chicken meat, chitosan, edible coating, *Murraya koenigii*, curry leaf essential oil, postmortem glycolysis, lipid oxidation, protein oxidation, shelf life

1. Introduction

Poultry meat has become an important source of animal protein because of its affordability, nutritional value and broad consumer acceptance. The increasing demand for chilled and minimally processed chicken products has intensified the need for preservation systems that maintain safety and quality while reducing dependence on synthetic additives. Chicken meat is particularly vulnerable to deterioration because of its high water activity, nutrient-rich composition and susceptibility of unsaturated lipids to oxidation. The thesis literature identifies microbial proliferation and oxidative reactions as major contributors to quality loss during refrigerated storage, with consequences for colour, flavour, texture and consumer acceptability. Immediately after slaughter, the cessation of blood circulation interrupts oxygen supply and causes a shift from aerobic to anaerobic metabolism. Muscle glycogen is consequently metabolized through postmortem glycolysis, producing lactate and lowering muscle pH. The rate and extent of this process influence rigor development, protein functionality, water-holding capacity, tenderness and colour. Abnormal or excessively rapid acidification may promote undesirable pale, soft and exudative characteristics.

During subsequent storage, oxidative and microbial processes become increasingly important. Lipid oxidation produces secondary compounds such as malondialdehyde and volatile aldehydes that contribute to rancid flavour and off-odour. Protein oxidation can produce carbonyl derivatives, loss of sulfhydryl groups and structural modifications that affect protein functionality and water retention. Microbial spoilage further accelerates quality loss.

Corresponding Author:
Dr. R Umayya Suganthi
Principal Scientist,
Department of Biochemistry,
NIANP, Bengaluru, India

Edible coatings provide an attractive strategy because they can be applied directly to the meat surface and function both as physical barriers and as delivery systems for antimicrobial and antioxidant compounds. Chitosan is especially attractive because of its film-forming capacity, cationic antimicrobial activity, antioxidant potential and biodegradability. Incorporation of essential oils can add complementary biological activities. The present mini-review therefore focuses on the scientific rationale for chitosan-CLEO coatings and the need to evaluate their effects not only on shelf-life indicators but also on postmortem biochemical changes.

2. Postmortem biochemistry and meat quality

2.1 Postmortem glycolysis

Postmortem glycolysis begins when oxygen delivery to muscle stops. Glycogen becomes an important substrate for anaerobic ATP production, with pyruvate being converted to lactate and contributing to acidification. The decline in pH is

central to meat-quality development because it influences protein conformation, water distribution, colour chemistry and rigor development. The thesis review emphasizes that optimal pH decline can help preserve protein functionality, whereas abnormal acidification may contribute to pale, soft and exudative meat.

2.2 Glycolytic enzymes

The glycolytic pathway contains multiple enzymes, but hexokinase, phosphofructokinase, pyruvate kinase and lactate dehydrogenase are particularly relevant when examining postmortem metabolic progression. Hexokinase catalyses the initial phosphorylation of glucose to glucose-6-phosphate. Phosphofructokinase regulates an important committed step of glycolysis, while pyruvate kinase converts phosphoenolpyruvate to pyruvate with ATP generation. Lactate dehydrogenase converts pyruvate to lactate and regenerates NAD⁺, allowing anaerobic glycolysis to continue.

Table 1: Key glycolytic enzymes and their relevance to postmortem muscle metabolism

Enzyme	Reaction catalysed	Relevance to postmortem muscle
Hexokinase	Glucose → glucose-6-phosphate	Initiates glycolysis by phosphorylating glucose
Phosphofructokinase	Fructose-6-phosphate → fructose-1,6-bisphosphate	Major regulatory step controlling glycolytic flux
Pyruvate kinase	Phosphoenolpyruvate → pyruvate	Generates ATP and pyruvate during later glycolysis
Lactate dehydrogenase	Pyruvate + NADH → lactate + NAD ⁺	Supports continued anaerobic glycolysis through NAD ⁺ regeneration

Although glycogen depletion, lactate formation and pH decline are well recognized, the temporal behaviour of individual glycolytic enzymes during rigor development is comparatively less documented. This represents an important opportunity for biochemical research, particularly when evaluating whether natural preservation systems influence the progression of postmortem metabolism.

3. Major deterioration mechanisms in chicken meat

3.1 Colour deterioration

Meat colour is closely associated with myoglobin chemistry and pH. Deoxymyoglobin gives freshly cut meat a purplish-red appearance, oxygenation produces oxymyoglobin and the desirable bright-red colour, whereas oxidation promotes metmyoglobin formation and brown discoloration. Therefore, interventions that reduce oxidative stress and maintain an appropriate surface environment may contribute to colour stability.

3.2 Water loss and water-holding capacity

Drip loss reflects the release of fluid from meat during storage. As pH approaches the isoelectric region of muscle proteins, electrostatic repulsion decreases and protein-associated water is released. Oxidative modifications, temperature and handling can further influence water distribution. Excessive drip loss reduces saleable yield and can negatively affect juiciness and texture.

3.3 Lipid oxidation

Poultry meat is particularly susceptible to lipid oxidation because of its unsaturated fatty-acid content. Oxidative reactions generate primary and secondary products, including malondialdehyde, aldehydes and ketones. These

compounds contribute to rancid flavour, off-odour and discoloration. TBARS-based measurements are therefore frequently used to compare the ability of natural antioxidants and edible coatings to retard oxidative deterioration.

3.4 Protein oxidation

Protein oxidation is an important but less visible component of meat deterioration. Reactive oxygen species can modify amino-acid side chains, producing carbonyl derivatives and oxidizing sulfhydryl groups. These changes may promote cross-linking, reduce solubility and alter texture, water-holding capacity and nutritional functionality.

3.5 Microbial spoilage

The high moisture and nutrient content of chicken meat supports growth of spoilage microorganisms during storage. Aerobic mesophilic and psychrotrophic populations can increase under refrigerated conditions, with organisms such as *Pseudomonas* spp. and members of Enterobacteriaceae contributing to off-odours, slime formation and other signs of deterioration. Temperature control, hygienic handling and packaging therefore remain fundamental components of shelf-life management.

4. Chitosan as a natural active-coating material

Chitosan is produced mainly by deacetylation of chitin and is composed of glucosamine and N-acetylglucosamine units. Its functional properties depend strongly on degree of deacetylation, molecular weight, concentration and formulation conditions. The polymer can form adherent films and semi-permeable barriers and is compatible with a range of natural bioactive compounds.

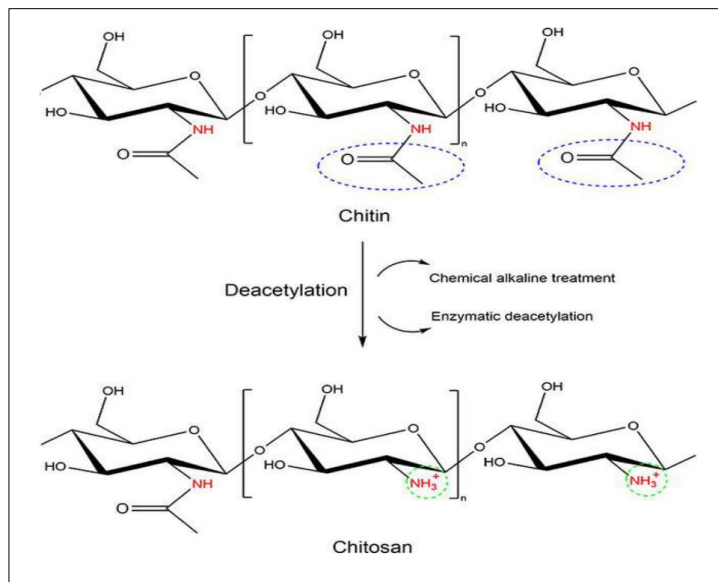


Fig 1: Chitosan formation from chitin by deacetylation. Reproduced from the structural illustration in the thesis review of literature

4.1 Antimicrobial activity

The antimicrobial activity of chitosan is associated largely with its cationic character. Protonated amino groups can interact electrostatically with negatively charged microbial surfaces, disturbing membrane integrity and increasing permeability. The magnitude of the effect depends on polymer characteristics and environmental conditions.

4.2 Antioxidant and barrier functions

Chitosan may also contribute to oxidative stability through free-radical-scavenging and metal-chelating effects. In addition, the polymeric film can reduce direct contact between the meat surface and environmental oxygen and can influence moisture transfer. These complementary properties help explain why chitosan has been investigated extensively as a coating for meat and other perishable foods.

5. Essential oils and their preservative role

Essential oils are complex mixtures of volatile compounds obtained from aromatic plants. Their composition can include terpenes, phenolics, aldehydes, ketones, esters and alcohols. Antimicrobial activity may involve membrane disruption, increased permeability and interference with microbial enzyme systems, while antioxidant effects may arise from radical-scavenging and inhibition of oxidative chain reactions.

Despite these advantages, direct incorporation of essential oils into aqueous food systems can be challenging because of hydrophobicity and volatility. Incorporation into polymeric matrices such as chitosan may improve dispersion, surface retention and practical application. Nevertheless, concentration must be optimized because strong aroma and flavour can affect sensory acceptability.

6. *Murraya koenigii* essential oil

Table 2: Application of essential oils in food preservation and packaging

EO / Material	Packaging context	Main finding / application	Reference
Cumin EO (CEO) & Eucalyptus EO (EEO)	Packaging context	Biodegradable; suggested wide use in food preservation and packaging.	-
Chicken meat + chitosan + Ajwain EO	Refrigerated storage	Combination inhibited microbial spoilage flora of fresh chicken meat.	Babolanimogadam <i>et al.</i> (2020) ^[18]



Fig 2: Curry leaf (*Murraya koenigii*) used as the botanical source of curry leaf essential oil. Illustration reproduced from the thesis review of literature

Murraya koenigii, commonly known as curry leaf, is an aromatic plant widely used in South Asian cuisine and traditional medicine. The literature summarized in the thesis describes the plant as a source of alkaloids, essential oils, phenolics and terpenoid-related constituents and reports antioxidant and antimicrobial activities. Curry leaf essential oil is generally obtained from the leaves by steam distillation or hydrodistillation.

The biological activity of CLEO is likely to arise from the combined contribution of multiple volatile constituents rather than a single compound. Compounds reported in the thesis include β -caryophyllene, α -pinene, limonene, linalool, terpinene-4-ol, myrcene, α -terpinene and eugenol. Their reported functions include antimicrobial, antioxidant, aromatic and anti-inflammatory activities.

Table 3: Selected bioactive constituents reported for *Murraya koenigii* essential oil and their potential functional relevance

Constituent	Reported activity/potential relevance
β -Caryophyllene	Antimicrobial; antioxidant/anti-inflammatory potential
α -Pinene	Antimicrobial; antioxidant potential
Limonene	Antioxidant; aromatic; antimicrobial potential
Linalool	Antimicrobial; aromatic
Terpinene-4-ol	Antifungal; antibacterial
Myrcene	Antioxidant/anti-inflammatory potential
α -Terpinene	Antioxidant; antimicrobial potential
Eugenol	Antimicrobial; antioxidant; aromatic

7. Chitosan-CLEO coatings: Rationale and potential

Combining chitosan with CLEO provides a logical multifunctional preservation system. Chitosan supplies the structural matrix, adhesion and barrier properties, while CLEO contributes volatile phytochemicals with

antimicrobial and antioxidant potential. The resulting coating may simultaneously reduce microbial proliferation, restrict oxygen exposure and suppress lipid and protein oxidation.

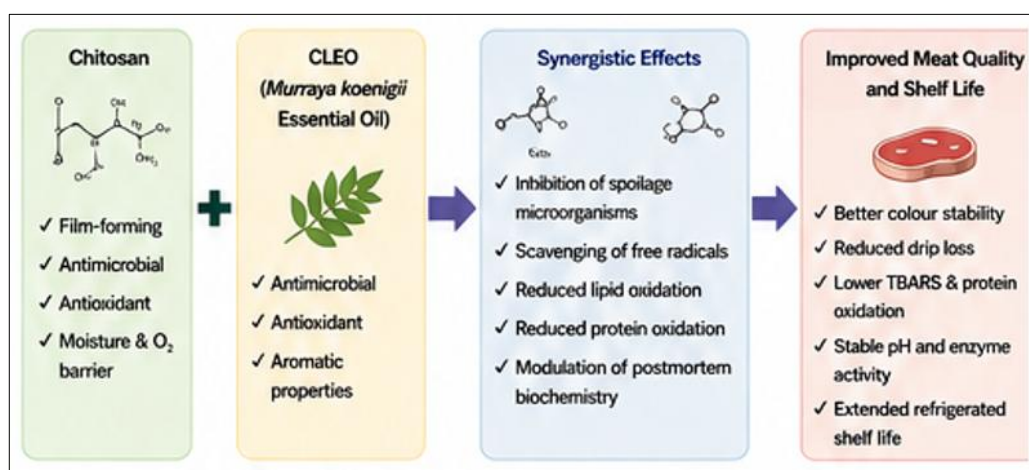


Fig 3: Proposed mechanism by which a chitosan-CLEO coating may protect chicken meat from microbial and oxidative deterioration and support biochemical stability

Table 4: Reported effects of chitosan-essential oil coatings on poultry meat quality

Essential oil	Coating formulation	Storage conditions	Key outcomes	Reference
Ajwain (<i>T. ammi</i>)	1% chitosan + 2% EO	4 °C, 12 days	Lower TVC, reduced TBARS, better colour and shelf life	[28]
Thyme	Chitosan + thyme EO	4 °C, 10 days	Reduced microbial growth, lipid oxidation	[29]
Cinnamon	Chitosan + cinnamon EO	4 °C, 12 days	Lower microbial counts, improved sensory scores	[30]
Cumin + Eucalyptus	Chitosan film with EOs	4 °C, 14 days	Antimicrobial, biodegradable packaging potential	[31]

The literature on related chitosan-essential-oil systems supports this rationale. Studies summarized in the thesis include chitosan combined with ajwain, thyme, cinnamon, cumin and eucalyptus oils. Across these systems, reported outcomes include inhibition of spoilage microorganisms,

reduction of oxidative deterioration, improved colour retention and extension of refrigerated shelf life. However, differences in coating composition, essential-oil concentration, food matrix and storage conditions limit direct comparison among studies.

Table 5: Selected literature on chitosan-essential-oil systems relevant to poultry-meat preservation

Essential oil/system	Coating formulation	Storage	Reported outcome
Ajwain (<i>T. ammi</i>)	1% chitosan + 2% EO	4 °C; ~12 d	Lower microbial counts; reduced oxidation; improved quality
Thyme	Chitosan + thyme EO	Refrigerated	Reduced microbial growth and lipid oxidation
Cinnamon	Chitosan + cinnamon EO	4 °C; ~12 d	Lower microbial counts; improved sensory characteristics
Cumin + eucalyptus	Chitosan film + EOs	4 °C; ~14 d	Antimicrobial and biodegradable packaging potential
<i>M. koenigii</i> (CLEO)	Chitosan + CLEO	Refrigerated; evidence limited	Promising antimicrobial and antioxidant potential

8. Integrated biochemical perspective

A major opportunity for future research is to connect surface preservation with postmortem muscle biochemistry. Most edible-coating studies emphasize microbial counts, TBARS, pH, colour, water-holding capacity and sensory traits. Comparatively fewer studies examine the behaviour of individual glycolytic enzymes alongside glycogen, lactate and oxidative markers.

An integrated model can be proposed in which postmortem glycolysis determines the trajectory of pH decline, while the coating modifies the external environment by limiting microbial proliferation and oxidative stress. These processes may interact because microbial activity and oxidation can influence protein functionality and water retention, while pH changes influence microbial ecology and the stability of muscle proteins. Evaluating these parameters together could therefore provide a more mechanistic assessment of coating efficacy.

9. Research gaps and rationale

The literature reviewed in the thesis supports several specific research gaps:

- Limited information is available on the effect of chitosan-CLEO coatings on postmortem glycolytic enzyme activities, particularly hexokinase, phosphofructokinase, pyruvate kinase and lactate dehydrogenase.
- Comparatively little information is available on how such coatings influence the temporal relationship among glycogen depletion, lactate accumulation and pH development.
- Existing studies frequently examine microbial or oxidative quality separately rather than integrating microbial, lipid-oxidation, protein-oxidation, physicochemical and biochemical indicators.
- Although several essential oils have been evaluated with chitosan, comparatively fewer studies have investigated CLEO as an active component of poultry-meat coatings.
- The optimum CLEO concentration must balance preservation efficacy with coating properties, aroma and sensory acceptance.

These gaps provide a direct rationale for the experimental work described in the M.V.Sc. thesis. The central scientific opportunity is to determine whether chitosan-CLEO coatings can influence not only conventional shelf-life indices but also the biochemical trajectory of postmortem chicken muscle. Such evidence would strengthen the mechanistic basis for using natural active coatings in poultry preservation.

10. Future perspectives

- Optimization of chitosan concentration, molecular weight, degree of deacetylation and essential-oil concentration.
- Use of nanoemulsions or encapsulation to improve essential-oil dispersion, stability and controlled release.
- Standardization of CLEO through GC-MS characterization and correlation of chemical composition with biological activity.
- Integrated evaluation of glycolytic metabolism, oxidative stability, microbial quality, physicochemical traits and sensory acceptance.

- Pilot-scale and commercial validation addressing coating application, packaging compatibility, cost and regulatory requirements.
- Assessment of consumer acceptance, particularly with respect to the characteristic aroma and flavour contributed by essential oils.

11. Conclusion

Chicken meat deterioration is driven by interconnected biochemical, oxidative and microbial processes. Postmortem glycolysis establishes the biochemical environment through glycogen utilization, lactate formation and pH decline, while subsequent lipid oxidation, protein oxidation and microbial proliferation progressively compromise quality. Chitosan offers a biodegradable and multifunctional coating matrix with film-forming, barrier, antimicrobial and antioxidant properties. Essential oils can complement these functions by supplying plant-derived antimicrobial and antioxidant compounds.

Murraya koenigii essential oil is a promising candidate for incorporation into chitosan coatings because of its diverse phytochemical profile and reported biological activities. The combined system has the potential to delay microbial spoilage and oxidative deterioration while supporting preservation of physicochemical quality. Nevertheless, stronger mechanistic evidence is required, particularly regarding postmortem glycolytic enzyme dynamics and the integration of biochemical, oxidative and microbiological indicators. Addressing these gaps could support development of effective, sustainable and consumer-oriented natural preservation systems for chicken meat.

Taken together, the literature supports a transition from descriptive shelf-life studies toward mechanism-oriented preservation research. Such studies can establish not only whether a coating extends shelf life, but also why it works, which components are responsible, what concentration is optimal and how the biochemical response relates to consumer-relevant quality. This mechanistic approach would strengthen the scientific basis for chitosan-CLEO coatings and facilitate their future translation into practical poultry-preservation systems.

The review also suggests that storage duration should be interpreted together with the kinetics of each quality parameter. Some variables change rapidly during the first hours after slaughter, whereas others develop progressively over days of refrigeration. A two-phase sampling strategy—early postmortem sampling for metabolic measurements and longer-term storage sampling for oxidation and microbial quality—may therefore provide a more biologically meaningful picture of preservation. This distinction is particularly relevant when studying glycolytic enzymes, whose activities may change substantially before conventional shelf-life deterioration becomes obvious.

Within this framework, CLEO concentration should be treated as a dose-response variable rather than simply as a treatment label. A low concentration may provide insufficient biological activity, whereas an excessive concentration may create sensory or formulation problems. Similarly, chitosan concentration should be optimized for film integrity and biological activity. Factorial or response-surface designs could therefore be useful for identifying an optimal combination of polymer and essential oil. Such approaches would provide stronger evidence than

comparisons based on a small number of arbitrarily selected concentrations.

A useful framework for future investigations can be organized into four interconnected levels. The first level is formulation: chitosan characteristics, CLEO concentration, emulsification and coating thickness should be standardized. The second level is biochemical response: glycogen, glycolytic potential, lactate, pH and glycolytic enzyme activities should be followed over defined postmortem intervals. The third level is deterioration: microbial counts, TBARS, protein carbonyls, sulfhydryl groups, colour, water-holding capacity and drip loss should be monitored during refrigerated storage. The fourth level is practical validation: sensory acceptance, stability, cost and scale-up should be evaluated. This framework would allow future studies to connect molecular composition with biochemical response and ultimately with measurable shelf-life outcomes.

13. Proposed conceptual framework for future research

Finally, translation from laboratory experiments to commercial application requires attention to practical parameters such as coating application method, drying time, packaging compatibility, storage stability, cost, regulatory requirements and consumer acceptance. The most promising future direction is therefore not simply to increase the concentration of bioactive compounds, but to rationally design a stable coating system in which chitosan provides the structural matrix and CLEO provides complementary biological activity. Such an approach could support development of sustainable, biodegradable and multifunctional preservation technologies for poultry meat.

The potential relevance of molecular approaches should also be considered. Chemical profiling of CLEO can identify abundant constituents, while computational approaches such as molecular docking may generate hypotheses concerning interactions between individual phytochemicals and biologically relevant enzymes. However, docking results should be treated as hypothesis-generating rather than definitive evidence of biological inhibition. Confirmation requires appropriate biochemical or microbiological experiments. Integrating chemical profiling, *in vitro* assays and meat-quality studies would provide a stronger evidence chain.

A mechanistic framework combining glycolytic and oxidative measurements may therefore improve interpretation of preservation effects. For example, a coating-associated difference in pH should be interpreted together with glycogen utilization and lactate formation rather than as an isolated numerical change. Similarly, lower protein carbonyl formation should ideally be evaluated alongside sulfhydryl preservation, lipid oxidation and microbial growth. Such integrated datasets can help distinguish direct biochemical effects from secondary consequences of reduced microbial or oxidative stress.

The most important knowledge gap identified by this review concerns the interface between coating technology and postmortem muscle metabolism. Traditional shelf-life studies frequently measure total viable counts, TBARS, pH, colour, drip loss and sensory quality. These endpoints are valuable but largely describe the consequences of deterioration. Measurement of glycogen, lactate, glycolytic potential and activities of key glycolytic enzymes can

provide additional information about the biochemical processes that precede or accompany those quality changes. The physical chemistry of the coating is also important. Essential oils are hydrophobic and volatile, whereas chitosan is generally prepared in an aqueous acidic medium. Poor dispersion may result in non-uniform coating thickness and inconsistent delivery of active compounds. Emulsification, surfactants, nanoemulsions or encapsulation can improve dispersion and potentially modify release kinetics. Controlled release is particularly attractive because rapid loss of volatile components from the coating surface could reduce long-term activity during refrigerated storage.

An additional consideration is the balance between biological efficacy and sensory acceptability. Increasing essential-oil concentration may increase antimicrobial or antioxidant activity, but it can also increase aroma intensity and potentially alter the characteristic flavour of chicken meat. The most effective laboratory concentration is therefore not necessarily the most appropriate concentration for commercial use. Future optimization should identify a concentration range that provides measurable preservation benefits while remaining acceptable to consumers.

The same principle applies to essential oils. Essential oils should not be treated as chemically uniform materials because their composition changes with plant genotype, geographical origin, season, maturity, extraction technique and storage. Two oils obtained from the same botanical species can therefore exhibit different biological activities. Standardized chemical characterization, preferably by chromatographic profiling, is important when attempting to associate a preservation effect with particular constituents. In the case of CLEO, the biological response is likely to reflect the combined activity of multiple terpenoid and related volatile compounds rather than the action of one major component alone.

Chitosan provides a useful platform for this multifunctional approach because its activity is not restricted to one preservation mechanism. Its film-forming property enables formation of a continuous layer over the meat surface, while its cationic groups provide a basis for interaction with microbial membranes. Its antioxidant and barrier characteristics may additionally reduce conditions favouring oxidative reactions. However, these effects are sensitive to formulation variables. Degree of deacetylation, molecular weight, concentration, pH, solvent system and plasticizer content can influence film strength, adhesion, permeability and antimicrobial performance. Consequently, reporting only the nominal chitosan concentration is insufficient for robust comparison between studies.

The preservation value of an active coating should be interpreted as the combined result of several interacting mechanisms rather than as the effect of a single antimicrobial or antioxidant component. In chicken meat, microbial growth, lipid oxidation, protein oxidation, moisture migration and postmortem metabolic changes are not independent events. For example, oxidation can alter protein functionality and water distribution, while microbial metabolism can modify the local chemical environment and accelerate undesirable odour and texture changes. A coating that simultaneously modifies microbial load and the availability of oxygen at the meat surface therefore has the potential to influence several quality attributes at once.

14. Critical synthesis and translational considerations

Limitations of the current evidence

Interpretation of the available literature requires caution because studies differ substantially in meat type, coating formulation, essential-oil concentration, storage temperature, sampling schedule and analytical methods. Consequently, apparent differences in preservation efficacy cannot always be attributed to the active ingredients alone. Standardized reporting of chitosan molecular characteristics, essential-oil composition and coating preparation would substantially improve comparability.

Another limitation is that many studies evaluate endpoints at relatively broad storage intervals. This can obscure early biochemical events that may determine later quality. In particular, glycolytic enzyme activities can change during the immediate postmortem period, whereas microbial and oxidative deterioration may become prominent later. Coordinated sampling across these time scales is therefore important when attempting to establish causality.

The evidence base for CLEO specifically remains smaller than that for several extensively studied essential oils. This does not imply lower potential; rather, it indicates an opportunity for systematic characterization. Future studies should distinguish the effects of the complete essential oil from those of individual major constituents and should verify whether activity is retained after incorporation into the chitosan matrix.

Finally, positive laboratory findings should not automatically be interpreted as evidence of commercial readiness. Industrial application requires reproducibility, sensory acceptability, process compatibility, economic feasibility and appropriate regulatory assessment. These considerations should be incorporated early in development so that formulation optimization is guided by both biological efficacy and practical usability.

References

- Smith DR, Northcutt JK, Berrang ME. Poultry meat processing and quality. *Poultry Science*. 2019;98(11):1-60.
- Chen Y, Zhao Y, Zhuo H. Factors influencing the quality of poultry meat during storage. *Food Research*. 2021;17:24-40.
- Shah MA, Bera J, Malit J. Quality deterioration of chicken meat: A review. *Journal of Food Science and Technology*. 2019;56(11):5965-5975.
- Hassan B, Majeed A, *et al.* Edible coatings for food products: A review. *Food Packaging and Shelf Life*. 2022;33:100851.
- Fak HK, Myers SP. Antimicrobial activity of chitosan and its derivatives. *International Journal of Food Microbiology*. 2010;138:1-28.
- Rinaudo M. Chitin and chitosan: Properties and applications. *Progress in Polymer Science*. 2006;31:603-632.
- Burt S. Essential oils and their antibacterial properties. *International Journal of Food Microbiology*. 2004;94:223-253.
- Singh G, Maurya S, Catalan C, de Lampasona MP. Chemical composition and antimicrobial activity of *Murraya koenigii* leaf oil. *Journal of Medicinal Plants Research*. 2011;5(1):19-31.
- Bhusal R, Thakur N. Pharmacological properties of *Murraya koenigii*. *Pharmacognosy Reviews*. 2021;15(29):14-23.
- Valarezo E, Salazar J, *et al.* Antioxidant activity of curry leaf extracts. *Antioxidants*. 2025;14(2):233.
- Soulaimani PJ, Elmansouri A, Bouyahya A, Dakka N. Antioxidant and antimicrobial mechanisms of curry leaf essential-oil phytochemicals. *Journal of Food Biochemistry*. 2022;46(7):e14132.
- Wang L, Zhao Y, Sun H, Zhang X. Changes in glycolytic enzyme activity and glycogen content postmortem in chicken muscle. *Food Chemistry*. 2017;234:370-377.
- Sun Y, Li J, Wang X, Zhou G. Changes in phosphofructokinase activity during postmortem glycolysis in chicken meat. *Poultry Science*. 2019;98(6):2631-2638.
- Wang Y, Liu Q, Zhao L, Chen H. Postmortem changes in glycogen metabolism of broiler chicken breast muscle. *Poultry Science*. 2024;103(7):103511.
- England EM, *et al.* Postmortem metabolism and meat quality. *Meat Science*. 2016;118:28-35.
- Warriss PD, Kestin SC, Brown SN, Wilkins LJ. The influence of preslaughter stress on glycogen reserves in broiler chicken muscles. *British Poultry Science*. 1995;36(5):739-750.
- Karimnezhad F, Jalili M, Mousavi S, Azizi H. Effect of chitosan-ajwain essential oil coatings on chicken fillets. *Journal of Food Safety*. 2017;37(2).
- Babolanimogadam N, Ehsani A, Hosseini H, Rezaei M. Chitosan-ajwain essential oil combination inhibits microbial flora of chicken meat. *LWT - Food Science and Technology*. 2020;128:109543.
- Sheerzad T, Khan A, Gulzar M, Ali S. Effect of chitosan-cinnamon essential oil coatings on poultry meat. *Food Packaging and Shelf Life*. 2024;34:101042.
- Barik A, Ghosh S, Kumar P, Singh R. Biodegradable chitosan films with cumin and eucalyptus essential oils. *Food Packaging and Shelf Life*. 2024;44:101211.
- Yuan Y, Zhou T, Chen X, Wang J. Barrier properties of chitosan coatings. *Food Packaging and Shelf Life*. 2024;40:101217.
- Qu T, Li D, Zhang R, Zhao L. Application of chitosan films in meat preservation. *LWT - Food Science and Technology*. 2025;167:114012.
- Scarcelli F. Antimicrobial activity of chitosan: Recent insights. *Carbohydrate Polymers*. 2025;321:121432.
- Babaei-Ghazvini A, Shahidi F, Rafe A, Khanjari A. Solubility and functional properties of chitosan in food. *Food Hydrocolloids*. 2021;117:106701.
- Zhao Y, Chen Y, Feng J, Zhou H. Advanced extraction methods of essential oils. *Food Engineering Reviews*. 2024;16(2):234-251.