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Shelf-Life Extension of Paneer Using Natural Preservatives

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ABSTRACT

Paneer, the fresh acid-coagulated cheese of South Asia, is moist, rich in protein and fat, and handled by hand after cooking, so it spoils quickly even under refrigeration. Interest in replacing or reducing chemical preservatives with natural ones, namely bacteriocins such as nisin, antifungal natamycin, plant essential oils and extracts, protective lactic acid bacteria and chitosan films, has grown with consumer demand for simpler labels. This narrative review asks how far the published literature supports using such agents to extend the shelf life of paneer, and it reports no new data. Work on paneer itself is thin, so the review draws mainly on soft and fresh cheeses and on laboratory studies of the agents. Three themes emerge. Activity in culture medium is routinely larger than activity in a food, because fat, protein and low water activity protect microbes and bind the active compounds. Each agent covers part of the spoilage and safety spectrum only, which favours combinations, ideally placed alongside good hygiene, cold storage and packaging. Doses that preserve are sometimes doses that change flavour. The review concludes that natural preservatives are a credible part of a multi-barrier approach but that paneer-specific, sensory-tested and properly replicated storage trials are still needed, and it outlines what such trials should report.

Keywords: Paneer; Shelf life; Natural preservatives; Nisin; Essential oils; Hurdle technology; Narrative review

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Article Class: Narrative Review

1. Introduction

Paneer is the fresh, unripened cheese that South Asian households and dairies make by heating milk and curdling it with acid. It is pressed, cut and sold within a day or two, and it is a common source of protein in vegetarian cooking. It is also a food that does not keep. The curd is moist, rich in

protein and fat, and close to neutral in taste, which is a comfortable setting for bacteria, yeasts and moulds, and it passes through many hands between the vat and the plate (1, 2).

Chemical preservatives could in principle stretch its life, but many buyers prefer a short ingredient list, and regulators and



processors alike have turned toward agents of natural origin. These include the bacteriocin nisin (3, 4), the antifungal natamycin (5), plant essential oils and extracts (6, 7), protective lactic acid bacteria (8) and chitosan films (9). Reviews describe them with enthusiasm (10, 11).

The reality is more mixed. Most of the experimental work has been done in culture media or in other foods, and paneer is rarely the test material. This review therefore asks what the published literature can tell us about extending the shelf life of paneer with natural preservatives, and where it runs out. It reports no data of our own, and no local or plant-level measurements. The aim is a fair account of what is known and what is merely repeated.

2. Literature Review

2.1 Why Paneer Spoils

Raw milk carries a varied microbial community, and heating removes most of it but not all (12). What remains, together with whatever lands on the curd afterwards, determines how fast the product deteriorates. Spoilage in fresh cheese usually shows as surface slime, off-odours, sourness and, later, mould or yeast growth. Soft, moist cheeses are especially hospitable (1).

Safety is a separate question from spoilage. *Listeria monocytogenes* can grow at refrigeration temperatures and survives in many environments inside food plants, which makes it a recurring concern for soft and fresh cheeses (13, 14). A product can look acceptable while carrying a pathogen, so delaying visible spoilage solves only half the problem. Each of these steps is simple, and each is easy to skip.

2.2 Bacteriocins and Protective Cultures

Nisin is the best-studied bacteriocin in food. It is produced by *Lactococcus lactis*, acts mainly on Gram-positive bacteria, and works by binding the cell-wall precursor lipid II and forming pores (15, 16). It has a long history of use in dairy products (3). A study in ricotta-type cheese found that nisin could limit *Listeria* in a product closely related to paneer in composition (17), which is about as near as the literature gets to a direct precedent.

The limits are equally well known. Gram-negative bacteria are protected by an outer membrane, and nisin on its own does little against them unless that barrier is weakened (18). It does nothing to yeasts and moulds. Reviews of bacteriocin-based strategies stress that these peptides work best as one component of a broader scheme (19, 20).

Protective cultures take a different route. Selected lactic acid bacteria compete with spoilage organisms and may also make bacteriocins or organic acids (8, 21). For a product prized for its mild flavour, the acid and aroma a culture produces may change the taste. A dairy owner reading a trial report wants to know whether it would work in an ordinary kitchen-scale or small-plant setting. A shelf-life gain that customers cannot taste past is not much of a gain.

2.3 Plant Essential Oils and Extracts

Many herbs and spices contain compounds with antimicrobial activity, among them thymol, carvacrol, eugenol and cinnamaldehyde. Laboratory screens show broad activity against both Gram-positive and Gram-negative bacteria, with differences between oils and between organisms (22, 23, 24). Work on oregano oil and its phenolic components has linked activity to damage of the cell membrane (25, 26), and reviews describe a range of modes of action (27, 28). Extracts of



rosemary and of various dietary spices have been tested in the same way (29, 30). This is why the same herb can look remarkable in one report and unremarkable in the next.

What happens in a food is less encouraging. In food model media, fat and protein reduce the activity of essential oils, and the concentrations needed are higher than those that work in broth (31, 32). Reviews of essential oils in food systems repeat the point: the matrix binds the active compounds, and some oils change flavour well before they act on microbes (33, 34). The point is not that a study is poor, only that its result travels less far than its abstract suggests. A study of essential oils in soft cheese is among the few close to our subject, and it supports the idea that some oils can be applied to cheese while also showing that effects differ by oil and by organism (35).

Table 1 lists the main agents considered for fresh cheese together with their usual targets and caveats. The pattern is that no single agent covers the whole spoilage and safety spectrum, so the sensible expectation is partial coverage from each.

2.4 Natamycin, Enzymes and Edible Films

Natamycin is a polyene antifungal that binds ergosterol in fungal membranes (5). It acts on yeasts and moulds and not on bacteria, which makes it a good complement to nisin and a poor substitute for it. The lactoperoxidase system, a natural antimicrobial arrangement of milk enzymes, has been proposed for dairy use and needs its substrates present to function (36). Because spoilage fungi in a stored cheese tend to start on the surface, a surface application is the natural choice for natamycin. That keeps the treatment where it is needed.

Table 1. Main classes of natural preservative considered for fresh cheese.

Agent	Source	Chief target	Main caveat
Nisin	Lactococcus lactis bacteriocin (3, 4)	Gram-positive bacteria, including Listeria (17)	Weak on Gram-negatives and moulds (18)
Natamycin	Streptomyces fermentation product (5)	Yeasts and moulds	No effect on bacteria
Essential oils	Herbs and spices (6, 27)	Broad, dose dependent (23, 24)	Flavour; binding by fat (31)
Lactoperoxidase system	Milk enzymes (36)	Broad	Needs added substrates
Protective cultures	Lactic acid bacteria (8, 21)	Competing flora	Acid and flavour change
Chitosan	Crustacean shell polymer (9, 37)	Bacteria, some fungi	Film properties, taste

Note: Qualitative summary of the cited literature; effective doses depend on the food and are not given.

Edible films and coatings carry preservatives onto the surface, where most contamination of a cut cheese begins. Chitosan, a polymer derived from crustacean shell, has antimicrobial properties of its own and forms films (9, 37, 38). An active film has to release enough compound, at the right rate, to act on the surface (39, 40). For a product sold loose in many markets, packaging itself is a barrier that is not always present. That is a modest claim, but it is the one the literature currently bears.

3. Materials and Methods

3.1 Scope

The review asks one question in two parts. Does the published evidence support the



use of natural preservatives to lengthen the shelf life of paneer, and how much weight can that evidence carry? We separated it into what is known about paneer spoilage, about each class of agent, and about how well claims transfer from other foods. Such losses look small at the counter and large across a week of sales.

3.2 Literature Assembly

We drew on peer-reviewed reviews and primary studies of food preservation, dairy microbiology, bacteriocins, plant antimicrobials and active packaging, selecting items for relevance, influence in the field and clarity of method. We did not run a formal systematic search and we do not claim one. This is a narrative synthesis, and the choice of sources reflects the judgement of the authors.

3.3 Appraisal Framework

To judge how far a report could be trusted for paneer, we asked four questions. Was the test done in a food or only in a medium (28, 31)? Was the target an organism that actually limits shelf life, or a convenient laboratory strain (41)? Was the dose stated in the product and tested for taste (34)? And were repeated batches examined so that variation could be seen (42)? Table 2 and Table 3 summarise the stages at which preservatives might act and the items a study should report.

4. Results

4.1 Where Natural Agents Could Act

Figure 1 sketches the generic path of paneer from milk to retail. The first contamination risk comes from the milk and from survivors of heating (12). The second and larger risk arrives after cooking, when curd is drained, pressed, cut and packed by hand or on shared surfaces. This is where a surface treatment or a film has most to offer (35, 39). A food that is cooled promptly behaves differently from

one that sits warm for an hour.

Table 2. Where contamination and growth enter the paneer chain, and natural options at each point.

Stage	Risk	Natural option
Milk and heating	Raw-milk flora; survivors of heating (12)	Quality milk; adequate heat
Coagulation and draining	Acid-tolerant flora; handling	Starter-type or protective cultures (43)
Pressing and cutting	Hands, cloth, knives (14)	Hygiene; surface treatment with extracts (35)
Chilling and soaking	Slow cooling; wash-water	Prompt chilling; antimicrobial soak (9)
Packing	Air, residual moisture	Film or coating (39, 40)
Storage and retail	Temperature abuse	Cold chain; combined barriers (44)

Note: Points follow the generic process; individual dairies differ.

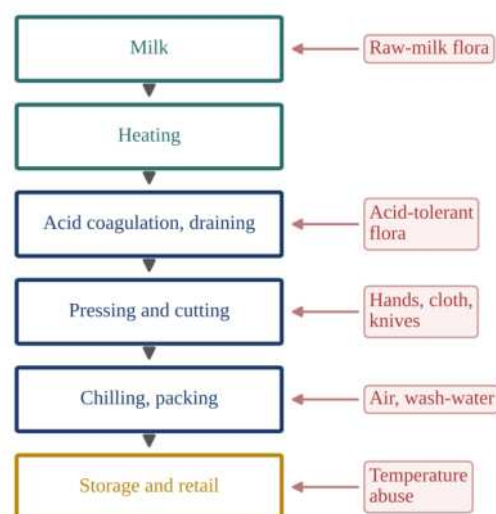


Figure 1. Paneer production flow with the points where contamination can enter (schematic, not data).

4.2 Coverage and Compatibility of the Agents

Figure 2 sets out, qualitatively, which groups of organisms each agent is



generally expected to act on, based on the sources above. Nisin addresses Gram-positive bacteria and, with help, some Gram-negatives (18). Natamycin handles yeasts and moulds (5). Essential oils are broad but dose limited (6, 45). The food matrix changes all of these.

	Gram-positive	Gram-negative	Yeasts, moulds
Nisin	main	little	little
Natamycin	little	little	main
Essential oils	partial	partial	partial
Protective cultures	partial	little	partial
Chitosan	partial	partial	partial

Qualitative tendencies; schematic, not data

Figure 2. Qualitative coverage of natural agents against groups of organisms (schematic, not data).

4.3 Hurdles, Not Silver Bullets

The concept of hurdle technology holds that several mild barriers, each modest alone, can together prevent growth where none would suffice individually (44, 46). It fits fresh cheese well. General accounts of shelf-life extension follow the same logic (41, 47). In paneer the barriers might be prompt chilling, packaging that limits recontamination, a surface treatment and a modest level of nisin or a plant extract, as sketched in Figure 3.

5. Discussion

5.1 Interpretation

The main finding of this review is conditional. Natural preservatives are credible components of a plan to lengthen the shelf life of paneer, and the strongest support lies with nisin for Gram-positive bacteria, natamycin for fungi, and selected plant compounds at doses the product can tolerate. The weakest part is the step from the laboratory to the product. Reviews of this kind are more useful when they say

where the evidence stops than when they smooth it over.



Figure 3. Layered barriers to spoilage in paneer (schematic, not data).

5.2 Limitations

This is a narrative review and shares the limitations of that form. The selection of sources reflects judgement, no formal search or scoring was done, and we do not quote figures from individual paneer experiments because we could not check them against the primary reports. A reader who needs an effect size should consult the original studies directly, or wait for a systematic review of the field. Much of the cited evidence comes from other cheeses and model media, which are imperfect proxies for paneer. Seen this way, a failure to detect an effect in a small experiment is not evidence that there is none.

5.3 Future Work

A study that could settle the matter would describe the milk, the fat level and the process, and apply each agent at stated concentrations in the product itself, with an untreated control from the same batch. It would follow spoilage organisms and a safety indicator under realistic storage temperatures, and test sensory acceptance in cooked dishes. Results from several batches would be reported with their spread, as Table 3 suggests. Without these details, results from different laboratories cannot be compared. It is a habit worth keeping even when the answer seems



obvious.

Table 3. What a shelf-life study of paneer should report.

Item	Why it matters	Often missing?
Milk type and fat	Matrix shapes protection (32)	Often
Dose in the product	Medium results do not transfer (31)	Sometimes
Target organisms	Spoilers differ from pathogens (41)	Often
Storage temperature	Drives growth rate	Rarely
Sensory testing	Preserving doses may offend (34)	Very often
Replication	Batch-to-batch variation (42)	Often

Note: Items reflect good practice discussed in the cited literature; no study is singled out.

6. Conclusion

Natural preservatives offer a realistic way to extend the shelf life of paneer when they are added to good hygiene, cold storage and suitable packaging, and the literature describes mechanisms and limits clearly enough to guide selection. What it does not yet supply is a body of well-replicated, sensory-tested trials in paneer, so the size of any benefit remains uncertain.

For the producer, the message is practical. Start with the process, add barriers one at a time, and measure what each does in the product. For the researcher, the task is to turn plausible ideas into measured results.

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9. Conflict of Interest

The authors declare no conflict of interest.

10. Author Contributions

M.L. conceived the review and wrote the sections on dairy processing and spoilage. G.A.D. wrote the sections on antimicrobial agents and packaging. B.v.d.H. wrote the sections on food microbiology and study design. All authors revised the manuscript and approved the final version.

11. Ethics Statement

This is a review of published literature. No human participants or animals were used and no ethical approval was required.

12. Data Availability

No new data were generated. All sources are cited in the reference list.

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