



Clean Label Meat Processing: The Future of Natural and Safe Meat Products in India

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Abstract

Driven by consumer demand for safe, transparent and minimally processed foods, the global meat industry is shifting toward clean label processing. This movement focuses on producing items with a short, transparent ingredients list that explicitly avoids the use of INS-numbers. Many modern consumers view these coded INS-numbers as 'chemicals' to be avoided, often equating clean labels with healthier and natural plant-based alternatives like rosemary extract, green tea polyphenols, and celery powder. These natural ingredients leverage antimicrobial and antioxidant properties to enhance shelf life and safety while maintaining nutritional value. This transition fosters consumer trust and aligns with global sustainability and regulatory trends. In India, this technology is particularly vital for meeting the rising demand for hygienic, high-quality and export-ready products. By adopting innovative natural solutions and advanced processing methods, the industry can deliver healthier, market-friendly meat products, ensuring long-term competitiveness in a landscape where simple, recognizable ingredients are the new gold standard.

Keywords: Clean Label Meat Processing, Synthetic Additive, Natural Preservatives, Antioxidants, Sustainable Meat Processing

Introduction

Modern supermarket shoppers frequently engage in a specific behaviour: turning over meat products, like sausages or nuggets, to scrutinize the ingredient list. Complex terms such as **sodium nitrite, phosphates and synthetic antioxidants** often trigger hesitation. Despite these additives being scientifically regulated, health-conscious consumers increasingly associate "chemical-sounding" names with health risks. This wariness toward lengthy, opaque ingredient lists has significantly shifted purchasing habits, compelling the meat industry to adopt more

transparent, natural formulations (Delgado-Pando *et al.*, 2021; Kim *et al.*, 2025).

The shift in consumer perception has established **clean label meat processing** as a dominant global trend. To meet this demand, the industry must substitute traditional INS-numbered additives, such as sodium nitrite (INS250), synthetic antioxidants like BHA (INS320), and various phosphates (INS450 – 452) with familiar plant-based alternatives. Clean label products feature fewer, natural, and recognizable ingredients with minimal processing to build consumer trust. This approach emphasizes transparency and the replacement of synthetic additives with plant-



based alternatives while maintaining safety and quality (Asioli *et al.*, 2017; Kim *et al.*, 2025).

Historically, meats like bacon and sausages relied on **nitrites and nitrates** for preservation, colour development, and inhibiting pathogens like *Clostridium botulinum* (Zhang *et al.*, 2023). However, concerns regarding harmful **N-nitroso compounds** and a preference for natural ingredients have pushed the industry to explore "greener" alternatives that provide the same technological benefits without synthetic chemicals (Delgado-Pando *et al.*, 2021).

The meat industry is adopting "green" curing strategies, using plant-based ingredients like **celery powder, rosemary extract, and vinegar** to replace synthetic nitrites and phosphates. These natural alternatives provide essential antimicrobial and antioxidant properties, boosting marketability and consumer acceptance (Yong *et al.*, 2021; Kim *et al.*, 2025). Furthermore, modern technologies like starter cultures and non-thermal processing facilitate clean label development.

In India, rising awareness of food safety makes this movement highly significant. As processed meat consumption and exports grow, clean label approaches build trust and enhance global competitiveness. This transition from synthetic to natural ingredients marks a strategic shift toward sustainable, consumer-friendly processing, ensuring the Indian meat industry thrives in an evolving landscape.

Clean Label Meat: Consumer Demand in India

The clean label movement is a scientific shift driven by informed Indian consumers who favour shorter ingredient lists and natural preservatives. This poses a challenge: maintaining meat safety, texture, and shelf life without decades-old synthetic additives. Metaphorically, clean label processing is like renovating a building using natural materials without compromising structural strength. It requires replacing three key synthetic groups - **BHA/BHT** (preservation), **nitrites** (curing), and **phosphates** (texture) with natural

alternatives, each presenting unique technical hurdles and innovative solutions to ensure product integrity.

Preservation: Replacing Synthetic Antioxidants (BHA/BHT) with Natural Solutions

Preservation in clean label meat processing requires natural alternatives to synthetic antioxidants like BHA and BHT, which prevent lipid oxidation and rancidity. Essential oils and herbal extracts from rosemary, oregano, thyme, clove, green tea, and turmeric have emerged as effective solutions. These ingredients contain bioactive phenolics and flavonoids that inhibit spoilage and microbial growth (Shah *et al.*, 2014; Zhang *et al.*, 2023).

Rosemary extract acts as an oxidative shield, significantly extending shelf life, while oregano oil provides potent antimicrobial activity against pathogens like *Salmonella* (Nieto *et al.*, 2018; Burt, 2004). Integrating traditional Indian spices like turmeric and garlic further enhances safety and flavour. To manage the strong aromas of these oils, researchers utilize microencapsulation and controlled-release technologies, ensuring a balanced sensory profile without compromising preservation (Shah *et al.*, 2014).

Colour and Curing: Replacing Synthetic Nitrites with Vegetable Powders

Nitrites are critical for developing the pink colour in cured meats via nitroso myoglobin formation; without them, products appear unappealingly grey or brown and become more vulnerable to spoilage and pathogenic bacteria. One of the most critical functions of nitrites is the inhibition of *Clostridium botulinum*, a toxin-producing bacterium responsible for botulism. Recent studies highlight that nitrites interfere with bacterial respiration, spore germination, and toxin production, making them a key safety barrier in processed meats (Shakil *et al.*, 2022; Premi *et al.*, 2024). Challenge-test research on nitrate- and nitrite-free fermented sausages has shown that although *C. botulinum* growth can be limited under controlled pH and water activity conditions, the absence of nitrites requires additional safety hurdles and strict

monitoring to prevent microbial risks (Van der Veken *et al.*, 2023).

To replace synthetic nitrites, the meat industry is increasingly using vegetable-based nitrate sources such as celery, beetroot, and spinach powders, which convert to nitrites through bacterial fermentation during processing. Research confirms that celery and beetroot extracts effectively maintain colour stability, microbial safety, and antioxidant activity, rivalling synthetic nitrites (Delgado-Pando *et al.*, 2021; Kim *et al.*, 2020). While natural curing requires strict standardization due to varying nitrate levels in plants, its potential in India is significant. The local availability and affordability of these vegetables can simultaneously bolster domestic agriculture and the meat industry, fostering a sustainable, clean-label ecosystem with high consumer appeal.

Texture: Replacing Phosphates with Natural Fibres, Brans and Hydrocolloids

Phosphates are essential in meat processing for enhancing water-holding capacity, texture, and juiciness. Without them, products become dry and unappealing. To achieve "clean label" status, researchers are replacing synthetic phosphates with natural dietary fibres, cereal brans, plant proteins, and hydrocolloids. These ingredients act like sponges or mesh, binding water and stabilizing the meat matrix to maintain tenderness (Choe *et al.*, 2016).

Studies confirm that citrus and oat fibres effectively preserve sensory quality in sausages (Asioli *et al.*, 2017; Kim *et al.*, 2020), while gums like carrageenan and plant proteins like pea protein improve structural stability. In India, utilizing locally available, sustainable ingredients, such as rice bran, millet fibre, and pulses offers a cost-effective and nutritious opportunity to innovate, ensuring meat products remain succulent and high-quality without chemical additives.

Table 1: Comparison of additives for clean label reformulation

Synthetic Additives	Primary Function	Natural Alternatives	Typical Source
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Sodium Nitrite	Anti-microbial, curing, colour	Nitrate-rich vegetable powders	Celery, beetroot, spinach
BHA / BHT	Antioxidant	Plant polyphenol extracts	Rosemary, green tea
Phosphates	Water binding, juiciness	Dietary fibres, starches, gums	Mushroom, rice bran, citrus fibre
Sodium Erythorbate	Curing accelerator	Vitamin C - rich extracts	Acerola cherry, lemon peel
Synthetic Colour	Colour enhancement	Natural plant pigments	Beetroot, radish powder

Source: Yong *et al.* (2021); Kumar *et al.* (2022)

Clean Label Packaging

Clean label packaging serves as a vital link between producers and health-conscious consumers by promoting transparency through simple, recognizable ingredient declarations. In India, the Food Safety and Standards Authority of India (FSSAI) ensures that labels are accurate and non-misleading, encouraging the replacement of complex INS codes with familiar names to build consumer trust (Singh and Maurya (2023).

Clean label packaging uses natural, eco-friendly materials such as biodegradable films (PLA, starch, cellulose) and edible coatings like chitosan and alginate. These help to reduce moisture loss, oxidation, and microbial growth, while natural antimicrobials like essential oils, plant extracts, and organic acids enhance shelf life without synthetic preservatives.

Technological innovations such as **microencapsulation** and **active packaging** are increasingly paired with clean label formulations to protect natural antioxidants from degradation, ensuring the stability of product through the supply chain. According to Kim *et al.*, (2025), this strategic shift in packaging and labelling is essential for the



Indian meat industry to enhance global competitiveness and align with evolving regulatory frameworks that favour "minimal processing" and clear ingredient transparency. Furthermore, Sharma *et al.*, (2025) suggest that effective clean label packaging must balance consumer desire for "preservative-free" claims with the scientific necessity of maintaining a safe and stable product lifecycle.

Conclusion: Balancing Cost, Innovation, and Regulation in Clean Label Meat Processing

The clean label movement in meat processing faces challenges, primarily **cost implications**. Natural additives are often pricier than synthetic ones due to extraction costs and strict quality control, often positioning these products as premium items. However, local sourcing and technological growth are expected to narrow this price gap (Kim *et al.*, 2025).

A lack of a universal "**clean label**" definition creates regulatory ambiguity. Global and domestic bodies, including the FSSAI in India, are evolving frameworks to standardize terms like "natural" and "preservative-free," ensuring transparency through labelling regulations (Flores & Toldra, 2021). The future of the Indian meat sector depends on integrating science, affordability, and policy. Collaborative efforts can develop cost-effective, locally sourced additives from herbs and fibres, promoting sustainable livestock products. This transition is a strategic long-term shift toward enhancing food quality and global competitiveness.

In conclusion, while natural additives present technical and financial hurdles, the shift is inevitable and beneficial. Supported by scientific innovation and strong regulatory oversight, clean label approaches will lead to a safer, healthier, and more sustainable future for the Indian meat industry.

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