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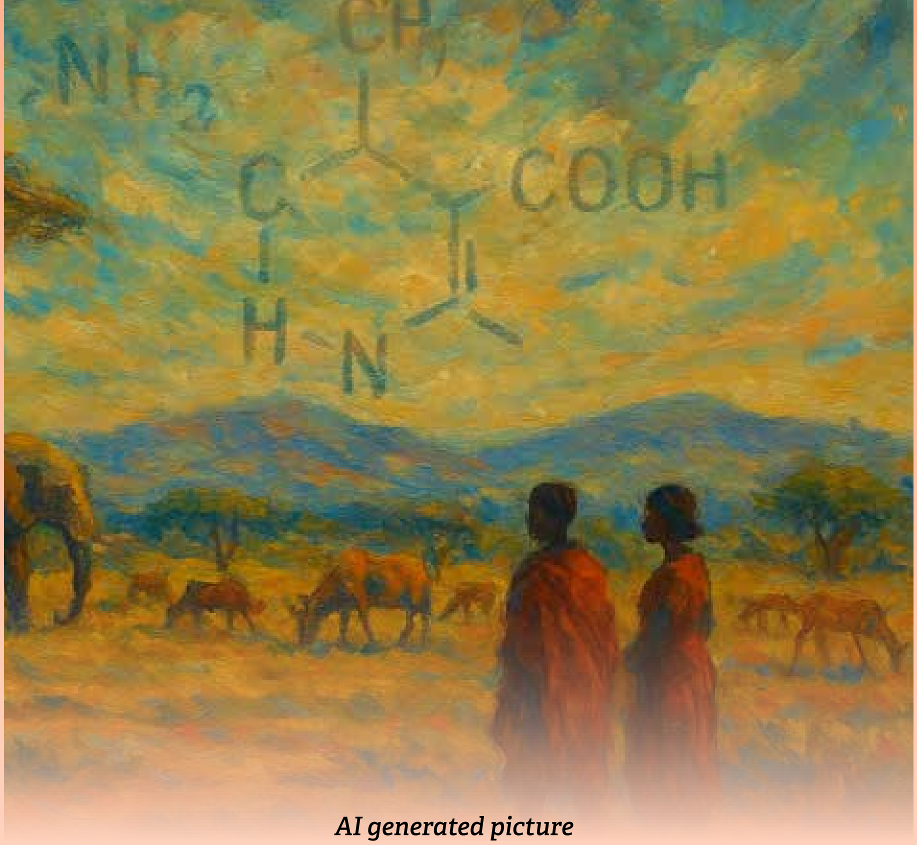
The future of meat as a circular bioresource

By Prof Arun Tiwari

Human beings have eaten meat for thousands of years, but the world around that act has changed. What was once a straightforward exchange between hunter and prey has become a massive industrial enterprise that shapes land use, water demand, biodiversity, and greenhouse emissions. Today, livestock occupy nearly 80 percent of agricultural land while providing less than 20 percent of global calories. This mismatch between resource use and nutritional output forces us to rethink meat not as a single product, but as a biological system that needs scientific redesign. The challenge is not to end meat consumption, but to make it compatible with the ecological realities of the 21st century.

Meat is biologically rich. It contains complete proteins, essential amino acids, iron, zinc, B vitamins, and lipids our bodies can easily absorb. Yet this nutrient density comes with a high input cost. Animals convert only a small portion of the calories and proteins they consume into muscle tissue. Beef cattle often require 6 to 10 kilogrammes of feed for every kilogramme of weight gain, while poultry and fish are far more efficient with feed conversion ratios closer to 1.5. These ratios matter at scale because livestock, especially ruminants, also emit methane, require large amounts of water, and depend on feed crops that could otherwise nourish humans or restore ecosystems. The environmental cost of meat, therefore, is not inherent in biology; it arises from how we manage and value the entire animal and its resource flows.



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A huge opportunity lies in expanding our definition of "meat" and treating the entire animal as a multistream biological resource, much like how sugarcane is used for sugar, ethanol, bagasse, pulp, and even electricity. In most countries, only about 55-60 percent of animals end up as conventional meat. The rest is treated as low-value byproducts, even though science reveals enormous potential inside these overlooked fractions. Less desirable cuts, trimmings, and organ tissues can be transformed using enzyme-assisted extraction, heat-stable gelation, and shear-cell structuring to produce high-quality proteins with improved nutrient density and lower fat content. These restructured products not only reduce waste but also deliver healthier options without moving away from animal-based nutrition.

Tissues rich in collagen, such as skin, bones, and connective matter, can be hydrolysed into gelatin and peptides that serve as raw materials for pharmaceuticals, nutraceuticals, and regenerative medicine. Organ meats, long undervalued, are micronutrient powerhouses that can be incorporated into fortified foods, clinical nutrition, and specialised dietary products. Even blood and digestive tract contents, usually discarded, contain proteins and substrates that can feed precision-fermentation microbes to produce enzymes, biostimulants for agriculture, and biodegradable materials. When these streams are seen not as waste but as untapped biological capital, the entire economic and environmental footprint of meat shifts.

Viewing livestock as a "crop" further clarifies this opportunity. Crops are judged by land use, water intensity, carbon balance, residues, and total usable output. Livestock systems can be evaluated similarly. Pasture-based small ruminants, for example, turn grasses that humans cannot digest into high-quality protein while their manure enriches soils and their grazing maintains grassland ecology. Integrated poultry-fish systems recycle nutrients with remarkable efficiency, where poultry manure fertilises ponds, ponds grow plankton, and fish convert plankton into protein. Even beef systems, when equipped with optimised feed, improved genetics, and methane-reducing supplements, can halve emissions. The crop mindset encourages us to measure not just kilogrammes of edible meat but also kilogrammes of usable protein, biomass, biomaterials, soil enrichment, and ecosystem services generated by livestock systems.

At the same time, biology is expanding beyond the farm. Advances in cultured meat, microbial proteins, and hybrid protein engineering enable us to combine animal- and non-animal-based inputs in intelligent ways. This emerging landscape includes traditional meat from efficient systems, enhanced meat created by blending or restructuring proteins, and cultured components such as fats or flavour molecules that deliver sensory quality without requiring entire animals. Instead of a binary choice between "meat" and "no meat," we get a spectrum of protein possibilities that reduce environmental pressure while maintaining cultural and nutritional continuity.

What we need is a new ecological contract around meat. If animal-based foods are to remain part of global diets, every gramme must be valued, every tissue utilised, and every emission minimised. The science already exists to rethink meat in this way: better feed conversion, precision bioprocessing, circular nutrient loops, and biotechnologies that elevate low-value fractions into high-value products. Treating meat as a renewable bioresource rather than an expendable commodity allows us to maintain its place on the plate while easing its burden on the planet. Ultimately, meat value addition is not just an economic strategy. It is an environmental necessity and a scientific invitation to redesign one of humanity's oldest foods with intelligence, restraint, and respect for the living systems that make it possible.

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