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# Balancing culinary excellence with ethical responsibility: A scientific perspective on animal welfare in gastronomy

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#### ABSTRACT

The culinary industry not only seeks gastronomic excellence but must also address society's mounting concern for animal welfare. This review explores scientific and technological advances shaping animal welfare across the contemporary food system, mapping five critical value-chain stages, animal breeding and rearing; transport and handling; slaughter practices; distribution and procurement; and culinary preparation, where ethical tensions and welfare risks converge. It synthesizes welfare frameworks from the "Five Freedoms" to sentience-based and competence models, highlighting empirical gaps, particularly for crustaceans and insects, that have prompted precautionary bans such as Switzerland's prohibition on boiling lobsters alive. It is catalog key innovations, cultured meat regulatory milestones on March 21 and July 2023, plant-based analogues from pea protein to seitan, and emerging insect-protein applications and assess their potential to decouple gastronomic quality from animal harm. By comparing EU and US regulatory frameworks and private certification schemes, it identify fragmented standards as a barrier to coherent supply-chain compliance. The paper concludes by outlining a roadmap to integrate animal welfare science into culinary curricula, foster multi-stakeholder partnerships, and leverage precision livestock and vertical-farming technologies to advance a sustainable, responsible, and compassionate gastronomy.

# 1. Introduction

In the last decades, concerns about animal welfare, sustainability and ethical food consumption have increased. Thus, the demand for food systems and culinary practices that prioritize animal welfare together with the delivery of exceptional gastronomic experiences is rapidly growing (Parodi et al., 2018). Gastronomy is a holistic and interdisciplinary field that merge both the preparation and presentation of food and also social, cultural, and environmental factors that shape and influence the contemporary culinary landscape (Pieroni, 2023). Gastronomy requires a wide perspective to address the challenges that result from the interaction between food quality, animal welfare, and environmental sustainability (Batat, 2020) (see Image 1).

As described by Johnston and Baumann (2007), the interaction between culinary excellence and ethical responsibility in gastronomy is triggered by the cultural consumption patterns. While an inclusive ideology of democratic cultural consumption may call for greater accessibility and consideration of diverse food sources, the exclusive ideology of taste and distinction often privileges a limited set of ingredients and preparation methods associated with gourmet dining. This conflict between democratic and elitist perspectives requires an examination of the underlying values, power structures, and ethical considerations that shape contemporary gastronomy. In addition, culinary excellence and innovation usually leads to prioritization of certain expensive ingredients and techniques that may cause detrimental effects on animal welfare. Thus, the current growing emphasis on ethical consumption and sustainability pushes gastronomy community to reconsider their practices and seek for more sustainable food sources and also high standards of animal welfare. Therefore, reaching a balance between culinary ideals and ethical responsibilities is crucial for the future development of the gastronomy field.

The concern for animal welfare has a long and fascinating history, evolving from basic ideas of preventing cruelty to deeper insights on animal sentience and rights. The history of animal welfare is a rich and

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**Image 1.** Title. Chef & ethical plating Location. By line 56. Caption: Louis Hansel, Unsplash (free licence).

complex tapestry, woven with the evolving moral, philosophical, and scientific perspectives of societies across time and geography. In the Western tradition, the discourse on our ethical obligations to other sentient beings can be traced back to ancient philosophers, such as Pythagoras, Aristotle, and the Stoics, who widely addressed the humananimal relationship and the moral status of non-human creatures (Black, 2004). These early thinkers laid the groundwork for later development in the field of animal welfare, which gained momentum in the 19th and 20th centuries as public awareness and concern for animal suffering grew.

Historically, the treatment of animals was mainly driven by the practical considerations of husbandry, where the well-being of animals was valued as long as it ensured their productivity and utility to human societies (Rollin, 2019). This pragmatic approach, which viewed animals as mere means to an end, was the dominant perspective for centuries. However, this insight underwent a remarkable transformation in the 19th century, as the growing concern for animal cruelty and the rise of organized animal welfare movements began to challenge the established norms/rules/directives (Buller et al., 2018). These early advocates recognized the intrinsic value of animals and their capacity to suffer, sparking a fundamental shift in societal attitudes towards the treatment of non-human creatures.

The industrialization of agriculture in the 20th century, marked by the rise of high-technology, factory-style farming, further complicated the landscape of animal welfare. These intensive production systems prioritized efficiency and profit over the inherent needs of animals, often exposing them to harsh living conditions and neglecting their physical, mental, and behavioral well-being. This led to a growing public outcry, which in turn prompted the development of explicit farm animal welfare standards and regulations in many developed countries to address these concerns and improve the care of livestock (Rollin, 2019; Fraser, 2003).

Today, the field of animal welfare science has become increasingly sophisticated, drawing on a range of disciplines to assess and address the physical, mental, and behavioral needs of animals (Webber et al., 2022). The recognition that animals are sentient beings capable of experiencing both positive and negative mental states has been a pivotal shift, underscoring the moral imperative to ensure their well-being (Englund and Cronin, 2023).

Present review proceeds by first mapping the five key stages of the culinary value chain breeding and rearing, transport and handling, slaughter, procurement, and preparation to pinpoint where welfare risks and ethical tensions arise. It then evaluates the evolution of welfare frameworks, from the "Five Freedoms" to sentience-and competencebased models, highlighting empirical gaps that drive precautionary measures. Next, it analyzes how chef and student attitudes predict the adoption of welfare-friendly practices. The review then catalogs technological and regulatory advances cultured meat, plant-based and insect alternatives, EU and U.S. welfare standards and assesses how fragmented policies hinder coherent implementation. Finally, it synthesizes these insights into a roadmap for integrating welfare science into culinary education, forging multi-stakeholder partnerships, and leveraging innovative farming technologies to foster a more responsible and compassionate gastronomy.

But how do these evolving perspectives on animal welfare intersect with the world of gastronomy? The present manuscript aims to explore and elucidate the intersection between culinary excellence and ethical considerations, particularly regarding the welfare of animals used in food production within the field of gastronomy.

# 2. Historical context of animal use in gastronomy

The relationship between gastronomy and the use of animals as food sources is a long-standing and complex one, deeply rooted in cultural traditions, economic factors, and evolving social values. Historically, the treatment of animals within the culinary field has often been driven by pragmatic concerns of productivity and profitability, with animal welfare being a secondary consideration. This approach was shaped by the economic situation of the time, in which food production needed to be efficient and cost-effective to meet the growing demands of an increasingly urbanized population (Preece, 2011). As described in "Animal Welfare Across the World" (Rollin, 2019), the "ancient contract" represented by traditional husbandry practices, which emphasized the humane treatment of animals to ensure their productivity, was gradually abandoned in the name of profit during the Industrial Revolution, promoting the prioritization of efficiency and yield over animals well-being, leading to the widespread adoption of intensive farming practices that are now widely recognized as detrimental to animal welfare (Gatward, 2001).

This shift away from traditional husbandry practices and towards industrialized animal production has had a profound impact on the contemporary gastronomy landscape, as the availability and accessibility of cheap animal-based ingredients has shaped the culinary preferences and expectations of consumers. In recent decades, after the introduction of new ideas in animal welfare such as the five freedoms (Cesarani and Pulina, 2021), there has been an increasing focus of public attention on the treatment of animals used in food production. This increased awareness has been driven in part by a greater understanding of the impact of intensive farming on animal welfare, as well as a growing emphasis on the ethical considerations surrounding the use of animals in the food system (Napolitano et al., 2013). As a result, there is a greater demand for more humane and sustainable food production practices, which in turn has prompted chefs, restaurateurs, and the broader gastronomy community to deal with the challenge of balancing culinary excellence with ethical responsibility.

#### 3. Scientific aspects of animal welfare

Animals have specific biological and behavioral needs, that when deprived can lead to negative experiences and poor welfare. Experts from the field of animal science have developed a variety of guidelines to assess and ensure animal welfare, such as the "five freedoms" approach (Rollin, 2019). This framework suggests that animals should be free from hunger and thirst, discomfort, pain, injury, and disease, as well as able to express their natural behaviors and avoid fear and distress (Alonso et al., 2020).

More recently, approaches to animal welfare have shifted to focus not only on the absence of negative states, but also on the presence of positive experiences and emotional well-being. Wünderlich et al. (2021) in their manuscript entitled "Animals in Our Lives: An Interactive Well-Being Perspective" highlights that modern interpretations of animal welfare encompass both physical and mental states, recognizing the animal must be healthy, comfortable, well-nourished, safe, free from unpleasant states, and able to engage in important behaviors in their relationship with humans.

Farming and slaughter practices can significantly impact animal well-being, and as a result, scientific research on animal cognition, emotions, and behavior is instrumental in identifying and addressing the negative effects of these practices on animal welfare (Cesarani and Pulina, 2021). Indeed, particular attention has been paid lately to the controversial ritual slaughter exceptions, which have raised concerns about animal welfare (Żurek et al., 2021). The challenge that the gastronomy community must navigate is the delicate balance between upholding the high standards and innovative culinary practices that define the field, while simultaneously ensuring that the animals used in the production of food are treated humanely and with due consideration for their welfare.

### 4. Ethical considerations in gastronomy

The increased awareness of animal welfare issues within the broader public and among consumers has placed significant pressure on the gastronomy industry to re-evaluate its practices and prioritize more ethical and sustainable approaches (Thibault et al., 2022). This heightened awareness has led to a growing recognition that the use of animals in food production, while central to many culinary traditions, must be tempered by a deeper consideration of the ethical implications.

As highlighted by Poletto and Hötzel (2012) there is a need for "implementing a 'clean, green, and ethical' animal husbandry, while ensuring food is produced under high animal welfare standards". This underscores the imperative for the gastronomy industry to adopt more holistic and responsible practices that not only prioritize culinary excellence but also ensure the humane treatment of animals throughout the food production process.

Beyond the practical and logistical challenges of ensuring animal welfare, the ethical questions surrounding the use of animals in gastronomy are complex and multifaceted. Some argue that the consumption of animal-based foods, regardless of the conditions in which the animals were raised, is inherently unethical and that truly ethical gastronomy must eschew the use of animal products altogether (Coulter, K. & Milburn, J., 2022). Others contend that the humane treatment of animals used in food production is sufficient to satisfy ethical concerns, provided that their welfare is prioritized (Buller et al., 2018).

These debates are not easily resolved through scientific information alone. They are deeply rooted in fundamental differences in individual value systems, philosophical perspectives, and personal convictions about the moral status of animals. The question of whether the use of animals for human culinary pleasure can be ethically justified, even when their welfare is prioritized, hinges on one's underlying beliefs about the inherent rights and intrinsic worth of non-human sentient creatures. These are complex, nuanced issues that extend beyond the empirical findings of animal science and require careful, holistic consideration of the ethical frameworks, cultural contexts, and moral reasoning that shape our views on the legitimacy of animals as food sources (Croney et al., 2012).

While there is ongoing scientific debate about the extent to which crustaceans like lobsters and crayfish experience pain and suffering in a manner similar to mammals (Diggles, 2019), some countries and regions have implemented precautionary bans or restrictions on transport and boiling these animals alive. These regulations often stem from a precautionary principle, acknowledging the potential for crustaceans to experience distress or negative experiences, and aiming to minimize any possible suffering.

For instance, Switzerland banned the practice of boil lobsters alive in 2018 (Diggles, 2019) (https://lenews.ch/wp-content/uploads/2018/ 01/Animal-treatment-rules-in-Switzerland.pdf). This decision was likely influenced not only by emerging scientific evidence, but also by growing public awareness and concern over animal welfare issues in food production. However, the available research on crustacean nociception and the capacity for pain experience remains inconclusive, and the specific motivations behind such bans can involve a complex interplay of ethical, cultural, and scientific factors.

The debate over the ethical treatment of crustaceans in gastronomy is an ongoing and nuanced discussion, without clear consensus. As the gastronomy community seeks to balance culinary excellence with responsible practices, they must carefully weigh the scientific evidence, ethical considerations, and diverse societal perspectives on this issue. This includes evaluating the philosophical arguments around the moral status of crustaceans, as well as the cultural traditions and economic realities that shape the use of these animals in cuisine.

Consequently, the gastronomy community must engage in deep, ongoing dialogue and deliberation to navigate these complex ethical waters. They must draw upon a diverse range of perspectives and authoritative sources of knowledge, including philosophical frameworks, cultural contexts, and empirical findings from animal science, to thoroughly inform and refine their practices and decision-making processes. This comprehensive approach is essential for the gastronomy sector to address the multifaceted challenges of balancing culinary excellence with the ethical imperative of ensuring the humane treatment of animals used in food production. As societal expectations and scientific understanding evolve, the gastronomy industry must continue to adapt and innovate in order to uphold the highest standards of ethical responsibility while preserving the artistry and innovation that define the culinary arts.

### 5. Sustainable gastronomy and animal welfare

As the gastronomy industry has increasingly prioritized sustainability and environmental responsibility, the issue of animal welfare has gained significant prominence (Hampton et al., 2021). Sustainable gastronomy is a multifaceted approach to food production and consumption that strives to minimize environmental impact, uphold ethical practices, and ensure economic viability. This involves reducing waste and emissions, sourcing ingredients responsibly, supporting sustainable farming and fishing, promoting fair labor practices and animal welfare, preserving cultural heritage and biodiversity, bolstering local economies, and ensuring fair pricing for both producers and consumers (Jong et al., 2018; Batat, 2020; Zanella, 2020).

The growing consumer demand for ethically-sourced and sustainable food options has compelled the gastronomy sector to re-evaluate its practices and implement more rigorous animal welfare standards. Consumers are increasingly aware of the importance of animal welfare and are willing to pay more for products that align with their ethical values. This consumer-driven shift has necessitated a comprehensive reevaluation of the gastronomy industry's approach to food production and sourcing (Thibault et al., 2022).

According to the decision tree analysis described in Sahin and Demir (2023), the most important factor in predicting consumers' behavioral intention towards sustainable food choices was their attitude towards sustainable food options. The study found that this attitudinal factor was the most effective in determining the dependent variable of behavioral intention. This suggests that chefs and culinary professionals have a significant influence on the broader food system, as their menu selections and sourcing decisions can profoundly impact both food producers and consumers. Recognizing the influential role of chefs, the gastronomy industry must carefully consider the ethical implications of their practices and make concerted efforts to promote more sustainable and animal welfare friendly food production through their culinary choices and supply chain management. By leading the way in adopting and promoting sustainable and ethical practices, the gastronomy sector can drive positive change throughout the food system and inspire consumers to make more informed and responsible choices.

In addition, some Michelin-starred chefs have begun integrating animal welfare considerations more prominently into their culinary

#### A. Argüello et al.

philosophies and business models, as described by Batat (2020). This research found that these pioneering chefs' motivations to adopt and promote sustainability encompass not only extrinsic factors like regulatory compliance and shifting market demands, but also deeply held intrinsic values and a personal commitment to ethical food production. These chefs are driven by a profound sense of responsibility to ensure the humane treatment of the animals that are the foundation of their culinary creations.

By elevating animal welfare as a core tenet of their sustainable gastronomy approach, these chefs are actively reshaping expectations and norms within the industry. Their actions demonstrate a compelling vision where culinary excellence and ethical food sourcing are not mutually exclusive, but can in fact be mutually reinforcing when approached with intentionality, care, and a genuine dedication to minimizing the suffering of animals used in food production. This holistic perspective recognizes that truly world-class gastronomy must be underpinned by a reverence for the wellbeing of the creatures that provide the foundation for these exquisite culinary experiences. These chefs are leading the way in redefining the relationship between gastronomy and animal welfare, inspiring the broader industry to embrace more sustainable and ethical practices in their own kitchens and supply chains (Batat, 2020).

Organic husbandry exemplifies how modern gastronomy can pair animal welfare with environmental stewardship under the current EU Regulation 2018/848 (European Commission, 2018) and comparable standards worldwide. Recent syntheses confirm that, when well-managed, organic systems deliver higher behavioral freedom, lower routine mutilations, and better opportunities for preventive health than their intensive counterparts, although outcomes still depend on good stock-manship and breed choice (Presto Åkerfeldt et al., 2021).

Organic birds (hens and ducks) live cage-free with daily outdoor access, litter for dust-bathing, and prohibition of beak-trimming. Studies in commercial flocks report better plumage scores and stronger bones, provided range design offers shade and shelters (Bonnefous et al., 2022; Göransson et al., 2023). Ducks additionally receive open-water facilities for bathing critical for eye, plumage, and leg health (Babington and Campbell, 2022).

Gestation and farrowing crates, tail-docking, and routine teethclipping are banned; sows nest in straw-bedded huts and piglets are weaned  $\geq$ 40 d. Group-housing on pasture or deep litter cuts stressrelated lesions and supports rich rooting behaviour, although piglet mortality remains an on-farm challenge requiring design refinements in free-farrowing pens (Rangstrup-Christensen et al., 2018).

Mandatory pasture grazing (Image 6) and high-forage diets reduce lameness, stress markers and sub-acute ruminal acidosis (Blaga Petrean et al., 2024; Ramos et al., 2021). Pasture access also lowers milk-cortisol, indicating reduced systemic stress (Ghassemi Nejad et al., 2021). Transport limits ( $\leq 8$  h in the EU) and no growth-promoting drugs further safeguard welfare and reinforce a "clean-label" narrative attractive to farm-to-table chefs.

In reference to Sheep, extensive grazing with rotational parasite control replaces prophylactic anthelmintics; mutilations such as mulesing are forbidden, and tail-docking is either avoided or painmitigated. Hardy local breeds and outdoor lambing yield low stocking stress, though vigilance for weather exposure and predation is essential (Presto Åkerfeldt et al., 2021).

Organic salmon, trout and warm-water species are stocked at roughly half conventional densities, fed certified organic feeds, and stunned humanely before slaughter. Lower crowding and chemical restraint improve fin condition, immune competence and fillet quality, supporting premium positioning in sustainable seafood menus (Dara et al., 2023).

Recent literature cautions that organic systems are not automatically superior in every welfare or sustainability metric. Large field surveys show that outdoor farrowing can raise piglet mortality by 3–5 percentage points compared with indoor crate systems if hut design or weather

International Journal of Gastronomy and Food Science 40 (2025) 101203



Image 2. Title. Vertical lettuce Location. Line 454 Caption: Bright Agrotech, CC BY-SA 4.0. Wikimedia Commons.



**Image 3.** Title. Beyond Meat Pattie: plant-based gluten free and soy free alternative of burger meat Location: line 376

Caption: Marco Verch, Creative Commons 2.0.

protection is sub-optimal (Rangstrup-Christensen et al., 2018). In laying hens (Image 7), free-range access improves behaviour but is also associated with higher predation and Campylobacter exposure when range management is poor (Schuck-Paim et al., 2021). Health mapping of EU organic farms reports greater parasite loads in lambs and calves unless strategic anthelmintic treatments and pasture rotation are rigorously applied (Presto Åkerfeldt et al., 2021). From an environmental



Image 4. Title. Cultivated hamburger. Location. Line 360 Caption: Mosa Meat, CC BY 4.0, Wikimedia Commons.



Image 5. Title. Bugsbites Location. Line 114 Caption: Antti30, CC BY-SA 4.0, Wikimedia Commons.



Image 6. Title. Grass feed Location. Line 289 Caption: Alexander Startsev, Unsplash (free licence).



**Image 7.** Title. Free range hens Location. Section 5 Caption. Thomas Iversen, Unsplash (free licence).

standpoint, life-cycle models indicate that lower stocking densities can increase land demand and, in some cases, greenhouse-gas emissions per kilogram of product, especially for ruminants, unless productivity losses are offset by improved grazing management (Escribano et al., 2022). These findings underline the reviewer's point: best-practice management remains critical for organic initiatives to deliver the welfare and sustainability gains outlined in this paper.

#### 6. Technological innovations in gastronomy

Due to the consumers concerns about animal welfare (Thibault et al., 2022), as well as growing environmental and health considerations, the gastronomy industry has begun exploring innovative technological solutions to address these evolving priorities. Some restaurants have experimented with plant-based alternatives and cultured meat products as a means of reducing their reliance on conventional animal-based ingredients.

Researchers have made remarkable progress in developing techniques to culture meat (Image 4) from animal derived stem cells, with the ultimate goal of creating a viable non-farmed alternative that can satisfy the world's growing appetite for meat while addressing the pressing issues of resource consumption, environmental impact, and animal welfare (Mohorčich and Anthis, 2019).

The FDA release a constituent update about human food made from cultured animal cells on March 21, 2023, with the following text "The U. S. Food and Drug Administration (FDA) completed its second pre-market consultation for a human food made from cultured animal cells. We evaluated the information GOOD Meat, Inc (www.goodmeat.co) submitted to the agency and have no further questions at this time about the firm's safety conclusion. The firm will use animal cell culture technology to take living cells from chickens and grow the cells in a controlled environment to make the cultured animal cell food". The commpany receive the first ever USDA Label Approval for Cultivated Meat in July 2023, marking a significant milestone in the journey towards mainstream acceptance and adoption of this revolutionary technology (Heine et al., 2024). Previously to this milestone, Good meat, Inc, has produced and comercilized their product in Singapure since 2020. The first time of use GOOD Meat product was reported by the Eater Washington DC online journal with the following highlight "The chef and global humanitarian (José Andrés) hosted the landmark meal at his Penn Quarter Peruvian restaurant China Chilcano on Wednesday, July 5, preparing the charcoal-grilled chicken for a select crowd"(https://dc.eater.com/2 023/7/6/23785994/jose-andres-chicken-good-meat-china-chilcano).

The gastronomy industry has seen a proliferation of innovative plantbased alternatives that are challenging the traditional reliance on animal-derived ingredients. These technological advancements are enabling chefs and food producers to create novel culinary experiences while addressing the ethical and ecological concerns associated with conventional animal-based foods.

One prominent example of innovative plant-based alternatives is the rise of companies like Beyond Meat (www.beyondmeat.com) and Impossible Foods (www.impossiblefoods.com). These companies have developed plant-based burgers (Image 3), sausages, and ground "meat" products that closely mimic the taste, texture, and appearance of their animal-based counterparts. To achieve this meat-like experience, these innovative offerings primarily utilize ingredients such as pea protein (Moll et al., 2023), soy protein (Swann and Kelly, 2023), jackfruit (Mishal et al., 2022), and potato starch (Lyu et al., 2024). These plant-based meat alternatives have gained significant popularity among consumers, as they offer a more sustainable and ethical option while still delivering a familiar and satisfying culinary experience.

Mushrooms have also emerged as a popular and versatile meat substitute within the gastronomy industry. Varieties like king oyster, portobello, and shiitake offer a meaty texture, umami flavor, and fibrous consistency that can be seamlessly integrated into a wide range of dishes typically dominated by animal proteins (Ayimbila and Keawsompong, 2023; Mazumder et al., 2023). Chefs are leveraging the unique properties of these edible fungi to create innovative plant-based culinary experiences, from hearty steaks and stews to delectable pulled "pork" sandwiches. The use of mushrooms as a meat alternative not only addresses ethical concerns around animal welfare but also aligns with growing consumer demand for more sustainable and environmentally-friendly food options.

Another intriguing plant-based alternative is the versatile jackfruit. In its unripe state, jackfruit exhibits a stringy, shredded texture reminiscent of pulled chicken or pork, making it a popular meat substitute in the gastronomy industry. This neutral-flavored fruit is finding its way into a variety of culinary applications, from tacos and curries to BBQstyle sandwiches. Jackfruit is rich in fiber, antioxidants, and essential minerals, making it a nutritious and sustainable ingredient that aligns with the growing consumer demand for ethical and environmentallyfriendly food options (Cruz-Casillas et al., 2021; Nurhayati et al., 2021).

Legumes, including lentils, chickpeas, and beans, have long been staples in many cuisines and are now gaining increased recognition as versatile, nutritious, and sustainable plant-based protein sources. Chefs are increasingly incorporating these nutrient-dense and affordable ingredients into a diverse array of dishes, from hearty veggie burgers and flavorful meatballs to creamy dips, spreadable toppings, and even innovative pasta creations (Acevedo-Martinez and Mejfa, 2021; Mefleh et al., 2021; Schmidt and Oliveira, 2023). Legumes offer a range of culinary applications, allowing chefs to create delicious and nutritious plant-based options that can appeal to a wide variety of consumers seeking more ethical and environmentally friendly food choices.

Soy-based products like tofu and tempeh have been integral to Asian cuisine for centuries, and now, chefs are leveraging innovative techniques to create exciting new textures and flavors that go beyond the traditional stir-fry preparations. Tofu, in particular, has gained wide-spread popularity due to its versatility and ability to absorb flavors, making it a versatile ingredient for a wide range of culinary applications. Advances in processing methods have also improved the digestibility and nutritional profile of soy-based products, further enhancing their appeal to health conscious consumers (Guan et al., 2021; Andreani et al., 2023).

The rise of seitan, a wheat gluten-based product, has also garnered significant attention in the gastronomy industry for its versatile and meat-like properties. With a chewy, fibrous texture that closely mimics the mouthfeel of traditional animal-based proteins, seitan has emerged as a popular substitute for a wide range of dishes, from hearty steaks and flavorful stir-fries to innovative vegan charcuterie offerings (McClements, 2024). This versatile plant-based ingredient allows chefs to create satisfying and sustainable culinary experiences that cater to the growing consumer demand for ethical and environmentally friendly food options.

These technological advancements, combined with the growing consumer demand for more sustainable and ethically-sourced food options, have contributed to the rapid expansion of the plant-based meat alternatives market (Zhang et al., 2021; Swann and Kelly, 2023).

The emerging trend to use insects (Image 5) as a protein source deserves special mention. As this sector holds significant promise in addressing both the environmental and animal welfare concerns associated with traditional livestock production (Quintieri et al., 2023). For example, the manuscript by Valerón et al. (2022) proposes the innovative use of the cabbage butterfly (*Pieris rapae*) as a novel culinary ingredient. Insects, generally require far fewer resources to rear compared to traditional livestock, and they can be farmed with relatively low environmental impact. Additionally, the mass production of insects for food may raise fewer ethical concerns compared to the practices involved in industrialized animal agriculture.

However, the use of insects as a protein source remains controversial, with concerns raised about the potential ethical and environmental implications of insect farming. While insects may require fewer resources than traditional livestock, the ethics of mass-producing sentient creatures for human consumption remains a complex and debated issue, (Wade and Hoelle, 2020). In addition the scientific community are still debating about insect sentience (Gibbons et al., 2022). These authors in their manuscript entitled "Descending control of nociception in insects?" explores whether insects, like mammals, possess a neural mechanism for modulating their pain responses. This mechanism, known as descending control of nociception, allows animals to adjust their behavior in different contexts to maximize survival. The authors review existing research and propose that further investigation is needed to determine the presence and extent of this control in insects. Understanding this could have significant implications for insect welfare in various settings, including farming and research. In addition European Union has aproved four species in diferent presentations, Tenebrio molitor dried larva form (Tenebrio molitor eur-lex larva) or frozen, dried or powder form (Tenebrio molitor eur-lex frozen) frozen, dried and powder forms of Locusta migratoria (Locusta migratoria eur-lex), Acheta domesticus frozen, dried and powder forms (Acheta domesticus eur-lex frozen) and partially defatted powder (Acheta domesticus eur-lex powder) and frozen, paste, dried and powder forms of Alphitobius diaperinus larvae (Alphitobius diaperinus eur-lex).

In reference to the advances in farming techniques to enhance animal welfare (Abaajeh et al., 2023; Jiang et al., 2023), certain chefs have embraced innovative solutions like vertical farming (Image 2) and

precision livestock farming to optimize the health and wellbeing of the animals used in their kitchens. These practices, while still emerging, hold promise in reducing the stresses and negative impacts traditionally associated with conventional livestock production.

Livestock precision farming enabled by the application of real-time sensors and data analytics (Halachmi et al., 2018), can provide early detection of health issues, allow for personalized care, and minimize overall animal distress. Virtual fences technologies, for instance, can give animals greater freedom of movement and autonomy within defined boundaries, while still ensuring their safety and wellbeing through the use of digital perimeters and monitoring systems (Verdon et al., 2021). In a similar vein, vertical farming for poultry and other small livestock can drastically reduce the spatial requirements and improve environmental conditions, potentially leading to enhanced animal welfare (Specht et al., 2019).

### 7. Regulatory and policy frameworks

To address the growing concerns around animal welfare in the food industry, regulatory bodies and policymakers have begun to implement a range of policies and guidelines aimed at improving the conditions for animals used in food production.

In the European Union, for example, the EU Animal Welfare Strategy (Evaluation of the EU strategy on Animal Welfare, 2021) has set forth a comprehensive framework to enhance the welfare of farm animals, including provisions for minimum standards of housing, transportation, and slaughter practices. These regulations have driven the gastronomy industry to adopt more ethical sourcing practices and consider alternative protein sources that do not rely on conventional livestock.

Similarly, in the United States, the Humane Slaughter Act (Humane Methods of Livestock Slaughter, 2023) and the US Animal Welfare Act (Animal Welfare Act, 2022) have established guidelines for the humane treatment of animals in the food supply chain. These legislative efforts have prompted many food service providers, from restaurants to institutional cafeterias, to prioritize the procurement of animal products from producers with strong animal welfare credentials.

Furthermore, the OIE has developed internationally recognized standards for animal welfare, which are increasingly being incorporated into global trade agreements and supply chain management practices. This global coordination helps to ensure a more consistent approach to animal welfare across different regions and food systems.

However, the implementation and enforcement of these regulations remain a challenge, as the globalized nature of the food system makes it difficult to ensure consistent standards across all supply chains. Ongoing monitoring, auditing, and collaboration between regulatory bodies, industry stakeholders, and civil society are necessary to address these enforcement hurdles.

Additionally, the growing public awareness and concern for animal welfare have led to the development of private certification schemes, such as the Welfare quality (https://www.animalwelfair.com/es/biene star-animal/welfare-quality/). These voluntary certification systems provide a market driven approach to promoting higher animal welfare standards, as consumers increasingly demand more ethically sourced food products.

This review ideas aligns closely with several United Nations Sustainable Development Goals (SDGs). By advocating systematic integration of the "five freedoms" and other evidence-based welfare metrics throughout the food value chain, it advances SDG 12 (Responsible Consumption and Production) while simultaneously safeguarding terrestrial and aquatic biodiversity under SDG 15 (Life on Land) and SDG 14 (Life Below Water). The ideas presented in the present manuscript appraisal of precision-livestock farming, vertical farming, and alternative-protein technologies, including plant-based, insect-derived and cultivated meats addresses SDG 2 (Zero Hunger) by diversifying nutrient-dense protein sources and SDG 13 (Climate Action) by highlighting pathways to reduced greenhouse-gas emissions. Furthermore, the hiphotesis shift in consumer demand toward ethically sourced foods links animal-welfare-centered gastronomy to improved public-health outcomes, thereby supporting SDG 3 (Good Health and Well-being). Finally, the call to embed animal-welfare and sustainability science within culinary education programmes fosters human-capital development (SDG 4 Quality Education) and nurtures innovation in agri-food systems (SDG 9 Industry, Innovation and Infrastructure).

# 8. Remaining biases and gaps in gastronomy animal welfare research

Despite growing interest, research on animal welfare in gastronomy remains skewed by methodological and representational biases. First, empirical studies of sentience in decapod crustaceans and edible insects are sparse and often rely on proxy measures that may not capture true nociceptive capacities (Diggles, 2019; Gibbons et al., 2022). Second, evidence-based welfare interventions, such as humane slaughter protocols for seafood, are unevenly adopted in professional kitchens, revealing a gap in knowledge transfer between scientists and culinary practitioners. Finally, the discourse is often dominated by chefs' ethical narratives, while producers' perspectives on welfare feasibility receive less attention, risking misaligned priorities. Addressing these issues will require targeted invertebrate sentience research, structured culinary-science outreach, and inclusive stakeholder forums.

### 9. Challenges and future directions

While significant progress has been made in improving animal welfare practices in the gastronomy industry, there remain several persistent challenges that must be addressed to achieve a truly sustainable and ethical food system.

One of the primary challenges is the inherent tension between the pursuit of culinary excellence and the ethical imperative to ensure the wellbeing of animals. Many renowned chefs and restaurateurs, in their quest for the finest ingredients and most innovative dishes, have historically prioritized taste and aesthetic over the welfare of the animals that provide those ingredients (Lamey and Sharpless, 2018).

The solution to this challenge lies in fostering a deeper understanding and appreciation among chefs, food critics, and discerning diners of the importance of ethical animal husbandry practices. This can be achieved through collaborative efforts between the culinary community, animal welfare organizations, and the scientific community to educate and raise awareness about the latest advancements in sustainable and humane farming practices.

Another key challenge is the need to address the significant information asymmetry that often exists between food producers, retailers, and consumers. Consumers often lack the necessary knowledge and transparency to make informed choices about the welfare conditions of the animals used in the production of the foods they consume (Cornish et al., 2016).

To address this, a multi-pronged approach is required, involving improved labeling and traceability standards, as well as enhanced consumer education initiatives. Policymakers and industry leaders must work together to establish clear and comprehensive labeling requirements that provide consumers with detailed information about the welfare practices employed in the production of animal-based food products.

Chefs and restaurateurs, as the intermediaries between producers and consumers, have a crucial role to play in driving the shift towards more ethical and sustainable food systems. By actively sourcing from producers with strong animal welfare credentials, highlighting these considerations on their menus, and educating their patrons, the gastronomy industry can exert significant influence on consumer behavior and the broader food supply chain.

The future trends in gastronomy and ethical animal use are promising. The growing public awareness and demand for more ethical food choices, coupled with advancements in animal welfare science and technology, suggest that the gastronomy industry is well-positioned to lead the way in reconciling culinary excellence with ethical responsibility.

Finally, incorporating animal welfare into the curricula of culinary schools is highly recommended. This would help future chefs and culinary professionals develop a deeper understanding of ethical animal husbandry practices and the importance of prioritizing animal welfare alongside culinary excellence. By educating the next generation of gastronomy leaders on these critical issues, the industry can drive a meaningful and lasting shift towards more sustainable and humane food systems.

#### Implications for gastronomy

The paper accentuates the developing position of gastronomy in overcoming issues of ethics and sustainability, while putting great stress on requiring an enhanced more ethical style of producing food. The paper underlines that professional cooks must pursue taste and appearance perfection as much as ensure they factor ethics into what they do, specifically focusing on animal well-being. As demand and public consciousness for humane and sustainable sources of food grow, the gastronomy industry must adapt by accessing ethically raised animals, leveraging plant and cultured options, and adopting transparent supply chain practices. In addition, the paper urges chefs, restaurateurs, and culinary instructors to assume leadership positions in changing public perception and industry standards so that gastronomy is not merely about flavor but also about responsibility. The integration of values of animal welfare in gastronomy education and professional practice is envisioned as a trajectory towards the production of food culture that is both sustainable and ethical, and toward gastronomy evolution in harmony with the values of contemporary society.

#### CRediT authorship contribution statement

Anastasio Argüello: Writing – review & editing, Writing – original draft, Conceptualization. Marta González-Cabrera: Writing – review & editing. Antonio Morales-delaNuez: Writing – review & editing. Lorenzo E. Hernández-Castellano: Writing – review & editing. Manuel Betancor-Sánchez: Writing – review & editing. Noemí Castro: Writing – review & editing, Writing – original draft, Conceptualization.

# Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Jenni.ai in order to improve the text English grammar. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

#### Declaration of competing interest

Anastasio Argüello, I have nothing to declare. Marta González-Cabrera, I have nothing to declare. Antonio Morales-delaNuez, I have nothing to declare. Lorenzo E. Hernández-Castellano, I have nothing to declare. Manuel Betancor-Sánchez, I have nothing to declare. Noemí Castro, I have nothing to declare.

# Data availability

No data was used for the research described in the article.

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#### A. Argüello et al.

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