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BRAZIL: REGULATORY OR TECHNOLOGICAL LAG?**

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**A EMERGÊNCIA DA INDÚSTRIA DE
PROTEÍNAS ALTERNATIVAS NO BRASIL: DEFASAGEM REGULATÓRIA OU
TECNOLÓGICA?**

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RESUMO

Este artigo analisa a emergência da indústria de proteínas alternativas no Brasil e examina em que medida a regulação nacional fomenta um ambiente favorável à consolidação do setor. A pesquisa combina uma revisão bibliográfica com entrevistas realizadas com pesquisadores, empreendedores, gestores públicos e parlamentares. O marco conceitual integra as abordagens de defasagem regulatória (*regulatory lag*), problema do descompasso (*pacing problem*) e padronização como instrumento regulatório. Os resultados mostram que, no Brasil, disputas semânticas que emergem em estágios posteriores do ciclo regulatório dos produtos *plant-based*, em vez de proporcionarem clareza e previsibilidade, reforçam a ambiguidade institucional e podem dificultar tanto a inovação quanto o investimento no setor. Por outro lado, a regulação de novos alimentos e ingredientes avançou mais rapidamente do que a maturidade tecnológica. Isso sugere que o problema do descompasso deve ser compreendido como um contínuo, que vai da defasagem regulatória à defasagem tecnológica. O artigo também introduz a noção de coevolução travada como lente para explicar as dinâmicas de setores emergentes: enquanto reguladores aguardam evidências técnicas, as empresas adiam a submissão de dossiês de produtos em função da incerteza normativa, e os consumidores permanecem sem padrões claros de identidade e segurança.

Palavras-chave: indústria emergente; proteínas alternativas; regulação econômica; transição sociotécnica.

ABSTRACT

This article analyzes the emergence of the alternative protein industry in Brazil and examines the extent to which national regulation fosters a favorable environment for sectoral consolidation. It combines a literature review with interviews conducted with researchers, entrepreneurs, public officials, and legislators. The conceptual framework integrates the approaches of regulatory lag, the pacing problem, and standardization as a regulatory instrument. The findings show that, in Brazil, semantic disputes emerging at later stages of the regulatory cycle for plant-based products, rather than providing clarity and predictability, reinforce institutional ambiguity and may hinder both innovation and investment in the sector. On the other hand, the regulation of novel foods and ingredients has progressed more rapidly than technological maturity. This suggests that the pacing problem should be understood as a continuum, ranging from regulatory lag to technological lag. The article also introduces the notion of blocked co-evolution as a lens to explain the dynamics of emerging sectors: while regulators await technical evidence, firms postpone the submission of product dossiers under normative uncertainty, and consumers remain without clear standards of identity and safety.

Keywords: alternative proteins; economic regulation; nascent industry; sociotechnical transition.

1 INTRODUCTION

The food industry has historically been characterized by technological incrementalism. Each year, it launches a large number of new products, yet only a small fraction qualifies as radical innovations—the vast majority represent incremental modifications of existing products (Winger & Wall, 2006).

This landscape has shifted in recent years. Information and communication technologies, together with the rise of scalable, mission-driven business models led by startups, have begun to reshape the food system, resulting in technological trajectories that embody radical innovations in

food production (Wilkinson, 2024). From a long period of technological change within the food system, we now observe a sociotechnical transition (Geels, 2004), marked by systemic, long-term transformations in the food industry.

The technological trajectories that underpin the emergence of this new sector are diverse, with concrete manifestations in Brazil. The Brazilian market for plant-based milk reached approximately USD 499.7 million in 2024, while the plant-based meat market surpassed BRL 1.1 billion in retail sales in 2023¹. Precision fermentation remains at an incipient stage, with startups engaged in R&D, academic research advancing, and growing interest from established corporations. Insect protein production is taking its first steps toward applications in animal feed. Cultivated meat initiatives, grounded in biotechnology and tissue engineering, are increasingly marked by the involvement of large corporations: JBS acquired the Spanish company BioTech Foods in 2021 and is building a cultivated meat R&D center in Florianópolis (SC); BRF has established a strategic partnership with Israel's Aleph Farms. According to Fairbairn and Reisman (2024), these novel foods represent part of a "fourth agricultural revolution." They argue that the speed and scale enabled by venture capital-backed technologies may accelerate structural change in the sector with increasing participation of incumbents².

The emergence of this new industry is unfolding in a period that some authors have termed regulatory capitalism, a political-economic order in which regulation, rather than deregulation, constitutes the hallmark of capitalist governance. It is characterized by the expansion of rulemaking, the proliferation of regulatory agencies, and the diffusion of regulatory techniques across an ever-increasing range of social and economic domains (LEVI-FAUR, 2017).

¹ GRAND VIEW RESEARCH. Brazil Plant-based Milk Market Size and Share Report, 2024–2030. San Francisco: Grand View Research, 2024. Available at: <https://www.grandviewresearch.com/horizon/outlook/plant-based-milk-market/brazil>. Accessed on: 12 set. 2025.

GOOD FOOD INSTITUTE BRASIL (GFI Brasil). Mercado brasileiro de carnes vegetais ultrapassou a marca de R\$ 1 bilhão em 2023. São Paulo: GFI Brasil, 2024. Available at: <https://gfi.org.br/mercado-brasileiro-de-carnes-vegetais-ultrapassou-a-marca-de-r-1-bilhao-em-2023/>. Accessed on: 12 set. 2025.

² For the authors, an incumbent firm is a well-established company that numbers among the largest and most influential in the sector.

Consistent with this perspective, major scenario studies on the growth of the emerging alternative protein sector identify regulation as a critical determinant of consolidation. A highly influential report assumes, in a baseline case, the need for consistent consumer acceptance, regulatory support, and technological change (BCG/BHC, 2021).

Nevertheless, few studies have addressed the regulation of alternative proteins in Brazil. Notable exceptions include the Regulatory Study on Alternative Proteins in Brazil (GFI Brasil; ITAL, 2022), which provides technical guidance for the design of a more adequate regulatory framework for alternative proteins—including plant-based, fermentation, and cultivated meat, and the Regulatory Impact Assessment Report on Novel Foods (ANVISA, 2022).

However, there are no studies that explicitly examine the relationship between regulation and technology in the emergence of alternative proteins in Brazil. Against this backdrop, the objective of this article is to analyze the extent to which regulation of alternative proteins in Brazil creates a favorable technological environment for the development of the new alternative protein industry.

The following section presents the conceptual framework adopted, the subsequent sections describe the methodology and report the results, and the final section outlines the main conclusions of the research.

2 CONCEPTUAL FRAMEWORK

A sociotechnical transition can be understood as a set of processes that produce a fundamental, far-reaching transformation within a given sociotechnical system—such as the food system—encompassing both radical and incremental innovations across multiple dimensions and over extended periods of time (Geels, 2004). Exogenous pressures on the food system have generated misalignments in the incumbent sociotechnical regime of conventional meat, opening windows of opportunity for the consolidation of new technological configurations that are sufficiently mature to contest and potentially occupy positions within the productive landscape (Tziva et al., 2020; Henchion et al., 2021; Dagevos, 2021). These new technological configurations crystallize into

sectors or industries, defined as sets of firms producing goods or services that are close substitutes (Carlton & Perloff, 2005)—in this case, the emerging alternative protein industry.

Regulation is the activity through which such economic sectors are structured and disciplined, whether carried out by the state in pursuit of the public interest (Di Pietro, 2022) or by networks of actors, as proposed by Black (2001) and Scott (2004).

Standards represent one of the most powerful contemporary forms of regulation, shaping markets and societies (Busch, 2011). The standardization approach highlights that regulation does not occur exclusively through formal legislation but also through the creation and diffusion of technical and quality standards. Standardization translates interests and ideas into rules (Latour, 2005). Studies on standards (Bowker & Star, 1999; Stark, 2009; Timmermans & Epstein, 2010; Busch, 2011) show that quality standards, metrics, and certifications operate as forms of “invisible regulation,” creating barriers to trade. Conversely, a facilitative perspective suggests that standards reduce transaction costs, increase trust, facilitate technological diffusion, and establish common languages for international transactions (WTO, 2020; FAO & WHO, 2018). Others argue that standards can serve both restrictive and facilitative functions (Blind, 2004).

Regulators tend to hesitate in the absence of clear standards of quality, identity, or safety. This hesitation may be termed regulatory lag, defined as the gap between the (rapid) pace of technological innovation and the (slow) institutional capacity to respond (Breyer, 1982; Marchant, Allenby & Herkert, 2011). It emphasizes a temporal delay.

The literature identifies multiple causes of regulatory lag. Merton (1940) highlighted bureaucratic inertia, showing how rigid structures and bureaucratic personalities hinder rapid responses. Breyer (1982) emphasized legal rigidity and limited administrative capacity, noting that regulatory frameworks often fail to keep pace with innovation. Stigler (1971) and Peltzman (1976) introduced the notion of regulatory capture, whereby interest groups distort regulation away from the public interest. Vogel (2012) and Majone (2002) pointed to scientific uncertainty and the precautionary principle, which lead regulators to adopt conservative stances toward new technologies. Abernathy and Utterback (1978) and Blind (2004), underscored the centrality of

standardization as a precondition for technological diffusion. Majone (1994), Levi-Faur (2011), and Gilardi (2021) stressed institutional fragmentation as a source of regulatory delay, while Baldwin, Cave and Lodge (2012) highlighted the limits of administrative capacity in contemporary settings.

In the context of disruptive innovation, this lag takes on a structural character: the pacing problem. Here, technologies advance at accelerated rates, while regulators move slowly due to institutional and political constraints (Marchant, Allenby & Herkert, 2011). Rather than a punctual delay, it reflects a systemic misalignment. With the accelerating pace of technological change — in fields such as artificial intelligence, biotechnology, and renewable energy — the pacing problem has gained renewed centrality in debates on the relationship between technology and regulation. A recent study by Ahern (2025) directly addresses this dilemma, arguing that traditional regulatory methods are prone to rapid obsolescence, thereby generating regulatory delays that may undermine both public safety and international competitiveness. The author proposes that a more anticipatory regulatory culture—incorporating regulatory foresight, regulatory experimentation (e.g., sandboxes and pilot projects), and iterative learning—should be systematically embedded into governance structures to mitigate this structural mismatch.

The innovation economics literature complements this framework by demonstrating that new sectors undergo phases characterized by competition among rival technological trajectories. Only after the emergence of dominant designs or widely accepted technical standards does accelerated diffusion occur (Abernathy & Utterback, 1978; Arthur, 1994; Blind, 2004). Avanci & Ruiz (2020) describe technological cycles in two phases: an initial stage, marked by discontinuity, diversity of trajectories, and low coherence; and a mature stage, characterized by greater continuity, convergence, and integration.

3 METHODOLOGY

This research was carried out in two stages. First, a literature review was undertaken on the economic regulation of specific sectors, with particular attention to the food sector in Brazil and, more

specifically, to alternative proteins. The review encompassed academic articles, opinion pieces, media reports, regulatory norms, draft bills, and publications from think tanks.

In the second stage, between October 2024 and April 2025, a total of 17 semi-structured interviews were conducted with researchers, entrepreneurs, industry leaders, public managers, and legislators. All interviews were recorded, transcribed, and subsequently analyzed by the researcher. To preserve anonymity while ensuring analytical transparency, respondents are cited throughout the text as E1, E2, etc., accompanied by a description of the actor group to which they belong.

In parallel with the interviews, we conducted on-site observation of five relevant events that took place during the study period: the First International Conference on Cell Ag Brazil and the First NAPI Alternative Proteins Meeting, held in July 2024 at the Federal University of Paraná, Curitiba; the First Latin American Forum on Agri-Food Ecosystems, held in November 2024 in Campinas; the 29th Brazilian Congress of Food Science and Technology (CBCTA), held in October 2024 in Florianópolis; the Fourth International Exhibition on Cultivated Meat and Alternative Proteins, held in March 2025 in São Paulo; and the National Workshop of the Climate Plan – Agriculture and Livestock Axis, held in April 2025 in Brasília.

The choice of a qualitative approach is justified by the exploratory nature of the study and by the need to understand the regulation of alternative proteins as a social, political, and institutional process in the making. Such an approach is appropriate when the goal is to capture meanings, perceptions, and practices of actors involved in the formulation and implementation of norms and standards, as well as to identify tensions and divergent interpretations within the regulatory field. The use of semi-structured interviews with representatives of the public sector, private firms, and civil society made it possible to capture heterogeneous perspectives on sectoral emergence, while the documentary analysis of bills, decrees, and regulatory norms complemented the triangulation of evidence.

Sousa and Batista (2025), for example, in analyzing the implementation of public procurement of innovation across Brazilian states, employed semi-structured interviews combined with documentary analysis of legislation and contracts, thereby demonstrating the methodological

pertinence of this strategy for studies addressing the articulation between regulatory frameworks and innovation dynamics.

In this sense, the present research situates itself within the same methodological tradition, contributing to the advancement of knowledge on how regulatory processes both shape and are shaped by innovation in emerging sectors.

4 RESULTS AND DISCUSSION

Below, we begin our analysis of regulation by examining regulatory lag using the four explanatory dimensions set out in the conceptual framework.

4.1 Normative slowness and rigidity

The first dimension is the sluggishness of legal proceedings and the limited ability to conduct comprehensive revisions of norms that affect alternative proteins.

Brazil's National Congress is currently considering more than fifteen bills on milk and meat analogs, alternative proteins, and cultivated meat. They vary in scope and objectives: from defining terminology such as "analogs" and the use of the terms such as "milk" and "meat" in plant-based foods; to consumer-protection provisions, rules disciplining alternative proteins, and specific treatment for cultivated meat. In the latter case, the ambivalence is explicit: one proposal seeks prohibition (PL 4616/2023) while another aims to promote its development (PL 3357/2024). The parallel, divergent processing of these texts reveals not only the slow pace of parliamentary procedure but also the lack of convergence around basic sectoral guidelines. As E1 (Federal Deputy) reported in the interviews: "[...] we had reached an agreement [...] to wait for the publication of the normative instruction [on analogs]. But MAPA (Ministry of Agriculture and Livestock) did not publish the rule and the bill went back to the table," adding that the process "will go through several committees [...] a long road ahead."

In the Executive Branch, we emphasize the role of the country's two main food regulatory agencies. The National Health Surveillance Agency (ANVISA) is responsible for assessing the safety

of ingredients such as enzymes, probiotics, dietary supplements, plant species, infant and enteral nutrition formulas, and foods for infants. The Ministry of Agriculture, Livestock, and Food Supply (MAPA) oversees the production, handling, and processing of foods of both animal and plant origin, as well as the inspection of beverages, meat, fish, and fresh produce. Although their mandates differ, the two agencies perform complementary functions.

E13 (consumer representation) remarked on the public hearing for plant-based analogs (under the auspices of Ordinance SDA/MAPA No. 831) that “We did not expect it to advance so quickly, given that it had been stalled at MAPA for such a long time, amid the ongoing dispute with ANVISA (Brazilian Health Regulatory Agency) over which institution has the authority to act.” The idea of slowness is also reinforced by the update to RDC 16/1999 (ANVISA, 1999), which, after a long public-consultation process, resulted in RDC 839/2023 (ANVISA, 2023), establishing a new regulatory framework for novel foods and ingredients. The agency’s stated goal, as conveyed in the interview, is to complete the novel-foods framework by 2025. This progress moves Brazil towards a stage of normative consolidation regarding novel foods and ingredients, as noted by a report in Revista FAPESP (2024): “The regulatory framework places Brazil in a prominent position globally. It also facilitates investment in sustainable food innovations.”

What these elements indicate is a natural trade-off between regulatory complexity and adherence to good regulatory practice. The legislature seeks to hear divergent interests; MAPA’s public consultation on plant-based analogs follows the same direction; and ANVISA’s Regulatory Impact Assessment (ANVISA, 2022) aligns with international good practice. While such processes entail delay, ANVISA’s actions, for example, help build a comprehensive rule set that is more likely to function in a manner conducive to the emergence of novel foods and ingredients.

4.2 Market pressures

Within the Executive branch of the Federal Government, the most recent regulatory debate on plant-based products has been conducted by MAPA, which launched the public consultation for Ordinance SDA/MAPA No. 831 (MAPA, 2023), concerning standards of identity and quality for

“analog” of meat and dairy. From the standpoint of regulatory cycles, plant-based proteins had already overcome the main standardization challenges for products and processes. The dispute over nomenclatures such as “meat” and “milk,” along with the emergence of divergent state-level legislation, exposes the vulnerability of sectors that, although mature, remain subject to normative ambiguity. In this context, regulation ceases to be merely technical disciplining and becomes a political-economic arena in which incumbents and entrants seek to shape identity standards for their products. Although the official stance is that the rule’s scope is limited to labeling and identity criteria, we anticipate the possibility of broader market and industry effects.

Additionally, E1 (Federal Deputy) emphasized that the legislative process has heard from the vegetarian/vegan movement, the dairy and meat value chains, the CNA (National Confederation of Agriculture), and MAPA, noting that “[...] we are trying to bring all these sectors together for a moment of convergence.” E2 (academia) reinforced the idea of multiple pressures by observing that “no politician wants to go against JBS or BRF,” while at the same time there is pressure from agribusiness and ranchers’ representatives opposed to the advance of new proteins. E15 (NGO) highlighted “the political and economic clout of the livestock lobby in Brazil.” MAPA also mentioned pressures channeled through its sectoral chambers, as in the case of demands regarding the terms “milk” and “meat.” E11 (NGO) affirmed that “we have a direct relationship with MAPA and ANVISA” ... “we have our team in Brasília participating in discussions not only on regulation but also on tax exemptions and other political battles.” This illustrates how the emerging sector mobilizes to gain representation, even as incumbents deploy their resources to shape the legislative and regulatory agenda. However, while legitimate regulatory pressure is clear, there is no indication of regulatory capture in the interviews.

4.3 Institutional capacity and regulatory coordination

Brazil possesses an established institutional capability—regulatory agencies and established legal frameworks—alongside governance arrangements such as AIR procedures, public consultations, and formally qualified human resources (lawyers, economists, engineers). Yet

interviewees pointed to limitations on the availability of technical information and in the cognitive/learning capacity of government institutions regarding knowledge specific to new technological trajectories. E2 (academia) highlighted the limited scientific-technical base to inform regulation: “In Brazil [...] we don’t have many [research groups]; if there are four or five in the whole country, that’s a lot.” E3 (firm) noted the lack of preparedness in inspection: “The first challenge will be for the health vigilance authority to understand that what we have is a food production environment, not a research environment.”

Coordination across agencies and federal tiers is considered fragile. Most salient are overlapping mandates between ANVISA and MAPA. Based on the reviewed norms, while Anvisa covers plant-origin products (and sanitary vigilance more broadly), MAPA handles beverages and animal-origin products. Additionally, ANVISA addresses horizontal issues (e.g., hygiene, contaminants), whereas MAPA acts more vertically along value chains—leading to overlapping attributions in inspections. According to E12 (academia), “So there’s an ongoing tussle between MAPA and ANVISA over regulation,” adding that “ANVISA has taken some steps, but the ministry (MAPA) is still far behind in the overall discussion.” E4 (municipal health vigilance) explained that many firms file applications “with the wrong body”: “often people file with ANVISA when they should file with MAPA [...] these are not agencies that help each other [...] each one does its own.” E15 (NGO) commented, “It’s a pity if the country (Brazil) doesn’t get organized because things have a coherence...” “...so we need to move quickly for Brazil to wake up.” From a federalist perspective, São Paulo State is illustrative: in 2024, the Legislative Assembly approved PL 304, banning the use of the word “meat” on labels and advertising for products not containing meat—an uncoordinated move relative to the ongoing national process, promoting regulatory fragmentation.

4.4 Scientific uncertainty, absence of standards

E3 (firm) captured the scientific uncertainty by noting, “I can’t guarantee that what we achieved at bench scale will work at scale [...] in larger bioreactors [...]” E6 (public research organization) reported uncertainties regarding scalability, contamination, and replicability of results.

E5 (academia) flagged doubts about nutritional value (of novel products) and risks associated with cultivation under artificial conditions. E7 (public research organization) explained they still work with prototypes, without official sensory-testing protocols in Brazil, signaling uncertainty regarding food safety and consumer acceptance: “There is no protocol [in Brazil] for sensory testing [...] we’re left with the electronic nose/tongue.” E4 (health surveillance) stated that insects are still treated as “contaminants,” which stalls regulatory advances. In parliamentary debate, E1 (Federal Deputy) observed that discussions over terminology— “milk is milk”—reflect the absence of a juridical-political consensus on identity standards for analogs and alternative meats.

Despite the recurrent use of the umbrella term alternative proteins (including in this article), there is a marked difference between plant-based proteins and other technological trajectories such as cultivated meat. Plant-based proteins exhibit higher technological maturity. There are dominant designs accepted as quality standards: extruded plant-based burgers, soy/oat/almond “milk,” pea-based chicken analogs, etc. By contrast, cultivated meat, precision fermentation, and insect protein are radical innovations in food production. There is no technical consensus on how to produce efficiently, safely, and at scale; critical control points are not universally agreed; sensory/safety protocols are not yet fully standardized. Regulation remains exploratory, there is no broad international convergence.

Our results indicate that, differently from plant-based, the technological trajectories leading to radical innovations in Brazil’s emerging alternative-protein sector are clearly at an early stage, characterized by scientific uncertainty, the absence of dominant technical standards, and disputes over regulatory nomenclature—a configuration of high variety, low coherence, and significant cognitive distance. We posit that overcoming this initial phase hinges on building regulatory frameworks that reduce dispersion, establish identity and safety standards, and thereby enable the transition toward greater convergence and sectoral maturity.

4.5 Beyond regulation: Technological bottlenecks

Although the focus here is the regulation of alternative proteins, the interviews showed that obstacles extend beyond the normative domain. They reveal a persistent technological lag that hinders the emergence of some of the technological trajectories. A central bottleneck regarding cultivated meat is the use of fetal bovine serum (FBS) as culture medium. E5 (academia) noted that eliminating FBS was already a challenge in 2020 and “remains a hurdle” for cultivated meat; E9 (SENAI) acknowledged that “we do not yet have a Brazilian FBS-free culture medium,” and E7 (public research organization) confirmed that the best results still depend on FBS. At the innovation frontier, E8 (firm) stressed the difficulty of replacing FBS, even when low-yield alternatives exist.

Another core technical constraint is the lack of suitable bioreactors, forcing teams to build equipment and cultivation systems “from scratch.” E9 (SENAI) stated: “we do not yet have a bioreactor adapted for animal-cell cultivation, at least not a Brazilian one,” while E9 (firm) reported having to develop dehydrators and extraction equipment for insect-based production on their own because “there’s nothing on the market.” Scaling up is seen by E9 (firm) as “the main challenge right now,” confirming that the transition from bench-scale prototypes to industrial scale remains a blind spot.

Technological readiness levels (TRLs) are another dimension. E5 (academy) pointed to uncertainties about nutritional value (e.g., micronutrient content) and risks associated with cultivation under artificial conditions. E8 (SENAI) stated that the technology “is still at the prototype stage, not at a JBS/BRF scale.” Scaffolds (tissue “scaffolding”) were also identified as a bottleneck. E5 (university) stressed the need to determine the most suitable scaffold to give volume to cell cultures, while E7 (public research organization) reported still-experimental processes with plant-based scaffolds, such as lupin.

4.6. Interaction between regulatory lag and technological lag: “Locked-in co-evolution” and the scale of misalignment

The innovation literature emphasizes the coevolution of technology and institutions (Rip & Kemp, 1998; Geels, 2004). In this view, the relationship between innovation and regulation unfolds

as a dynamic process of mutual adjustment, whereby advances in one sphere induce adaptations in the other. Our results point to a specific configuration that we call locked-in co-evolution. In this case, the expected feedback loop stalls: regulators wait for firms to file technical dossiers; firms postpone formal submissions in the absence of normative clarity and standards; and consumers remain uninformed, without identity and safety benchmarks. This mutual blockage prevents the simultaneous advance of technology and regulation, slowing sectoral diffusion.

The findings also suggest that “unlocking”, i.e., reintroducing a synergistic dynamic between regulation and technology during sectoral emergence, requires reframing the regulatory pacing problem.

From an international perspective, a recent study analyzed 292 novel-food authorization applications submitted to the European Food Safety Authority (EFSA) between 2018 and 2024 under Regulation (EU) 2015/2283 (Le Bloch et al., 2025). Results indicate that the average time from dossier submission to EFSA’s scientific opinion was 2.56 years (≈ 31 months), with delays related to validation stages, requests for complementary analyses, and additional data requirements (Le Bloch et al., 2025; Protein Production Technology, 2025). In light of this protracted timeline, pressures from multiple stakeholders—industry, regulatory agencies, and the European Commission—have driven a review of the regulatory framework, aiming at faster, more efficient, pro-innovation procedures (Food Navigator, 2025; National Law Review, 2025).

Conversely, while the literature typically suggests regulation lags behind innovation, we observed that—regarding novel foods and ingredients in Brazil—the regulatory apparatus has progressed faster than technological consolidation (culture media, bioreactors, scaffolds). Interview evidence and documents show that ANVISA’s RDC 839 opens the door to filing applications for novel products and ingredients. Yet, when ANVISA was asked explicitly in the interview whether pending applications for novel products were “on hold,” the answer was negative. This suggests a partial inversion of the classic pattern: technological maturity has become the main bottleneck.

Therefore, we propose that the pacing problem should be viewed dynamically, especially in the early stages of a sector’s emergence. On one hand, the inherent rigidity of regulatory processes

and the regulator's cognitive constraints can generate slowness consistent with the conventional formulation. On the other hand, two factors appear to have brought regulatory processes closer in step with technology: (i) growing anticipatory behavior among regulators; and (ii) evidence from our study that regulation has become a strategic priority for sectoral interest organizations, which have begun to influence regulatory dynamics at earlier stages.

In short, we suggest viewing the pacing problem as a gradient ranging from regulatory lag to the opposite extreme of technological lag. The pendulum of this scale operates dynamically, occupying different positions along the sector's development cycle.

On the other hand, the regulatory debate surrounding the labeling of plant-based products in Brazil requires a different perspective. Howlett and Newman (2013) suggest a regulatory life cycle model that moves from the emergence of regulatory problems and minimal intervention, through regulatory expansion and institutionalization, to a stage of stabilization, where rules become more coherent yet remain open to revision. Recent semantic disputes threaten to bring the plant-based segment back to an earlier stage of the regulatory cycle. While some actors advocate for the exclusive use of terms traditionally associated with animal-based products, others argue that expressions such as "plant-based milk" or "plant-based meat" are culturally established and widely recognized by consumers. This lack of consensus has contributed to a fragmented regulatory environment, in which public consultations, legislative proposals, and legal disputes have generated additional complexity. Rather than providing clarity and predictability, these processes have reinforced institutional ambiguity and may hinder both innovation and investment in the sector. Regulatory pressure may paradoxically generate a regulatory vacuum.

This situation connects to the concept of locked-in co-evolution, in which technological and market advances fail to find a corresponding regulatory and institutional adjustment capable of keeping pace. While demand for plant-based alternatives grows and diversifies, regulation oscillates between restriction and flexibility, generating barriers to coordination among stakeholders. Rather than enabling a fluid co-evolution between technology, markets, and institutions, the system becomes entangled in terminological disputes that reinforce regulatory lag. This blockage

demonstrates that the central challenge is not merely normative but structural: the absence of alignment between innovation, regulatory frameworks, and sectoral interests prevents the full potential of the alternative protein industry from being realized.

4.7 Unlocking co-evolution

International literature points to several avenues for addressing regulatory misalignment. It has developed the concept of anticipatory regulation, characterized by co-production with society and markets, iterative experimentation, and a results-oriented focus (Armstrong & Rae, 2017). The OECD has systematized experimentalist governance guidelines, advocating short review cycles, testbeds, and collaborative monitoring arrangements (OECD, 2021). Regulatory sandboxes, initially diffused in fintech, have expanded to domains such as AI and health, allowing innovations to be tested in controlled environments and generating evidence for normative adjustment (OECD, 2023). In parallel, governments such as the United Kingdom have created dedicated structures—e.g., the Regulatory Innovation Office—to accelerate approvals and coordinate multiple agencies, signaling the institutionalization of a regulatory ecosystem oriented toward innovation. Across these initiatives, the emphasis falls on proactive institutional mechanisms that anticipate innovation and reduce the regulation–technology gap that keeps sectors in a state of locked-in co-evolution.

In Brazil, progress of this sort remains sporadic, dependent on isolated initiatives by regulators or pressure from firms. Public consultations can be seen as co-production spaces in which ANVISA and MAPA receive input from companies and society. This procedure reflects a proactive attempt to bring regulators and emerging firms closer, thereby reducing the lag between innovation and standard-setting. However, there is no transparent monitoring of the decision criteria regarding what will be accepted. There is a demand for actions in the vein of experimental governance and regulatory sandboxes. Researchers reported the need to develop prototypes in experimental settings—with restricted public access and biosafety protocols—precisely to generate evidence that could underpin future norms. The fact that a startup interviewed is already testing alternative ingredients in partnership with major food companies, even prior to full approval, points to a sandbox-

like logic: controlled experimentation to generate regulatory and market data. When asked explicitly about the topic, ANVISA mentioned that certain units are “experimenting” with regulation, but that the idea is still far from implementation in the food domain.

Overall, the testimonies indicate that Brazil is already rehearsing responses to regulatory misalignment that are close to international practices—anticipatory consultations, experimental arrangements, and signs of institutional flexibility. However, unlike more structured experiences, such practices in Brazil remain fragmented, occasional, and highly dependent on the initiative of a few agencies and pioneering firms.

5 CONCLUSIONS

The institutional environment in which the sector of novel foods and ingredients—and particularly alternative proteins—emerges in Brazil is subject to the classical factors that produce regulatory lag: bureaucratic inertia, legal rigidity, limited administrative capacity, and scientific uncertainty.

Disruptive trajectories such as cultivated meat, precision fermentation, and insect-based food production clearly exhibit the features of the initial phase of sectoral structuring: high variety, low coherence, the absence of standards, and the lack of dominant designs. On the other hand, the regulation of novel foods and ingredients is at an implementation stage that does not prevent the submission of applications for the registration of new products and ingredients.

This suggests that the pacing problem should be viewed dynamically in the early stages of sectoral emergence. The rigidity of regulatory processes and cognitive deficiencies within regulators can lead to slowness and confirm the conventional formulation of regulatory lag. Yet the growing anticipatory behavior within the regulatory environment, combined with the vigorous action of sectoral interest organizations, has contributed to making the regulatory process more expedient. Hence, we propose that the pacing problem should be conceived as a gradient, ranging from regulatory lag to the opposite extreme of technological lag. The pendulum along this scale operates dynamically, occupying different positions throughout the sector’s development cycle.

Accordingly, the diffusion of alternative proteins in Brazil cannot be explained solely by regulatory lag or by the pacing problem. What we observe is a condition of locked-in co-evolution. While regulatory lag describes the delay in institutional responses to specific innovations, and the pacing problem refers to the structural acceleration of emerging technologies relative to slow-moving regulators, locked-in co-evolution highlights a third configuration: not merely temporal misalignment, but a reciprocal paralysis among regulatory, technological, and market actors, each reinforcing the other's uncertainty.

Overcoming this condition requires strengthening institutional capacity, consolidating technical standards, improving inter-agency coordination, and adopting mechanisms of anticipatory and experimental regulation.

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