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CONFIGURING TECHNOLOGICAL MATURITY IN NASCENT HIGH-TECH SECTORS: A set-theoretic analysis of CDMOs, infrastructure, and startup strategies in the alternative protein space

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Introdução

The growing interest in alternative protein sources is driven by their potential to reduce the environmental impacts of conventional livestock farming, including deforestation, biodiversity loss, and greenhouse gas (GHG) emissions (Reis et al., 2025; Sturme et al., 2025). Among these technologies, fermentation-based approaches—especially biomass and precision fermentation—are among the most mature and commercially viable. Among these technologies, fermentation-based approaches—especially biomass and precision fermentation—are among the most mature and commercially viable.

Problema de Pesquisa e Objetivo

Among these technologies, fermentation-based approaches—especially biomass and precision fermentation—are among the most mature and commercially viable. Our research objective is to examine how access to enabling structures, particularly CDMOs, configures viable development trajectories for startups in the alternative protein sector, and to identify which structural combinations support or constrain technological advancement.

Fundamentação Teórica

This study examines how CDMOs and enabling structures shape innovation in fermentation-based alternative proteins. It combines Entrepreneurial Ecosystem and Global Value Chain frameworks to show that CDMOs lower barriers to scale and act as strategic intermediaries. Governance types (e.g., relational, captive) influence outcomes. Success depends on infrastructure, firm capabilities, and alignment across technological, institutional, and market dimensions to unlock disruptive innovation.

Metodologia

This research uses a set-theoretic approach (Ragin, 2008) to explore how access to enabling structures—especially CDMOs—shapes startup development in the alternative protein sector. This method captures complex, asymmetric causal patterns and allows for multiple success paths (equifinality). It aligns with ecosystem and GVC theories, revealing how uneven CDMO access affects innovation. Unlike linear models, this approach accounts for the interplay of structural, financial, and organizational conditions in a fragmented and emerging bioeconomy.

Análise dos Resultados

Our findings support the argument that internal capabilities—such as vertical integration and technological specialization—can act as partial substitutes for external infrastructural gaps, a phenomenon especially relevant in structurally uneven innovation ecosystems (Teece, 2018; Apodaca et al., 2022, 2023). This insight serves as a bridge to understanding failure patterns when such substitutive or complementary elements are absent, as discussed next.

Conclusão

Technological advancement in the fermentation-based alternative protein sector relies on the alignment between enabling infrastructure and firm-level strategies. Regional CDMO access, when combined with internal capabilities such as fermentation expertise, vertical integration, and operational maturity, becomes a critical driver of success. Rather than following a single pathway, firms thrive through varied but coherent configurations. This underscores the importance of integrated innovation ecosystems that connect infrastructure, funding, and organizational development.

Contribuição / Impacto

This study shows how food-grade CDMOs enable diverse development paths in fermentation-based proteins. Using set-theoretic analysis, it identifies structural combinations that foster or limit innovation. Despite widespread fermentation specialization, firms differ in age, funding, integration, and access. The sector is both emerging and maturing, shaped by institutional support and firm capabilities. Gaps in CDMO access reflect global asymmetries, echoing ecosystem and GVC theories on uneven upgrading.

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