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METHOD FOR THE DEVELOPMENT
OF FOOD PACKAGING IN LOCAL
AGRI-FOOD SYSTEMS WITH A
FOCUS ON SUSTAINABILITY**

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Karan Valente¹ | Suezilde da Conceição Amaral Ribeiro²

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¹ PhD student in Sustainable Rural Development and Management of Agrifood Enterprises (IFPA).
Professor at the State University of Pará. Belém - PA, Brazil.
E-mail: karan.valente@uepa.br

² PhD in Food Engineering (UNICAMP).
Professor at the Federal Institute of Education, Science and Technology of Pará. Belém - PA, Brazil.
E-mail: suezilde.ribeiro@ifpa.edu.br

ABSTRACT

This study addresses the theoretical and methodological gap between the development of food packaging and the realities of Local Agri-Food Systems (LAFS). The objective was to devise an original and transdisciplinary design method that systematically integrates technical, sociocultural, and environmental dimensions in order to transform agri-food products into assets for territorial development. The research, which was applied in nature and qualitative in approach, combined narrative review and action research principles, resulting in a method called "Fractal." The original contribution of this theoretical-practical framework, in contrast to conventional approaches, lay in the systematization of a framework with fifteen dimensions of analysis to a multidimensional sustainability model - based on financial, environmental, shared, and creative economies - and in the centrality of co-creation with local actors. The approach also included an operational roadmap and diagnostic tools with 137 criteria. It is concluded that the method repositions packaging as a socio-technical communication device for development, offering a path for strategic design to strengthen the autonomy of rural producers, territorial identity, and the economic resilience of LAFS, in alignment with ten Sustainable Development Goals.

Key words: Local foods. Regional development. Transdisciplinarity. Sustainable development. Packaging design.

INTRODUCTION

The strengthening of Agri-Food Systems (AFS) emerges as a potential strategy for regional and local development, based on the valorization of territorial assets and the promotion of a socioeconomic dynamic that favors the circulation of value within the region itself (FAO, 2023; Valente, 2025). AFS are complex networks that articulate the entire food value chain, from production to disposal (Ericksen, 2008; FAO, 2014; HLPE, 2020). Although they generate US\$ 3.8 trillion and employ 26% of the global workforce (FAO, 2022, 2024), the hegemonic model—characterized by large-scale production and centralized distribution (Friedmann; McMichael, 1989; McMichael, 2009, 2013)—presents a paradox.

This system imposes “hidden” socio-environmental costs of US\$ 12.7 trillion annually, manifested in environmental degradation, diseases associated with inadequate diets, and chronic malnutrition, which still affects 811 million people (FAO, 2021, 2023; Valente, Ribeiro; Joele, 2023; Wahbeh *et al.*, 2022).

In dialectical contrast to this model, Local Agri-Food Systems (LAFS) are emerging, productive arrangements based on close relationships between their *stakeholders* and the valorization of territorial assets (Kwil; Piwowar-Sulej; Krzywonos, 2020). They are thus aligned with a development perspective that starts from the internal potential of territories, reinforcing value retention and the revitalization of local economies (Grisa *et al.*, 2022).

One of the major challenges, however, lies in the need to translate the intangible differences in their production—such as cultural identity, origin, and sustainability—into market value that is perceptible to consumers. In this scenario, food packaging plays a decisive role, not limited to the traditional functions of protection and packaging, but also acting as strategic elements for market differentiation and the communication of values (Lavuri, 2022; Siddiqui *et al.*, 2022).

Despite its strategic potential, systematic reviews of the literature reveal a notable methodological gap at the intersection between the development of packaging technologies and the realities of LAFS (Valente; Ribeiro, 2023, 2024). This lack of contextually appropriate approaches represents a bottleneck to local and regional development, especially for family farming, whose sustainability depends on the integration of economic, social, and productive



dimensions (Carneiro, 2008; Kato *et al.*, 2022). Overcoming this barrier therefore requires the construction of new interdisciplinary and transdisciplinary frameworks capable of addressing such complexity and innovations in an integrated manner, advancing beyond the limits of conventional design methods (Dörnyei *et al.*, 2023; Zhou *et al.*, 2023).

To address this gap, the present research was guided by the following question: how to conceive a packaging design method that integrates the socio-productive, environmental, and cultural dynamics of LAFS, transforming agri-food products into assets for territorial development? The central objective, therefore, was to devise an original transdisciplinary approach designed to respond to this challenge.

The contribution of this work lies in offering a theoretical-practical model for valuing regional-local territorial assets in their multiple dimensions, through strategic design, with special emphasis on the management of production chains, innovation, and sustainability. In doing so, the research also dialogues with the field of Communication for Development (C4D), proposing packaging as a tool for empowerment and local development. Aligned with multiple Sustainable Development Goals (SDGs), the proposal detailed here seeks to represent a theoretical-methodological advance with significant potential to strengthen local socio-productive systems.

THEORETICAL FOUNDATION

THE STRATEGIC ROLE OF LAFS AND PACKAGING IN REGIONAL DEVELOPMENT

The contemporary concept of regional development goes beyond purely economic analysis by adopting a multidimensional perspective that integrates the social, cultural, political, and environmental spheres of a territory (Dallabrida, 2022). From this perspective, LAFS stand out for promoting productive diversity and food security in the territory, while territorial identity emerges as a relevant communicational and strategic asset (Perafán, 2022; Preiss; Schneider, 2020).

Defined as networks where food production, processing, and marketing occur within specific geographical boundaries (Feenstra, 1997; Kneafsey *et al.*, 2013), LAFS are often associated with traditional production methods and short supply chains that strengthen the local economy and reinforce regional identity (Aguiar *et al.*, 2018; Kwil; Piwowar-Sulej; Krzywonos, 2020; Valente;



Ribeiro, 2024; Valente; Ribeiro; Joele, 2023). Although multiple terms are used—“localized,” “specific,” or “territorial”—their core characterization lies in three dimensions of proximity: (1) geographic, with distances ranging from 20 to 600 km; (2) relational, based on relationships of trust between actors; and (3) evaluative, focusing on origin, traceability, and quality (Kneafsey *et al.*, 2013; Enthoven; Van den Broeck, 2021).

Another distinctive feature of LAFS is the expansion of farmers’ roles, who often take on marketing and distribution activities to add value to their products (Darolt *et al.*, 2016; Martinez *et al.*, 2010). This proximity to the market allows for the valorization of production by emphasizing attributes such as authenticity and reliability, strengthening the links between producers and consumers and generating significant economic benefits.

However, there are practical obstacles to realizing this potential. The lack of coordination between public policies, the lack of technical assistance, and the difficulty of engaging multiple social actors to strengthen productive activities represent significant barriers to local development (Aguar *et al.*, 2018; Grisa *et al.* 2022; Wolff; Gomes, 2015).

In this challenging context, innovation in packaging design emerges as a competitive strategy for differentiating local products (Mestriner, 2007; Mount, 2012). In addition to its strategic function, packaging fulfills three essential roles: (1) ensuring the safe and economical delivery of products; (2) organizing goods for transport and consumption; and (3) integrating technical and commercial aspects to balance costs and maximize profitability (Coles, McDowell; Kirwan, 2003; Valente; Ribeiro, 2023).

Table 1 expands on this understanding, presenting a contemporary view of the functions considered essential to the development of food packaging, also incorporating an analysis of the methodological implications for the development of related projects in LAFS.

Table 1 | Theoretical summary of the multiple functions of food packaging and methodological implications

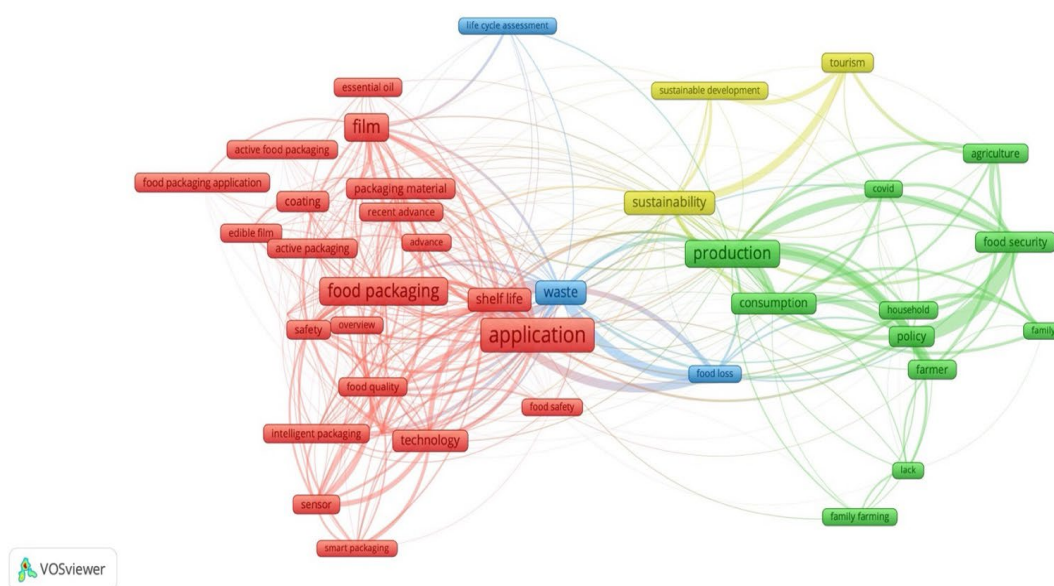
Function	Specification	Methodological implications for LAFS
Protection	Physical barrier that prioritizes the preservation of food integrity, protecting it from deterioration and external factors.	Need to adapt materials and technologies to local climatic conditions and specific characteristics of regional products.
Preservation-storage	Prevention of chemical and microbiological changes, extending the shelf life and commercial life of food.	Development of solutions that consider limitations in refrigeration infrastructure and logistics in remote regions.
Transport	Ensuring food preservation and integrity throughout the supply chain.	Consideration of road conditions and varying distances between production centers and consumers.
Marketing-promotion and sales	Application of marketing strategies to attract attention, stimulate desire to purchase, and overcome price barriers.	Integration of local cultural elements with contemporary design trends, balancing tradition and innovation.
Presentation-brand communication	Use of aesthetic elements to create visual impact, add value to the product, and reinforce the brand image, considering material, shape, and size to stand out at the point of sale.	Development of visual identities that communicate authenticity and territoriality without falling into stereotypes.
Ergonomics-Convenience	Ease of handling, opening, and closing, providing comfort and safety to the consumer.	Consideration of different user profiles, including rural and urban populations with different levels of familiarity with packaging.
Legal aspects	Compliance with current local laws and regulations.	Need to simplify the understanding and application of complex rules for small producers with limited access to legal advice.
Economy	Optimization of acquisition costs and efficiency in distribution, production, and storage.	Development of economically viable solutions on a small scale, considering the capital limitations of small producers.
Environmental	Minimization of environmental impact through sustainable materials and processes.	Integration of traditional knowledge with technological innovations to develop environmentally adapted solutions for specific contexts.
Food-packaging interactivity	Application of active and intelligent packaging technologies to optimize preservation and provide feedback to consumers.	Need for technological simplification without loss of functionality to enable adoption in contexts with limited resources.
Product-packaging unit	Recognition of the inseparability between food and its packaging.	Integrated development considering specific characteristics of regional products and their interactions with different packaging materials.
Sociocultural context	Valorization of local culture and context in food packaging.	Participatory methodologies that incorporate the perspectives and knowledge of producing communities in the design process.
Consumer awareness	Informing consumers about the sustainability of the product and packaging, promoting knowledge and awareness of sustainable practices.	Communication strategies adapted to different levels of consumer literacy and environmental awareness.

Source: Prepared by the authors (2025); adapted from Coles; McDowell; Kirwan (2003); Delfino (2013); Dörnyei *et al.* (2023); DuPuis; Silva (2011); Hussain; Akhter; Maktedar (2024); Mestriner (2007, 2017, 2018); Negrão; Camargo (2008); Sastre; Cesar (2024); Valente; Ribeiro (2023, 2024, 2025)

THE METHODOLOGICAL GAP: FRAGMENTATION OF KNOWLEDGE AND THE OPPORTUNITY FOR A TRANSDISCIPLINARY APPROACH

Bibliometric analysis of the available scientific literature on the development of food packaging for family farming and LAFS reveals a notable epistemological fragmentation between these fields (Valente; Ribeiro, 2024). Figure 1 shows a clear separation between the research clusters of “food packaging” and “agricultural production and consumption,” indicating that technological innovation often develops in isolation from the socio-productive realities of the territories.

Figure 1 | Segmentation analysis present in the research reviewed



Source: Valente and Ribeiro (2024)

This gap, which hinders value addition in the context of regional development, manifests itself in at least three central tensions (Valente, 2025): (1) Technical-productive tension: marked by the mismatch between advances in cutting-edge technologies, such as smart and active packaging and nanotechnology (Ahmed *et al.*, 2022; Perera *et al.*, 2022), and the lack of validation of their technical and economic viability on a small scale (Alp-Erbay, 2022; Zhou *et al.*, 2023); (2) Sustainability tension: in which new advanced materials such as bioplastics are sometimes seen as the definitive solution for food packaging in contexts involving the circular economy (Guillard *et al.*, 2018), and sometimes

criticized as merely shifting environmental impacts (Mendes; Pedersen, 2021); and (3) Regulatory tension: which emerges when legal frameworks designed for industrial scale impose barriers to the formalization and operation of small producers (Sgroi, 2021).

The combination of these tensions shows that the gap identified is not only thematic but fundamentally methodological, as no studies were found that propose specific methods for the development of packaging adapted to the realities of LAFS (Valente, 2025; Valente and Ribeiro, 2024, 2023).

MATERIAL AND METHODS

RESEARCH DESIGN

The objective of this research was to systematize the method called “Fractal”: a transdisciplinary and integrated methodological framework for the design of food packaging in LAFS. The method was designed to overcome the limitations imposed by the fragmentation of knowledge, aiming not only at a technical result but also at strengthening local capacities.

The research was characterized as applied, exploratory, and descriptive, with a qualitative approach (Gil, 2021). To conduct it, the hypothetical-deductive method (Popper, 2013) was combined with action research principles (Cornish *et al.*, 2023), which guided the construction and validation of the framework.

The work was guided by the central hypothesis that the systematic and transdisciplinary articulation of knowledge from areas such as design, engineering, and social sciences could result in more effective and contextually appropriate packaging solutions for LAFS, overcoming pre-existing conventional approaches and contributing positively to local-territorial development.

CONSTRUCTION OF THE FRACTAL METHOD: PHASES AND PROCEDURES

The construction of the Fractal method was organized into a sequential process, divided into two main phases, which supported the transition from the theoretical foundation to the architecture of the proposed approach (Table 2).



Table 2 | Phases and procedures for the construction of the Fractal method

Phase	Stage/Activity	Objective	Theoretical-conceptual foundation
1 Theoretical and conceptual basis	1.1 Analysis of previous systematic literature reviews (SLR)	- Map the state of the art and validate the theoretical and methodological gap at the intersection between LAFS, packaging technology, and developments for regional development.	- Valente and Ribeiro (2025, 2024, 2023)
	1.2 Conducting an unsystematic narrative review	- Synthesize and integrate knowledge from multiple fields to build a conceptual basis, defining the foundations of the method.	- Central pillars: Packaging design; Design thinking and Project management - Complementary perspectives: Ethnoecology (Toledo; Barrera-Bassils, 2009) and 4D Fluxonomy (Deheinzelin; Cardoso; Bittencourt, 2020).
2 Method architecture and supporting tools	2.1 Conceptual structuring (framework and roadmap)	- Development of the framework and systematization of the “3I” roadmap - Immersion, Ideation, Implementation.	- Specialized literature on marketing and innovation models
	2.2 Development of diagnostic tools	- Creation of diagnostic and operational tools for the method, based on a systematic inventory of parameters extracted from the literature.	- Specialized literature that underpins the 137 criteria of the instruments (Checklists and Briefing)

Source: Prepared by the authors (2025)

CONTEXT OF APPLICATION AND TERRITORIAL DELIMITATION

Based on the literature on LAFS, the method was designed to address its dynamics and particularities. However, its practical application and territorial scope were deliberately contextualized in the Brazilian Legal Amazon (BLA) (Brazil, 2020). This choice is justified because the BLA uniquely concentrates the characteristics that the study sought to address: a vast territory of high socio-biodiversity, where the prominence of family farming and extractivism coexists with profound socio-environmental challenges and the need for more inclusive and sustainable development models (Brondízio, 2021; Nobre *et al.*, 2023).

CASE SELECTION CRITERIA

For the future implementation of the proposal, four criteria were established for the selection of participating agri-food enterprises. The cases should: (1) be part of short marketing circuits, with geographical and relational proximity (Enthoven; Van den Broeck, 2021; Kneafsey *et al.*, 2013); (2) have a portfolio of products with a clear territorial identity (Souza *et al.*, 2020); (3) legally qualify as family farming, in accordance with Law No. 11,326/2006 (Brazil, 2006); and (4) express a willingness to actively engage in the co-creation process.

DATA COLLECTION AND ANALYSIS PROCEDURES

Data collection combined multiple instruments to ensure the depth of the analysis. Initially, semi-structured interviews were conducted with rural entrepreneurs to collaboratively fill out a briefing form, allowing for immersion in the context of each enterprise. This process was complemented by technical visits for participant observation of production routines, with systematic records in a field diary.

Next, for the technical diagnosis of existing packaging (T_0), we plan to apply Fractal Checklist 1, a tool with 127 criteria that diagnose the zero moment of related design variables. The analysis of data from transcripts and observations was complemented by the application of checklists, which use a three-level compliance scale (0, 1.5, and 3 points). The objective of this assessment was also to translate qualitative perceptions into metrics for future comparisons. The data were systematized to calculate percentage adequacy indices, allowing a visual comparative analysis—using radar charts—between the initial diagnosis (T_0) and the compliance potential of the new design proposal (T_1), generated at the end of the action research cycle.

ETHICAL CONSIDERATIONS

The research strictly followed ethical precepts, ensuring the strictly voluntary participation of the enterprises, formalized through informed consent after a detailed presentation of the study's objectives and procedures. Participants were guaranteed the right to withdraw from the research at any time, without prejudice. Confidentiality and anonymity were fundamental premises: the data



were treated confidentially, and the results were presented in aggregate form to prevent individual identification. The use of any information that could lead to identification was only permitted with the explicit consent of the representatives.

RESULTS AND DISCUSSION

This section presents the systematization of the Fractal method and discusses its components to position it as an original contribution to the field of regional development. The analysis deepens its concept, its transdisciplinary architecture, and the operational roadmap, demonstrating how the method aims to respond to concrete territorial challenges and differentiate itself from pre-existing conventional approaches.

THE CONCEPT “FRACTAL: NATURE AS INSPIRATION

The concept of “Fractal” was based on the analogy with the self-similar patterns of nature, where each component of a system reflects the structure of the whole at different levels (Mandelbrot, 1982). This approach recognizes that LAFS exhibit a similar multiscale organization: the dynamics of a single producer (microscale) are interconnected and mirror the resilience of the entire regional production chain (macroscale). Therefore, the method proposes to configure a solution that overcomes linear and reductionist approaches by incorporating the complexity inherent in the self-similarity of challenges and opportunities at multiple scales of the system.

FRAMEWORK ARCHITECTURE

The analysis of pre-existing methods revealed an emphasis on linear procedures, focused on market aspects and poorly connected to regional development dynamics. In contrast, critical analysis of the theoretical basis underpinning Fractal pointed to three patterns that justify a new approach: a) Structural convergence, as methodologies tend to follow a common cycle of diagnosis-ideation-implementation; b) Epistemological complementarity, where different areas offer synergistic contributions; and c) Contextual limitations, since no approach was designed for the specificities of LAFS.



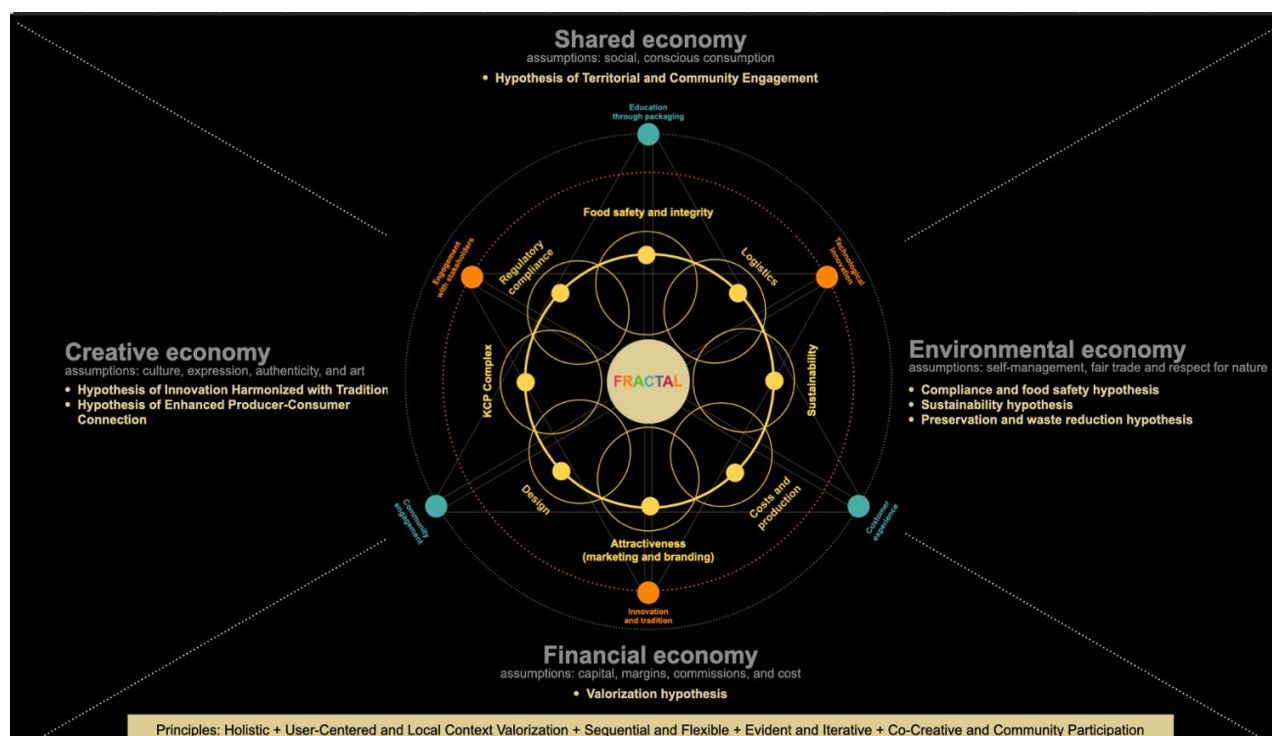
To fill this gap, the approach was designed on a transdisciplinary basis that articulates five domains of knowledge. Three acted as pillars of execution:

1. Design thinking: A knowledge approach central to the method, with a focus on humans and cycles of immersion, ideation, and implementation (Brown, 2010; Ferreira; Pinheiro, 2017; Ferro, 2018; Stickdorn; Schneider, 2014; Vianna *et al.*, 2012);
2. Packaging design: The specific technical domain for the creation of functional and communicational artifacts (Delfino, 2013; Dörnyei *et al.*, 2023; DuPuis; Silva, 2011; Mestriner, 2007, 2017, 2018; Negrão; Camargo, 2008)
3. Project management: The discipline that guided the rigor and feasibility of implementation management (PMI, 2017, 2018).

This structure was augmented by two immersion perspectives: (a) Ethnoecology: which sought cultural relevance through the analysis of the KCP Complex (*Kosmos-Corpus-Praxis*) (Toledo; Barrera-Bassols, 2009); and (b) 4D Fluxonomy: Provided the multidimensional sustainability model (Deheinzelin; Cardoso; Bittencourt, 2020).

The operationalization of this theoretical framework was guided by five principles and seven premises. The principles determined that the approach should be holistic, sequential, flexible, iterative, co-creative, and centered on the user and the local context, aligning with C4D. From this perspective, communication moves beyond the imperative of marketing and becomes a participatory social- y process that aims at change and empowerment, transforming communities from mere recipients into protagonists of their own development (Carniello *et al.*, 2016; Carniello; dos Santos; Máximo Pimenta, 2023). On this basis, seven premises are upheld that guide design toward product enhancement, sustainability, legal compliance, producer-consumer connection, preservation, innovation harmonized with tradition, and territorial engagement, the latter understood as a communication process carried out with and by the community to strengthen endogenous development (Santana *et al.*, 2023). This organization resulted in a non-linear and interconnected framework (Figure 2).

Figure 2 | Themes integrated by potential product level



Source: Prepared by the authors (2025)

The dimensions of analysis were organized into three levels of product value aggregation (Karatajaya, 2021; Kotler; Keller, 2019):

- Basic level: Fundamental requirements (Safety, Logistics, Sustainability, Costs, Design, Attractiveness, KCP Complex, and Regulatory Compliance).
- Expected level: Connection with context (Innovation and tradition, *Stakeholder* engagement, and Technological innovation).
- Enhanced level: Experience and social impact (Customer experience, Community engagement, Education, and Value proposition validation).

Encompassing this structure, the framework incorporated a sustainability model that evaluates projects from the perspective of four economies: financial (feasibility), environmental (circularity), shared (co-creation), and creative (cultural differentiation). By explicitly integrating these four lenses, the Fractal method encompasses natural, social, and cultural capital, which are relevant elements for sustainable regional development (Deheinzelin; Cardoso; Bittencourt, 2020).

ROADMAP DESIGN

The roadmap design converts the conceptual framework into a practical implementation path. As a strategic tool, it guides the innovation process by establishing a sequential view of the necessary actions (Bolboli; Reiche, 2013; Martins, 2022). Its construction was aligned with project management principles (PMI, 2017, 2018), seeking to incorporate good practices of sustainable optimization in all stages (Martins *et al.*, 2023; Moretto *et al.*, 2018). Thus, while the framework demonstrates the interconnection of the dimensions, the roadmap organizes its application in a systematic way, adapted to the local reality. Table 3 presents the detailed structure of this plan, with the phases of Immersion, Ideation, and Implementation.

Table 3 | Proposed *roadmap*

Phases - Objectives	Suggested tools	Key deliverables	Milestones	Potential challenges
1 Immersion: - Understand the productive context and environment of the enterprises	- Project briefing - Stakeholder map - Checklist 1 - Detailed schedule with defined actions	- On-site visits - Complete stakeholder map - Checklist 1 completed (T ₀) - Briefing and schedule finalized	- Documentation of project assumptions - Validation of briefing and schedule with stakeholders	- Cultural resistance to external collaboration - Difficulties in accessing isolated communities - Limitations on producer availability
2 Ideation: - Develop technical and creative solutions for food packaging, focusing on differentiation, value, and sustainability.	- Field study - Conceptual design - Design strategy	- Design strategy developed with initial concepts and graphic proposals	- Validation of the "Design Strategy" with stakeholders	- Tension between innovation and tradition - Limitations of local technical resources - Differences in perception between, designers, and producers
3 Implementation: - Investigate the interaction between packaging and food. - Refine and present graphic and structural design proposals. - Develop and test physical mockups. - Validate pilot batch of packaging with market feedback. - Monitor post-launch and implement continuous improvements.	- Simultaneous engineering (log of changes to mockups and prototypes) - Laboratory tests - Checklist 2 - A/B testing - Opinion surveys - Social media monitoring - Financial performance spreadsheet	- Approval of initial physical samples by suppliers - Experimental test reports on packaging-food interaction - Checklist 1 completed (T ₁) - Checklist 2 completed and prototype approved	- Refinement and approval of the packaging system - Validation of checklist 2 with stakeholders - Finalized prototype and technically completed project	- Associated prototyping costs - Limited access to testing laboratories - Difficulties in analyzing market data on a small scale - Continuity and sustainability of post-project improvements

Source: Prepared by the authors (2025)



CRITICAL ANALYSIS AND IMPLICATIONS FOR REGIONAL DEVELOPMENT

Fractal’s original contribution to the field of regional development becomes clearer when contrasted with conventional and pre-existing packaging design methodologies (Table 4)

Table 4 | Comparative analysis of Fractal versus pre-existing conventional approaches

Dimension of analysis	Conventional methodologies	Fractal method	Implications for regional development
Starting point	Marketing-design briefing focused on market positioning and competition.	Contextual immersion to understand local traditions, practices, and knowledge.	Valuing traditional local knowledge as the foundation of the value proposition, not as an accessory element.
Participation of producers	Advisory and specific, mainly in the validation stages.	Co-creative and continuous, with active involvement in all stages of the process.	Strengthening the autonomy, leadership, and training of local actors, reducing external dependence on the system.
Sustainability approach	Focus on materials and processes (e.g., recyclability), often to meet market demands.	Multidimensional (environmental, social, cultural, economic) and integrated with territorial identity.	Alignment with principles of food sovereignty and agroecology, generating value from endogenous sustainable practices.
Validation of results	Predominantly quantitative, based on sales metrics and technical tests.	Hybrid, combining technical and market analysis with sociocultural adequacy and community strengthening.	Recognition of forms of value (social, cultural) not captured by conventional market indicators.
Process logic	Linear and project-oriented with a defined beginning, middle, and end.	Cyclical and evolutionary, incorporating learning and feedback for continuous improvement and system resilience.	Promotion of the long-term sustainability of innovations, rather than one-off interventions.

Source: Prepared by the authors (2025)

In short, this analysis shows that Fractal shifts the focus from design to a socio-technical communication system for development. The underlying theory is that technical validation can support a narrative of socioeconomic value, configuring a model with significant analytical generalization capacity (Yin, 2018) and theoretically transferable to other contexts.

In the technical-economic sphere, the approach reconfigures the logic of value aggregation. Dimensions such as “Food safety and integrity” and “Regulatory compliance” have the potential to move beyond functions strictly associated with the current legal framework to underpin a narrative



of quality communicated to the consumer. The expected result is the transition of a product from a commodity logic to one of added value, with the potential for price repositioning and margin expansion. It is projected that, even considering the necessary investments, the Return on Investment (ROI) will be positive, strengthening the financial resilience of family businesses and boosting the local economy.

From a sociocultural perspective, the principles of “Co-creation” and “Engagement with stakeholders” are central. The participatory process aims to generate social and technological capital, promoting technical and managerial autonomy for producers. The creation of intangible assets, such as visual identity systems that reflect the KCP Complex, has the potential to transform a generic product into a distinctive offering, laying the foundations for the construction of “territorial brands” that strengthen regional identity and competitiveness.

In the environmental sphere, the approach seeks systemic alignment with sustainability. The emphasis on reducing post-harvest losses (“Preservation and waste reduction”) and encouraging the use of local inputs contributes to reducing the environmental impact of the production chain, in line with multiple SDGs. However, the materialization of these potentials faces practical challenges and limitations, the nature of which varies according to the regional socioeconomic context.

The Fractal concept was based on its applicability in complex scenarios such as the Legal Amazon, the territory that inspired its architecture. Although its application in LAFS in other regions is theoretically feasible, it will require contextual adaptations to the model. The success of the method therefore depends both on the rigor of the approach and on the flexibility to overcome local barriers and promote effective endogenous regional development.

FINAL CONSIDERATIONS

This work fulfills its central objective by presenting and substantiating the Fractal method, a transdisciplinary theoretical-practical framework for packaging design in LAFS. Its fundamental contribution lies in overcoming the dichotomy between purely technocentric approaches and the contextual demands of territories. By systematically articulating the technical, sociocultural, and environmental dimensions, the method represents an epistemological reorientation for the field, treating packaging not as an isolated artifact, but as a sociotechnical device capable of translating local assets into value and promoting multidimensional sustainability.



The method was designed to test the hypothesis that systematic collaboration between disciplines can generate innovative solutions to the development challenges of LAFS. Among the potential associated benefits are direct contributions to multiple SDGs, such as stimulating the local economy (SDGs 1 and 8), promoting food security and safe food (SDGs 2 and 3), innovation in productive infrastructure (SDG 9), reducing inequalities (SDG 10), encouraging sustainable consumption and production (SDG 12), mitigating climate impacts and conserving ecosystems (SDGs 13 and 15), and strengthening partnerships (SDG 17).

It is recognized that the participatory and transdisciplinary nature of the method itself constitutes its main inherent limitation at this stage: it requires significant engagement and careful adaptation to each context, which challenges the notion of uniform replicability. Additionally, infrastructure limitations in rural areas must be considered, as they can hinder or even prevent prototyping and advanced testing stages. Finally, the sustainability of innovations after the formal end of projects is an additional concern, requiring long-term technical and financial support mechanisms, which are often absent in these contexts.

The proposal of this methodological approach is the starting point for the future empirical stage of the investigation. The future research agenda unfolds in the validation of the method in real productive contexts, testing its applicability and, eventually, refining its tools. One categorical direction lies in exploring the applicability of Fractal at different scales, testing its modular and flexible structure in scenarios with varying levels of complexity. Practical implementation will require the involvement of a wide range of stakeholders—from producers and consumers to researchers, industries, and governments—whose role will be relevant to the success of the interventions.

Moving forward, the main challenge that this work proposes to address is to transform the theoretical potential presented here into concrete applications capable of strengthening regional development.

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