Mix Sustentável

Packaging design in Amazonian local agri-food systems: contributions and limitations for sustainability

Design de embalagens em sistemas agroalimentares locais amazônicos: ganhos e limites para a sustentabilidade

Diseño de envases en sistemas agroalimentarios locales amazónicos: aportes y límites para la sostenibilidad

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Resumo: Embalagens alimentícias constituem ativo estratégico de diferenciação e valoração de produtos dos sistemas agroalimentares locais, mas os métodos de design existentes não incorporam suas especificidades socioprodutivas. Este artigo examina em que medida uma intervenção projetual restrita ao produto atende aos requisitos de sustentabilidade desses sistemas produtivos. As fases de Imersão e Ideação do método Fractal foram aplicadas em dois empreendimentos de agricultura familiar do nordeste do Pará, Amazônia Legal brasileira. A pesquisa, aplicada e exploratório-descritiva, articulou pesquisa-ação e estudo de caso múltiplo, com evidências qualitativas sintetizadas em indicadores de conformidade. Um instrumento de avaliação com 127 critérios distribuídos em 14 dimensões foi aplicado às embalagens em uso e às soluções projetadas. O índice médio de conformidade passou de 11,5% para 60,1% no primeiro caso e de 5,2% para 63,0% no segundo. Os ganhos concentraram-se nas dimensões sob controle do projeto, como atratividade, design e conformidade regulatória. Os resultados indicam que o design de embalagens amplia a conformidade dos casos estudados aos requisitos de sustentabilidade, mas essa contribuição é delimitada pelas condições materiais e institucionais do território. Reconhecer esses limites é o que distingue um design responsável de uma promessa de sustentabilidade que a escala do produto sozinha não pode cumprir.

Palavras-chave: Design para a sustentabilidade; Inovação em embalagens; Agricultura familiar; Desenvolvimento local; Amazônia.

Abstract: *Food packaging is a strategic asset for differentiating and adding value to products in local agri-food systems, but existing design methods do not incorporate their socio-productive characteristics. This article examines the extent to which a design intervention focused solely on the product meets the sustainability requirements of these production systems. The Immersion and Ideation phases of the Fractal method were applied to two family farming enterprises in northeastern Pará, Brazilian Legal Amazon. The applied and exploratory-descriptive study combined action research and a multiple-case study, with qualitative evidence synthesized into compliance indicators. An evaluation tool with 127 criteria distributed across 14 dimensions was applied to packaging currently in use and to designed solutions. The average compliance index rose from 11.5% to 60.1% in the first case and from 5.2% to 63.0% in the second. The improvements were concentrated in dimensions under the project's control, such as attractiveness, design, and regulatory compliance. The results indicate that packaging design enhances the compliance of the cases studied with sustainability require-*

permite o compartilhamento do trabalho com reconhecimento da autoria e publicação inicial nesta revista.

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ments, but this contribution is limited by the material and institutional conditions of the region. Recognizing these limits is what distinguishes responsible design from a promise of sustainability that the product alone cannot fulfill.

Keywords: *Design for sustainability; Packaging innovation; Family farming; Local development; Amazon.*

Resumen: *Los envases alimentarios constituyen un activo estratégico para la diferenciación y la valorización de los productos de los sistemas agroalimentarios locales, pero los métodos de diseño existentes no incorporan sus especificidades socioproductivas. Este artículo examina en qué medida una intervención proyectual restringida al producto atiende a los requisitos de sostenibilidad de estos sistemas productivos. Las fases de Inmersión e Ideación del método Fractal se aplicaron en dos emprendimientos de agricultura familiar del noreste de Pará, Amazonía Legal brasileña. La investigación, aplicada y exploratorio-descriptiva, articuló investigación-acción y estudio de caso múltiple, con evidencias cualitativas sintetizadas en indicadores de conformidad. Un instrumento de evaluación con 127 criterios distribuidos en 14 dimensiones se aplicó a los envases en uso y a las soluciones proyectadas. El índice medio de conformidad pasó del 11,5% al 60,1% en el primer caso y del 5,2% al 63,0% en el segundo. Las mejoras se concentraron en las dimensiones bajo control del proyecto, como atractivo, diseño y conformidad regulatoria. Los resultados indican que el diseño de envases amplía la conformidad de los casos estudiados con los requisitos de sostenibilidad, pero esa contribución está delimitada por las condiciones materiales e institucionales del territorio. Reconocer esos límites es lo que distingue un diseño responsable de una promesa de sostenibilidad que la escala del producto, por sí sola, no puede cumplir.*

Palabras clave: *Diseño para la sostenibilidad; Innovación en envases; Agricultura familiar; Desarrollo local; Amazonía.*

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1 INTRODUCTION

The Brazilian Legal Amazon combines the largest tropical forest on the planet with high sociocultural diversity and with economic models that add little value to biodiversity resources, which limits the benefits captured by local populations (Brondízio *et al.*, 2021; Nobre *et al.*, 2023). In this territory, Local Agri-Food Systems (LAFS) organize production and consumption around geographic, relational, and value proximity between producers and consumers (Kneafsey *et al.*, 2013; Enthoven; Broeck, 2021).

A recurring bottleneck of these systems is translating intangible attributes, such as territorial identity and sustainable practices, into perceived value, a task in which packaging occupies a strategic position (Dörnyei *et al.*, 2023). Reviews at the interface between packaging technology and LAFS, however, found no structured design approach adapted to the socio-productive specificities of these systems (Valente; Ribeiro, 2023; Valente; Ribeiro, 2024). The Fractal method was proposed to address this gap (Valente; Ribeiro, 2025). Because it was formalized only recently, within a doctoral research project described by Valente (2025), no applications by other research groups were available at the time of this study, and its validation in real production contexts was indicated as the next step of its research agenda (Valente; Ribeiro, 2025).

This study applies the Immersion and Ideation phases of the method to develop packaging for products of two family farming enterprises in northeastern Pará, evaluates the projected compliance of the solutions against the packaging in use, and characterizes what this application reveals about the scope and limits of design for sustainability in these contexts. The guiding question was: how can a structured design method generate more competitive and sustainable packaging that balances technical-functional requirements, local production capacities, and perceived value in Amazonian LAFS, and which dimensions of this balance remain beyond the reach of the project?

The theoretical contribution does not lie in asserting that design interventions meet systemic limits, a proposition already established by the framework of innovation levels in design for sustainability (Ceschin; Gaziulusoy, 2016), but in demonstrating them empirically: the data show where the ceiling of a product-level intervention lies in an Amazonian LAFS with limited infrastructure and which compliance dimensions make up that ceiling. This delineation is also relevant to the 2030 Agenda, particularly to SDGs 2, 8, 12, and 15.

2 THEORETICAL FOUNDATIONS

2.1 Local agri-food systems and packaging in the Amazon

LAFS are production and service arrangements whose characteristics are linked to a specific territory and organized in short supply chains, in which producers often take on processing and direct sales (Grisa *et al.*, 2022; Kneafsey *et al.*, 2013). Their competitive differentiation rests on attributes of origin, artisanal processes, and territorial identity that are not perceptible in the product itself and must be actively communicated to

become market preference (Kneafsey *et al.*, 2013). In Brazil, the enterprises to which these dynamics apply are defined by the legal framework for family farming, Law No. 11,326/2006 (BRASIL, 2006).

In the Amazon, LAFS that generate value from non-timber forest products and native crops create market incentives for practices that sustain the biome, so that the valorization of local products becomes a conservation strategy (Brondízio *et al.*, 2021; Nobre *et al.*, 2023). This imposes on packaging a demand beyond conventional differentiation: to communicate the systemic value of the production chain that each product represents (Mendes; Pedersen, 2021). Packaging is the main interface between product and consumer at the point of sale and must simultaneously address food safety, regulatory compliance, logistics, sustainability, and the communication of identity (Dörnyei *et al.*, 2023), an integration of domains that rarely coexists in small enterprises (Valente; Ribeiro, 2023).

Three tensions follow: technical validation against economic viability at small scale (Valente; Ribeiro, 2024); material substitution against systemic redesign, with the risk of shifting impacts between life cycle stages (Mendes; Pedersen, 2021); and regulations designed for industrial scale against the compliance capacity of family farmers (Dörnyei *et al.*, 2023).

2.2 Packaging design for sustainability and the communication of sustainability attributes

Life-cycle-oriented design established that the environmental assessment of an artifact must consider all its stages, because isolated material substitutions tend to shift impacts rather than reduce them (Vezzoli and Manzini, 2008). Ceschin and Gaziulusoy (2016) organize design-for-sustainability approaches into four levels of innovation, namely product, product-service system, spatio-social, and socio-technical system, and show that the field moved from the artifact to system-scale interventions.

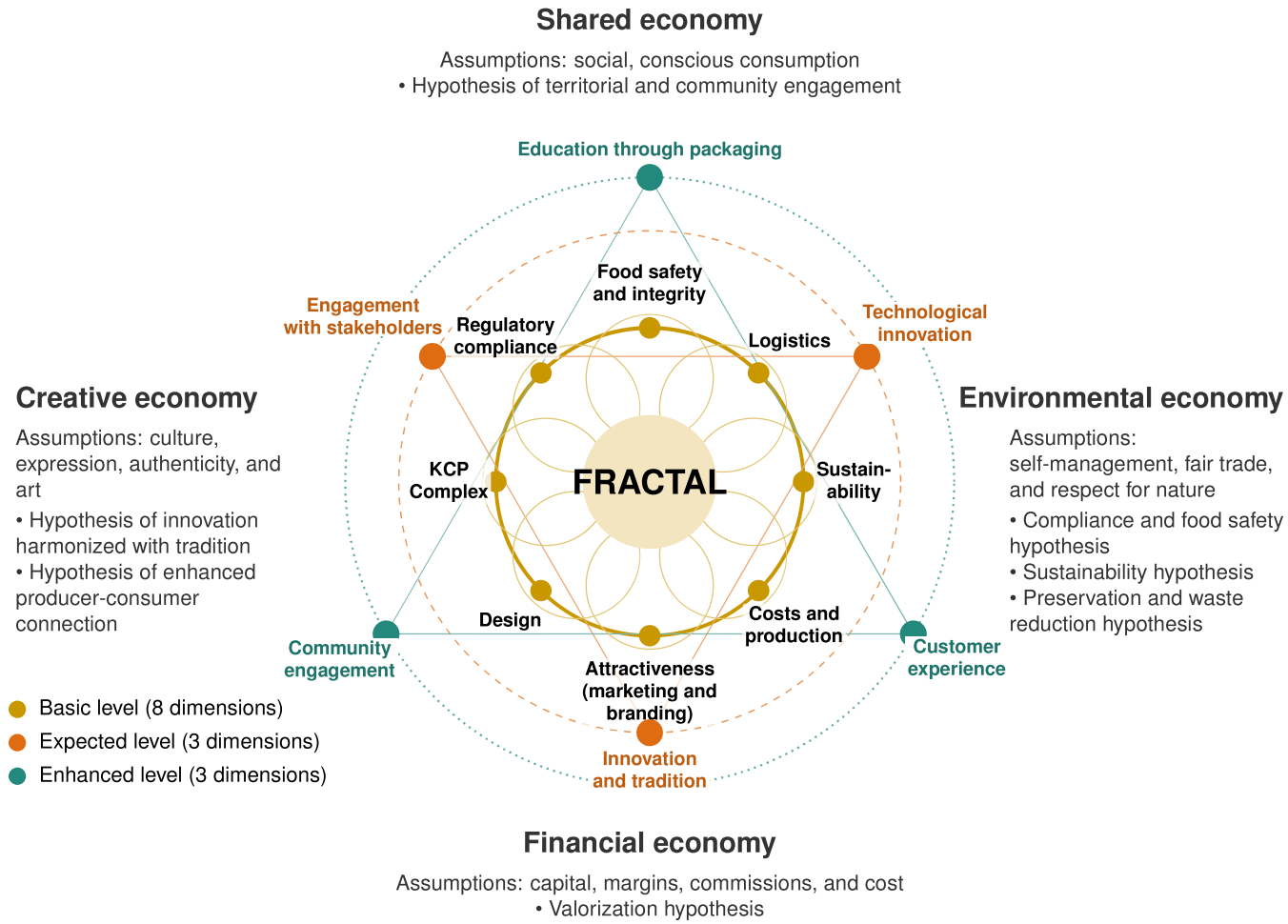
For food packaging, Dörnyei *et al.* (2023) synthesize eleven challenges, among them that protecting the food is the priority, that food and packaging form an inseparable unit, that not every packaging innovation is sustainable, and that the local context is fundamental to packaging sustainability. Mendes and Pedersen (2021) add four design parameters: improved barrier properties, design for recyclability, second-generation bio-based materials, and minimization of harmful chemicals. In agri-food systems, circular economy models require measurement through economic, environmental, social, and transversal indicators (Silvestri *et al.*, 2022). Methods and tools translate these principles into practice: a strategic design method based on the life cycle of the packaged product (Huerta *et al.*, 2022), life cycle approaches from design to end of life (Auras and Selke, 2022), food packaging design for sustainable development applied to paper and cardboard (Delfino, 2013), technological considerations for designers (Turan; Keukens; Schifferstein, 2024), design-for-sustainability tools integrating economic, environmental, and social dimensions (Santos *et al.*, 2024), and recommendations for sustainable packaging projects (Sastre and Cesar, 2024). These contributions offer criteria, sequences, and tools, but none was structured for the conditions that define LAFS: small scale, limited access to suppliers and testing laboratories, and the centrality of territorial identity in the value proposition (Valente; Ribeiro, 2023; Valente; Ribeiro, 2024; Valente; Ribeiro, 2025).

A related body of research examines how sustainability attributes are presented on packaging. Consumers infer packaging sustainability mainly from visible cues such as material and graphics, and these inferences diverge from life cycle assessments (Steenis *et al.*, 2017); verbal claims are more persuasive when the package looks ecological (Magnier; Schoormans, 2015); and environmental claims are more credible on fibre-based packaging (Magnier; Schoormans, 2017). Suppliers, in turn, often fail to communicate the environmental attributes their packaging actually has (Dörnyei *et al.*, 2022), and consumer response to environmentally friendly food packaging remains insufficiently understood (Ketelsen; Janssen; Hamm, 2020). This evidence comes mostly from consumers in Europe and the United States, and the cues consumers use to recognize such packaging are culturally acquired (Herbes; Beuthner; Ramme, 2020). Its transfer to Amazonian LAFS cannot be assumed, since in these systems the direct relation between producer and consumer is itself a channel of information about origin and practices (Kneafsey *et al.*, 2013; Enthoven; Broeck, 2021). What the literature establishes for any context is the risk: packaging can raise perceived sustainability independently of actual performance, the condition that Delmas and Burbano (2011) associate with greenwashing.

2.3 The Fractal method

The Fractal method structures five domains of knowledge in two planes (Valente; Ribeiro, 2025). Design thinking, packaging design, and project management form the execution pillars. Ethnoecology, operationalized by the Kosmos-Corpus-Praxis (KCP) complex, and 4D Fluxonomy form the immersion perspectives (Toledo; Barrera-bassols, 2009; Deheinzelin; Cardoso; Bittencourt, 2020). The KCP complex treats the beliefs (Kosmos), traditional knowledge (Corpus), and productive practices (Praxis) of communities as design variables equivalent to the material attributes of the packaging; 4D Fluxonomy evaluates solutions through financial, environmental, shared, and creative economies. The territory is thus a structuring variable of design decisions, not a context of application (Figure 1).

Figure 1 – Framework of the Fractal method



Source: adapted from Valente and Ribeiro (2025).

Figure 1 is read from the center outward. The eight dimensions of the inner ring form the basic level of the product, the requirements any packaging must meet; the intermediate triangle forms the expected level, which connects the packaging to its context; and the outer triangle forms the enhanced level, related to experience and social impact. The four economies frame the set and carry the premises of the method, and the bottom bar lists its five principles. The method is operated by a three-phase roadmap (Immersion, Ideation, Implementation) and three tools: a main checklist with 127 criteria in 14 dimensions, a complementary checklist with 10 criteria on the value proposition, a fifteenth dimension assessed only in Implementation, and a briefing form covering 15 themes (Valente; Ribeiro, 2025). The only empirical applications to date are the one reported here and the Implementation phase subsequently carried out for one of the products studied, described by Valente (2025); comparison with applications by other researchers is therefore not yet possible.

3 METHODOLOGICAL PROCEDURES

3.1 Research design and choice of the method

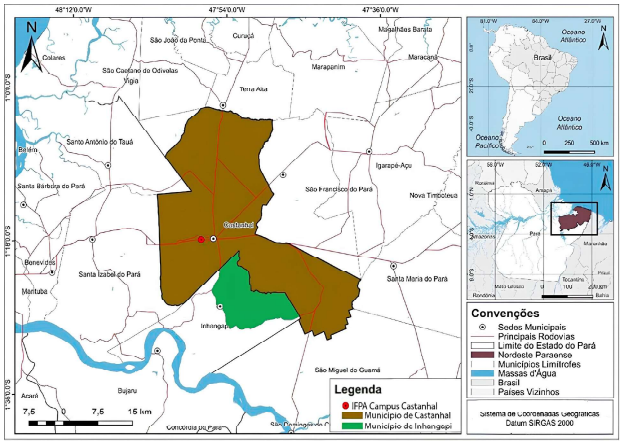
This is applied research, exploratory-descriptive and qualitative, with descriptive quantification of compliance indices. It combined action research, interventionist and collaborative (Cornish *et al.*, 2023), with a multiple-case study whose cases were selected by theoretical sampling, prioritizing informational richness over statistical representativeness (Yin, 2018).

The Fractal method was chosen for three reasons. The reviews that preceded it found no other packaging design method structured for the socio-productive conditions of LAFS (Valente; Ribeiro, 2023; Valente; Ribeiro, 2024); the research question requires treating territorial knowledge and the multiple dimensions of sustainability as design variables, which the method does through the KCP complex and 4D Fluxonomy; and its instrument allows the packaging in use and the designed solutions to be assessed against the same criteria. Since the criteria were formulated by the proponents of the method and scored by the research team, this first application is also a test of the method and carries a risk of evaluator bias, addressed in Sections 3.5 and 5.1.

3.2 Territory and cases

The research was conducted in the Guamá Integration Region, northeastern Pará, with two enterprises located in Castanhal and Inhangapi (Figure 2). The cases met four criteria: willingness to take part in collaborative action research; integration into short supply chains with territorial identity; a product portfolio allowing the method to be tested across food categories; and classification as family farming under Law No. 11,326/2006 (BRASIL, 2006).

Figure 2 – Location of the municipalities of Castanhal and Inhangapi, northeastern Pará, Brazil



Source: research data, adapted from Trindade *et al.* (2024).

Sementes da Amazônia (Case A), about 70 km from Belém, works in the non-timber forest products chain with Brazil nuts. Its operation was limited to manual collection of nut pods, storage, weighing, and packing, without sorting, shelling, sanitization, or drying; it sold only in the local market, without formal registration or trademark. Rancho Akueran (Case B), about 90 km from Belém in the Arraial dos Remédios community, Inhangapi, operates on about ten hectares combining food crops, regional fruits, and artisanal processing; affiliated with a cooperative, it sells at local fairs and directly in Inhangapi and Castanhal, and already had a brand without a structured visual identity. The contrast between the cases allowed the method to be observed under different initial conditions.

3.3 Fieldwork and data collection

The technical visits took place between March 2024 and July 2025 and covered the Immersion and Ideation phases. Five products were addressed: shelled Brazil nuts (Case A) and artisanal cassava cakes in three versions and vacuum-packed cassava pulp (Case B). The Implementation phase could not be carried out for this set of products because of financial constraints and personal circumstances of the producers; it was later carried out for a single product, as reported in Section 5.3 and detailed by Valente (2025). Table 1 summarizes the procedures.

Table 1 – Data collection procedures

Procedure (phase)	**Where and when**	**Participants**	**Data collected**	**Record**
Technical visits, three per enterprise (Immersion)	Production units in Castanhal and Inhangapi, March 2024 to July 2025	Researchers, owners, family members in production	Production processes, infrastructure, food handling, packaging practices; packaging in use	Field diary by four observation dimensions; photographs
Semi-structured interviews (Immersion)	Production units	Owners of each enterprise	15 open questions: history and context; products and processes; marketing and sales; packaging needs	Written notes (not audio-recorded)
Stakeholder mapping (Immersion)	In loco, in co-creation with the producers	Researchers and producers	Actors at three levels: direct, intermediate, tertiary	Stakeholder map
Market field study (Ideation)	Fairs and markets of the surrounding LAFS	Researchers	Competing packaging and communication practices	Photographs; benchmarking notes
Co-creation sessions (Ideation)	In-person sessions	Researchers, owners, family members	Choices among brand and packaging alternatives; validation of the briefing	Session notes; briefing; digital mockups
Diagnosis T0 (Immersion) and evaluation T1 (Ideation)	Packaging in use (T0); digital mockups (T1)	Authors	Scores of the 127 criteria	Checklist 1

Source: research data.

Participant observation captured tacit routines not verbalized in the interviews. The stakeholder maps

were built in loco with the producers at three levels: direct (researchers, producers, family members), intermediate (suppliers, distributors, consumers), and tertiary (regulators, service providers). In Ideation, co-creation sessions were supported by semantic panels built from the chromatic, formal, and cultural repertoire identified in Immersion.

3.4 Data analysis

Interview notes and the field diary were analyzed thematically with predefined categories aligned with the dimensions of the method. The results were consolidated in the project briefing, organized by the fifteen themes of the method and validated with the producers before Ideation. The qualitative record was compared with the T0 scores, and the diagnosis was consistent with the evidence from interviews and observations (Valente, 2025). The comparison between T0 and T1 was descriptive, using the indices defined below.

3.5 Diagnostic and evaluation instrument

Diagnosis and evaluation used Checklist 1 of the method, whose 127 criteria were derived from a systematic inventory of parameters in the specialized literature (Valente; Ribeiro, 2025). Table 2 shows their distribution by level and dimension; the full list is provided as Supplementary Material S1.

Each criterion was scored 3 (full compliance), 1.5 (partial), or 0 (non-compliance), with "not applicable" allowed for criteria incompatible with the product. The index of dimension d is

$$I_d = \frac{\sum_{i \in A_d} s_i}{3\,|A_d|} \times 100, \qquad s_i \in \{0;\ 1.5;\ 3\} \tag{1}$$

where A_d is the set of criteria of d applicable to the product. The mean index of a packaging is the arithmetic mean of its 14 dimension indices. The instrument was applied by the authors to the packaging in use (T0) and to the designs (T1). The roadmap foresees re-application only in Implementation, on prototypes; here it was brought forward to the end of Ideation, so T1 values are "projected compliance", based on digital mockups without prototyping, external evaluators, or market verification. Because the number of criteria varies from 3 to 26 per dimension, the smallest non-zero increment varies from 16.7 to 1.9 percentage points, which is considered in the interpretation.

Table 2 – Structure of Checklist 1: levels, dimensions, and number of criteria

Level	Dimension	n	Content of the criteria
Basic	Food safety and integrity	26	Protection against external agents and mechanical damage, sealing, shelf life, hygiene, traceability, tamper evidence
	Logistics	15	Distribution system, use of space, resilient materials, transport labeling, reverse logistics, drop and transport tests
	Sustainability	12	Low-footprint, recycled, and biodegradable materials; refill and reuse; disposal information; circularity; material reduction; certifications
	Costs and production	4	Local partnerships, cost and price analysis, risks, return on investment
	Design	8	Functionality, closure, protection, size and format, visibility of contents, labeling process, visual appeal and accessibility
	Attractiveness (marketing and branding)	14	Visual identity, representation of contents, local seals and narratives, information hierarchy, interactive technologies, brand values
	KCP complex	8	Local beliefs and traditions, traditional knowledge and practices, valorization of producers, endemic materials, authenticity
	Regulatory compliance	9	Records and licenses, safe and authorized materials, mandatory labeling, prohibitions, identity and quality standards, claims
Expected	Innovation and tradition	5	Feasibility of new technologies, community receptiveness, exchange of knowledge, joint validation
	Engagement with stakeholders	6	Stakeholder mapping, communication channels, supplier selection, partnerships
	Technological innovation	8	Viable active and smart packaging, simple indicators, partnerships, local availability of advanced materials
Enhanced	Customer experience	4	QR codes, digital platforms, incentives for feedback, special editions
	Community engagement	3	Community platforms, educational partnerships, local leaders
	Education through packaging	5	Producer stories, direct purchase and origin, training, responsible choices, testimonials
	Total	**127**	

Source: adapted from Valente and Ribeiro (2025).

4 RESULTS

4.1 Initial packaging

In Case A, Brazil nuts were sold in jute bags intended for bulk transport, without labeling, origin, nutritional information, or communication with the consumer. In Case B, empirical solutions coexisted, from plastic bags and reused containers to products sold without packaging, which compromised presentation, mandatory information, food safety, and legal compliance (Figure 3).

Figure 3 – Packaging in use at the time of the assessment. Case A: (a) jute bags for raw Brazil nuts. Case B: (a) plastic bag for selling beans; (b) reused container for storing beans; (c) cassava cake without specific packaging; (d) processed cassava in a plastic container



Source: research data.

The owners wanted solutions that protected the products, communicated their artisanal and territorial origin, and met legal requirements, while expressing concern about costs, a constraint that guided the design decisions. The market field study found that competitors generally met food safety rules but seldom communicated territorial identity or local traditions, and that local-origin seals were absent (Valente, 2025).

4.2 Design solutions

Visual identity systems were not foreseen in the roadmap, but Immersion showed they were critical in both cases, so their inclusion is a documented methodological adaptation (Figure 4). For Case A, the concept took the Brazil nut tree as its reference, an element that articulates ecological value, productive base, and cultural meaning in the territory (Valente, 2025). Of two proposals, the producers chose a circular icon evoking the tree and its seeds, with warm tones referring to the leaves, soil, and light of the forest and the tagline *Produtos da Floresta* (forest products). Case B required a redesign: the existing identity drew on Afro-Brazilian religious references of the producers, associated with abundance, hunting, and connection with nature (Valente, 2025), and co-creation chose to preserve this core rather than adopt generic "natural food" language. The selected symbol is a circle alluding to the sun, the production cycle, and the movement of an archer, in deep

greens, with the tagline *Alimentos da Terra* (food from the earth).

Figure 4 – Visual identity systems developed. Left, Case A: (a) logo; (b) palette; (c) symbol on textured background; (d) tonal applications. Right, Case B: (a) logo; (b) symbol on textured background; (c) tonal applications



Source: research data.

In Case A, the primary packaging is a 100-g stand-up pouch with zip-lock closure and a transparent window, in a flexible multilayer plastic structure with barriers against moisture, oxygen, and light. A QR code directs consumers to digital content that reinforces the narrative and value proposition of the product (Valente, 2025). The labeling includes the mandatory information and allergen warnings, guided by MAPA Ordinance No. 846/1976 and Normative Instruction No. 11/2010 (BRASIL, 1976; BRASIL, 2010); nutritional values are illustrative pending laboratory analysis. Secondary packaging in recyclable cardboard with heat-shrink film enables sale in portions instead of bulk (Figure 5); strength and drop tests were left to Implementation.

Figure 5 – Packaging designed for Case A: (a) primary packaging, 100-g stand-up pouch; (b) secondary packaging for logistics



Source: research data.

In Case B, the cakes are baked directly in aluminum containers with paper lids, in standardized portions, which eliminates portioning and reduces losses; aluminum was chosen for recyclability, heat resistance, impermeability to fats, organoleptic neutrality, and thermal conductivity. A kraft paper seal strip (>100 g/m^2), chosen for local availability, cost, and simplicity, ensures tamper evidence and organizes the information. The system was extended to caramelized and cupuaçu versions and complemented by kraft carrying bags. During Ideation, an unmet local demand for cassava pulp led to a vacuum-sealed multilayer nylon bag, validated by

the producers and requiring only a sealing machine, guided by ADEPARÁ Ordinance No. 8071/2022 (PARÁ, 2022) (Figure 6).

Figure 6 – Packaging designed for Case B: (a) cassava cake in aluminum tray with seal strip; (b) line extension; (c) and (d) cassava pulp, front and back



(a) **(b)** **(c)** **(d)**

Source: research data.

In both cases the KCP complex was only partially addressed: cultural graphic elements were integrated, but the systematic incorporation of knowledge, beliefs, and practices remained incomplete.

4.3 Projected compliance and asymmetry of gains

Table 3 and Figure 7 compare T0 and T1. Mean projected compliance rose from 11.5% to 60.1% in Case A and from 5.2% to 63.0% in Case B; the cassava pulp, previously sold without packaging, reached 65.4%. The more relevant finding is the unequal distribution of gains. Attractiveness, design, regulatory compliance, and food safety, which depend on design decisions, gained more than sixty percentage points in at least one case. Sustainability (13.6% and 36.4%) and community engagement (16.7% in both cases), which depend on external conditions, remained low, and innovation and tradition and the KCP complex stayed between 20.0% and 50.0%.

The resolution of each dimension conditions these readings. In community engagement, with three criteria, 16.7% corresponds to partial fulfillment of one criterion, the first non-zero value the scale allows; in innovation and tradition, with five criteria, 20.0% is the second possible level. These values indicate thresholds rather than continuous measures. The asymmetry repeats in both cases, with radar profiles of similar shape, and matches the nature of the criteria: design, attractiveness, and labeling depend on decisions about the artifact, whereas sustainability requires certified materials, accessible suppliers, reverse logistics, and recycling infrastructure, and community engagement depends on networks formed through continued interaction rather than on the delivery of an artifact (Manzini, 2015).

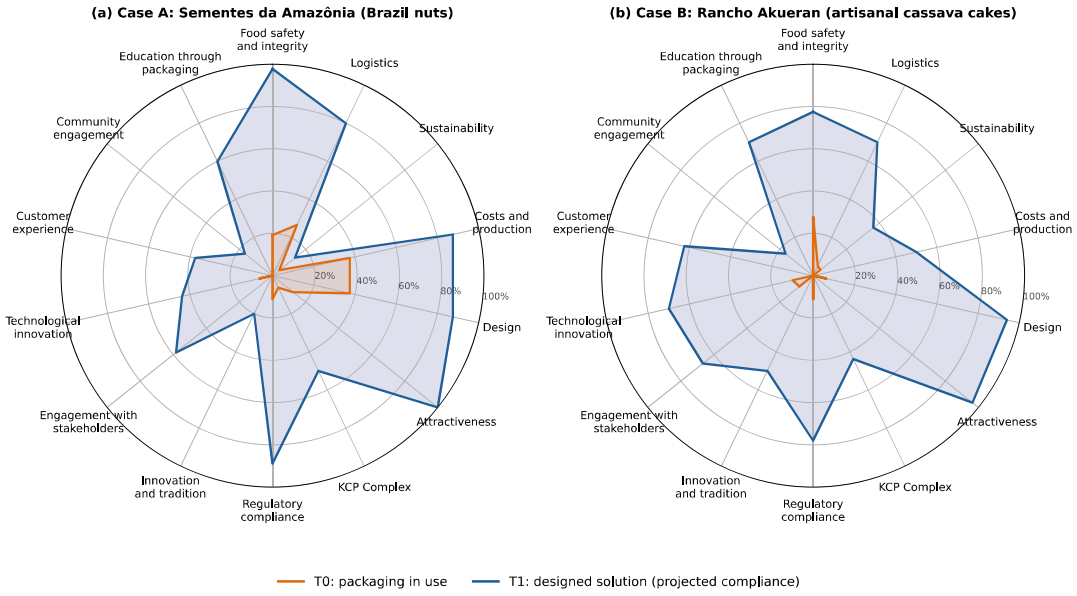
Table 3 – Thematic compliance indices of the packaging in use (T0) and of the designed solutions (T1)

#	Dimension	Case A: Brazil nuts T0	Case A: Brazil nuts T1	Case B: cakes T0	Case B: cakes T1	Case B: pulp T1*
1	Food safety and integrity	19.2	97.8	27.5	77.5	94.7
2	Logistics	26.7	80.0	5.0	70.0	80.0
3	Sustainability	4.2	13.6	4.5	36.4	27.3
4	Costs and production	37.5	87.5	0.0	50.0	62.5
5	Design	37.5	87.5	6.3	94.0	100.0
6	Attractiveness	12.5	100.0	0.0	96.4	96.0
7	KCP complex	6.3	50.0	0.0	43.8	50.0
8	Regulatory compliance	11.1	88.9	11.1	78.0	88.9
9	Innovation and tradition	0.0	20.0	0.0	50.0	50.0
10	Engagement with stakeholders	0.0	58.3	8.3	66.7	66.7
11	Technological innovation	6.3	43.8	10.0	70.0	50.0
12	Customer experience	0.0	37.5	0.0	62.5	62.5
13	Community engagement	0.0	16.7	0.0	16.7	16.7
14	Education through packaging	0.0	60.0	0.0	70.0	70.0
	Mean compliance index	**11.5**	**60.1**	**5.2**	**63.0**	**65.4**

Values in percent. *New product, previously sold without packaging.

Source: research data.

Figure 7 – Compliance profiles by thematic dimension: (a) Case A; (b) Case B



Source: research data.

5 DISCUSSION

5.1 The ceiling of a product-level intervention

The method was applied at the product level, and the results quantify the ceiling of that level (Ceschin; Gaziulusoy, 2016): dimensions under the control of the design process advanced by more than sixty percentage points in at least one case, while those that depend on the surrounding socio-technical system remained low, with sustainability below 40%. The contribution lies in demonstrating this distinction empirically in Amazonian LAFS, in line with the critique of reducing packaging sustainability to the choice of materials (Vezzoli; Manzini, 2008; Mendes; Pedersen, 2021).

The asymmetry might be an artifact of the instrument, since the criteria were formulated by the proponents of the method and scored by the research team. Two findings reduce this possibility. First, it persists within the same level: attractiveness, design, regulatory compliance, and sustainability are all basic-level dimensions, yet only the last remained below 40%. Second, the reasons for low sustainability were documented independently of the scores, in interviews and visits: minimum purchase volumes incompatible with the scale of the enterprises and the absence of regional reverse logistics. The low sustainability compliance therefore did not result from a design omission but from the regional unavailability of alternatives, a local expression of the tensions between new materials and impact shifting (Mendes; Pedersen, 2021) and of the barriers that industrial-scale markets and rules impose on small producers (Grisa *et al.*, 2022).

5.2 Communicating sustainability in LAFS without overstating it

The contrast between attractiveness, near full compliance, and sustainability, which remained low, shows that the capacity to communicate value may outgrow the capacity to incorporate it materially. In Case B, the kraft carrying bags were chosen as recyclable and biodegradable materials and the dark green palette was associated with sustainability (Valente, 2025), while compliance with the sustainability criteria remained at 36.4%. In both cases, the solutions depend on conventional materials, multilayer plastics and aluminum, whose life cycles and effective recyclability in the Amazon are complex, and on limited access to sustainable alternatives that are economically viable for small producers (Valente, 2025). Given that consumers infer sustainability from material and graphic cues (Steenis *et al.*, 2017; Magnier; Schoormans, 2015; Magnier; Schoormans, 2017), this combination falls within the risk zone that Delmas and Burbano (2011) associate with greenwashing.

The LAFS context changes the terms of this risk. Because cue recognition is culturally acquired (Herbes; Beuthner; Ramme, 2020) and most consumer evidence comes from other markets (Ketelsen; Janssen; Hamm, 2020), the effect of these cues on local buyers cannot be presumed; at the same time, the direct relation between producer and consumer that defines LAFS can either reinforce trust in the package or expose

the gap between discourse and practice (Kneafsey *et al.*, 2013; Enthoven; Broeck, 2021). Packaging messages in LAFS must therefore be grounded in what the material dimension supports. The Implementation phase offers an example: when laboratory analysis showed added sugar above the regulatory threshold, the mandatory front-of-pack warning was incorporated and the communication was rebuilt around verified attributes, such as fiber content, low sodium, and the absence of gluten (Valente, 2025; BRASIL, 2020).

5.3 Evidence from the subsequent Implementation phase

The Implementation phase was carried out for the artisanal cassava cake of Case B, as detailed by Valente (2025). Physico-chemical and microbiological analyses in an accredited laboratory showed compliance with the microbiological standards of Normative Instruction No. 161/2022 (BRASIL, 2022), as well as 48% moisture and 23 g/100 g of lipids, which require barriers against water vapor, oxygen, and light and support the aluminum tray chosen in Ideation. A physical prototype of the primary, secondary, and tertiary system was refined with the producer. Commercial shelf life was kept at up to five days under refrigeration below 5 °C, following technical guidelines for perishable bakery products; validating an extended shelf life remains a recommendation.

Costs and local reference prices were surveyed in loco in March 2025. The unit cost rose from R$ 4.55 to R$ 5.87, of which R$ 1.32 (22.5%) is packaging, and the price practiced rose from R$ 10.00 to R$ 15.00 (+50%); the gross margin went from 54.5% to 60.9%. For a projected 2,600 units per year, the additional packaging investment is R$ 3,432.00 (2,600 × R$ 1.32) and the additional gross profit is R$ 9,568.00 (2,600 × R$ 5.00 − R$ 3,432.00), a return on investment of 279% (9,568 ÷ 3,432 = 2.79) (Valente, 2025). The study also reports environmental gains, such as fewer losses through baking in the package and the recyclability of aluminum. Because Checklist 1 was not re-applied to the prototype, these gains could not be expressed in the sustainability index, and the dependence on regional recovery infrastructure discussed in Section 5.1 remains. These results concern one product, without packaging-food interaction or shelf-life tests, but indicate that dimensions with high projected compliance can be converted into verifiable attributes and economic value.

5.4 Analytical positioning and improvements to the method

Without other applications of the method, the results can be positioned against the sustainable packaging literature. The cases met the parameters of Mendes and Pedersen (2021) and the challenges of Dörnyei *et al.* (2023) where these depend on the artifact, such as barrier properties and the protection of the food, and failed where they depend on the territory, such as recyclability in practice, access to bio-based materials, and local recovery systems. This confirms, for LAFS, that the local context is decisive for packaging sustainability (Dörnyei *et al.*, 2023) and suggests that life cycle tools (Huerta *et al.*, 2022; Auras; Selke, 2022) need to be combined with an assessment of the regional availability of materials and recovery routes. For the method,

the results suggest unifying the diagnostic instruments, adopting a more granular scale, refining the criteria to reduce overlaps, and, above all, including evaluators from outside the project team.

5.5 Limitations

T1 was scored on digital mockups by the research team, without independent evaluators, so the indices reflect projected compliance. The restriction to Immersion and Ideation precludes conclusions on final effectiveness, and the Implementation phase covered one product without re-applying the instrument. The interviews were recorded as written notes, not audio recordings, which may have produced a more selective record. The two cases share one territory, and the results are a contextual proof of concept, generalizable only analytically (Yin, 2018). These limitations do not invalidate the central finding, which rests on the contrast between dimensions rather than on the magnitude of each index.

6 FINAL CONSIDERATIONS

This study applied the Immersion and Ideation phases of the Fractal method to two family farming enterprises in the Brazilian Legal Amazon, taking a framework previously described only in theoretical terms to a real production context. Its central finding is the resistance of the sustainability and community engagement dimensions to the design intervention: packaging design in LAFS operates within limits set by the material and institutional conditions of the territory. For territorial policies, it indicates that design interventions require complementary actions on infrastructure, supply, and community networks, with implications for SDGs 2, 8, 12, and 15. It also shows that the more effectively a package communicates sustainability, the more its claims must rest on what its materials and their regional recovery routes deliver. The research agenda includes completing Implementation for the other products, with external evaluators, and the application of the method by independent teams and in other territories, to test whether the asymmetry identified here is common to LAFS with limited infrastructure.

DATA AVAILABILITY

The data supporting the results of this study are available upon request to the corresponding author, because they include individual data of the participating entrepreneurs, whose confidentiality must be preserved. The diagnostic instrument (Checklist 1, 127 criteria) is provided as Supplementary Material S1. The enterprises consented to being identified by name in the text.

USE OF ARTIFICIAL INTELLIGENCE

The authors used the generative artificial intelligence tool Claude exclusively to assist with text editing, checking for clarity, cohesion, and spelling, and the DeepL tool to assist with translation. No AI tools were used in the research design, data collection or analysis, formulation of results, or drawing of conclusions. The authors have thoroughly reviewed the content produced with the assistance of these tools and assume full responsibility for the accuracy, scientific integrity, and interpretations presented in the final text.

REFERENCES

Auras, R. A.; Selke, S. E. M. **Life cycle of sustainable packaging**: from design to end-of-life. Hoboken: Wiley, 2022.

BRASIL. **Portaria nº 846, de 8 de novembro de 1976**. 1976. Ministério da Agricultura, Pecuária e Abastecimento. Brasília, DF: MAPA. Available at: <https://sistemasweb.agricultura.gov.br/sislegis/action/detalhaAto.do?method=visualizarAtoPortalMapa&chave=773319590>.

BRASIL. **Lei nº 11.326, de 24 de julho de 2006**. 2006. Diário Oficial da União: section 1, Brasília, DF, p. 2, 25 Jul. 2006. Available at: <http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2006/lei/l11326.htm>.

BRASIL. **Instrução Normativa nº 11, de 22 de março de 2010**. 2010. Ministério da Agricultura, Pecuária e Abastecimento. Brasília, DF: MAPA. Available at: <https://www.legisweb.com.br/legislacao/?id=78480>.

BRASIL. **Instrução Normativa nº 75, de 8 de outubro de 2020**. 2020. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Diário Oficial da União: section 1, Brasília, DF, 9 Oct. 2020. Available at: <https://www.in.gov.br/en/web/dou/-/instrucao-normativa-n-75-de-8-de-outubro-de-2020-282070610>.

BRASIL. **Instrução Normativa nº 161, de 1º de julho de 2022**. 2022. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Diário Oficial da União: section 1, Brasília, DF, 6 Jul. 2022. Available at: <https://www.in.gov.br/en/web/dou/-/instrucao-normativa-in-n-161-de-1-de-julho-de-2022-413366880>.

Brondízio, E. S. *et al.* Making place-based sustainability initiatives visible in the brazilian amazon. **Current Opinion in Environmental Sustainability**, v. 49, p. 66–78, 2021. Available at: <https://linkinghub.elsevier.com/retrieve/pii/S1877343521000464>.

Ceschin, F.; Gaziulusoy, I. Evolution of design for sustainability: from product design to design for system innovations and transitions. **Design Studies**, v. 47, p. 118–163, 2016. DOI: <https://doi.org/10.1016/j.destud.2016.09.002>.

Cornish, F. *et al.* Participatory action research. **Nature Reviews Methods Primers**, v. 3, n. 1, p. 34, 2023. DOI: <https://doi.org/10.1038/s43586-023-00214-1>.

Deheinzelin, L.; Cardoso, D.; Bittencourt, P. **Novas economias viabilizando futuros desejáveis**: introdução à fluxonomia 4d. São Paulo: Kindle Editions, 2020.

Delfino, R. A. **Design de embalagens de bens alimentares para o desenvolvimento sustentável**: aplicação ao caso das embalagens de papel e cartão. 2013. Doctoral Thesis (Design), Universidade de Lisboa, Lisbon. Available at: <https://www.repository.utl.pt/handle/10400.5/11747>.

Delmas, M. A.; Burbano, V. C. The drivers of greenwashing. **California Management Review**, v. 54, n. 1, p. 64–87, 2011. DOI: <https://doi.org/10.1525/cmr.2011.54.1.64>.

Dörnyei, K. R. *et al.* (not) communicating the environmental friendliness of food packaging to consumers: an attribute- and cue-based concept and its application. **Foods**, v. 11, n. 9, p. 1371, 2022.

Dörnyei, K. R. *et al.* Sustainable food packaging: an updated definition following a holistic approach. **Frontiers in Sustainable Food Systems**, v. 7, p. 1119052, 2023. DOI: <https://doi.org/10.3389/fsufs.2023.1119052>.

Enthoven, L.; Broeck, G. Van den. Local food systems: reviewing two decades of research. **Agricultural Systems**, v. 193, p. 103226, 2021. DOI: <https://doi.org/10.1016/j.agsy.2021.103226>.

Grisa, C. *et al.* **Sistemas alimentares e territórios no Brasil**. Porto Alegre: Editora da UFRGS, 2022. Available at: <https://lume.ufrgs.br/handle/10183/247725>.

Herbes, C.; Beuthner, C.; Ramme, I. How green is your packaging: a comparative international study of cues consumers use to recognize environmentally friendly packaging. **International Journal of Consumer Studies**, v. 44, n. 3, p. 258–271, 2020.

Huerta, O. *et al.* Method for strategic design in the food packaging system: packaged product life cycle tool. **E3S Web of Conferences**, v. 349, p. 01007, 2022. Available at: <https://www.e3s-conferences.org/10.1051/e3sconf/202234901007>.

Ketelsen, M.; Janssen, M.; Hamm, U. Consumers' response to environmentally-friendly food packaging: a systematic review. **Journal of Cleaner Production**, v. 254, p. 120123, 2020.

Kneafsey, M. *et al.* **Short food supply chains and local food systems in the EU**: a state of play of their socio-economic characteristics. Luxembourg: Publications Office of the European Union, 2013. Available at: <https://data.europa.eu/doi/10.2791/88784>.

Magnier, L.; Schoormans, J. Consumer reactions to sustainable packaging: the interplay of visual appearance, verbal claim and environmental concern. **Journal of Environmental Psychology**, v. 44, p. 53–62, 2015.

Magnier, L.; Schoormans, J. How do packaging material, colour and environmental claim influence package, brand and product evaluations? **Packaging Technology and Science**, v. 30, n. 11, p. 735–751, 2017.

Manzini, E. **Design, when everybody designs**: an introduction to design for social innovation. Cambridge: MIT Press, 2015.

Mendes, A. C.; Pedersen, G. A. Perspectives on sustainable food packaging: is bio-based plastics a solution? **Trends in Food Science & Technology**, v. 112, p. 839–846, 2021. DOI: <https://doi.org/10.1016/j.tifs.2021.07.014>.

Nobre, C. A. *et al.* **Nova economia da Amazônia**. São Paulo: WRI Brasil, 2023. DOI: <https://doi.org/10.46830/wrirpt.22.00034>.

PARÁ. **Portaria ADEPARÁ nº 8071, de 28 de dezembro de 2022**. 2022. Agência de Defesa Agropecuária do Estado do Pará. Belém: ADEPARÁ. Available at: <https://www.legisweb.com.br/legislacao/?id=440600>.

Santos, A. *et al.* **Design para a sustentabilidade**: ferramentas. Curitiba: Insight, 2024.

Sastre, R.; Cesar, K. S. **Recomendações para projetos criativos de embalagens sustentáveis**. 2024. São Paulo: ABEDESIGN. Available at: <https://www.marcavisual.com.br/_files/ugd/362643_98d5a53b1fb44ef39f85b0ee964f64bc.pdf>.

Silvestri, C. *et al.* Toward a framework for selecting indicators of measuring sustainability and circular economy in the agri-food sector: a systematic literature review. **The International Journal of Life Cycle Assessment**, 2022. Available at: <https://link.springer.com/10.1007/s11367-022-02032-1>.

Steenis, N. D. *et al.* Consumer response to packaging design: the role of packaging materials and graphics in sustainability perceptions and product evaluations. **Journal of Cleaner Production**, v. 162, p. 286–298, 2017.

Toledo, V. M. M.; Barrera-bassols, N. A etnoecologia: uma ciência pós-normal que estuda as sabedorias tradicionais. **Desenvolvimento e Meio Ambiente**, v. 20, p. 31–45, 2009. Available at: <http://revistas.ufpr.br/made/article/view/14519>.

Trindade, P. S. D. C. *et al.* Desenvolvimento de mudas de *Theobroma cacao* l. sob omissão de macro e micronutrientes. **Observatório de la Economía Latinoamericana**, v. 22, n. 1, p. 1276–1295, 2024. Available at: <https://ojs.observatoriolatinoamericano.com/ojs/index.php/olel/article/view/2439>.

Turan, D.; Keukens, B. M.; Schifferstein, H. N. J. Food packaging technology considerations for designers: attending to food, consumer, manufacturer, and environmental issues. **Comprehensive Reviews in Food Science and Food Safety**, v. 23, n. 6, p. e70058, 2024. Available at: <https://ift.onlinelibrary.wiley.com/doi/10.1111/1541-4337.70058>.

Valente, K. R. d. M. **Tecnologias de embalagens para diferenciação competitiva de produtos alimentícios em sistemas agroalimentares locais**. 2025. 321 f. Tese (Doutorado em Desenvolvimento Rural e Gestão de Empreendimentos Agroalimentares), Instituto Federal de Educação, Ciência e Tecnologia do Pará, Campus Castanhal, Castanhal.

Valente, K. R. M.; Ribeiro, S. C. A. Tecnologia de embalagens e sistemas agroalimentares locais: novas possibilidades. **Caderno Pedagógico**, v. 20, n. 9, p. 3700–3731, 2023. DOI: <https://doi.org/10.54033/cadpedv20n9-004>.

Valente, K. R. M.; Ribeiro, S. C. A. Current perspectives on the development of food packaging in local agri-food systems: an integrative review. **Revista de Gestão Social e Ambiental**, v. 18, n. 3, p. e06976, 2024. DOI: <https://doi.org/10.24857/rgsa.v18n3-112>.

Valente, K. R. M.; Ribeiro, S. C. A. Fractal: a transdisciplinary method for the development of food packaging in local agri-food systems with a focus on sustainability. **Revista Brasileira de Gestão e Desenvolvimento Regional**, v. 21, n. 3, p. 57–78, 2025. DOI: <https://doi.org/10.54399/rbgdr.v21i3.8064>.

Vezzoli, C.; Manzini, E. **Design for environmental sustainability**. London: Springer, 2008. DOI: <https://doi.org/10.1007/978-1-84800-163-3>.

Yin, R. K. **Estudo de caso**: planejamento e métodos. 6. ed. Porto Alegre: Bookman, 2018.