




# Entrepreneurial innovation through quality function deployment: From customer voice to measurable design in a ready-to-eat taro product

[10.29073/jer.v3i2.53](https://doi.org/10.29073/jer.v3i2.53)

**Received:** September 16, 2025.

**Accepted:** October 31, 2025.

**Published:** November 2, 2025.

**Author:** Marco Teles , University of Madeira, Portugal, [marcofantonio98@gmail.com](mailto:marcofantonio98@gmail.com).

## Abstract

This article couples a critical review of QFD in food engineering with a hands-on House of Quality for a ready-to-eat (RTE) taro product. We translate the Voice of the Customer (VoC) into auditable, process-controllable HOWs—including pH limits, shelf-life targets, validated allergen control, sensory thresholds, and quantified sustainability indicators (packaging oxygen transmission rate [OTR], water vapor transmission rate [WVTR], % recycled content, supplier certification criteria). Using exploratory consumer data ( $n = 24$ ) and expert judgment, we compute importance weights and roof correlations that surface key trade-offs among safety, texture, convenience, and clean-label positioning. The result is an ISO 16355-aligned blueprint that connects consumer value to engineering decisions and supplier QA, suitable for Stage-Gate governance. While the sample is modest and generalization is limited, the template is replicable and raises the bar for operationalizing “sustainability” and “quality” beyond declarative claims. We discussed limitations and provide a checklist to adapt the HoQ to other RTE products. Further, by tying VoC to measurable targets and gate reviews, the blueprint supports opportunity validation and de-risked commercialization pathways for entrepreneurial food ventures.

**Keywords:** House of Quality; ISO 16355; Oxygen Transmission Rate; Quality Function Deployment; Ready-to-Eat.

## 1. Introduction

Today’s food industry increasingly demands the continuous development of innovative products. (Costa et al., 2000) The future success of any food company depends upon the effective use of the New Product Development (NPD) process. (Stewart-Knox & Mitchell, 2003) A wide range of product development process factors influence product success and failure. (Stewart-Knox, & Mitchell, 2003) Such key factors for food product development are market and consumer knowledge and retailer involvement. (Stewart-Knox & Mitchell, 2003) Developing products that meet consumer expectations require careful and systematic research. (Pop et al., 2020) The European agri-food sector invests significantly less in research and development compared to other industries and tends to adopt a conservative stance on the innovations it introduces. Truly innovative products are quite rare, making up only 2.2% of all product launches. In contrast, around 77% of launches consist of variants or improvements of existing products. (Costa et al., 2006) To understand this conservative consumer’s behaviour is important to understand the food neophobia phenomena. The terminology of food neophobia is derived from the concept introduced by Rozin and Vollmecke about the “*Omnivore’s dilemma*”, which explains the tendency to select familiar and safe foods rather than novel and unfamiliar ones. (Siddiqui, S. A. et al., 2022) NPD is often recommended as an effective strategy to achieve competitive advantage and long-term financial success in today’s global food industry. (Costa et al., 2006) Consumer needs should be the primary focus of NPD. The NPD process must aim to satisfy these needs rather than solely emphasizing the development of enabling products or technologies. The success of an NPD process should be measured by how well the new product aligns with consumer needs. (Costa et al., 2006) In order to survive in the market, companies must produce exactly the product the consumer has been waiting for now the consumer wants it. (Benner et al., 2003) QFD is a planning process for the design of new products. (Bech et al., 1997) However, despite increasing calls for consumer-oriented innovation, few complete and published applications for Quality Function Deployment (QFD). Most



studies remain theoretical or restricted to the initial stages of the methodology, which leaves a clear gap in understanding how QFD can be effectively adapted to food product development.

In recent years, several studies have reinforced the relevance of QFD for innovation in the food and packaging industries. Recent applications have linked QFD with digital transformation, sustainability, and hybrid design methodologies (Santoso et al., 2024; Mudgal et al., 2024; Peres et al., 2025). These developments are discussed in more detail in Section 1.1.2, which reviews the most recent advances and emerging directions of QFD research in the food sector. This study presents a valuable contribution to the field of food product development by providing a practical case study that corroborates the effectiveness of the QFD methodology. This practical case study not only contributes to existing literature but also provides actionable insights for industry professionals seeking to apply QFD in their own product development efforts. While many studies discuss the theoretical aspects of QFD, this study stands out by showcasing its real-world application in the creation of a new functional food product: a ready-to-eat taro (*Colocasia esculenta*). This study goes beyond theoretical discussions by providing a concrete example of how QFD can be applied in the food industry to develop a new product. By combining a literature review with a practical case study, it bridges theory and practice, demonstrating how consumer insights can be systematically translated into product attributes. In doing so, it offers a structured framework for companies—particularly small and medium enterprises—to optimize their innovation and product development processes. Ultimately, the study highlights QFD as a practical and effective methodology for achieving success in new food product development. By integrating QFD with entrepreneurial innovation logic, this study positions methodological rigor as a lever for sustainable business creation and food system transformation.

### **1.1. Quality Function Deployment**

To provide a clearer understanding of the methodology applied in this study, this section outlines the foundations of QFD, its origins, principles, and relevance to food product development. QFD is a well-structured inter-functional planning technique, a methodology for continuous product improvement, focusing on multifunctional teams to integrate the voice of customer (VoC) in the stages of planning, (Pop et al., 2020) QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical requirements. (Chan and Wu, 2002) QFD facilitates the product development process, ensuring that customer requirements are considered throughout the technological process, and then reflecting in the final product. It takes a large effort and a lot of time to conduct QFD for the first time. However, once it has been executed it will speed up the time-to-market and enable the company to improve the product at less cost. (Benner et al., 2003) The QFD methodology, while widely used in industries such as automotive, remains underutilized in the food sector. This is due to both the complexity of the methodology and the lack of a structured approach that efficiently integrates consumer requirements into the final product's properties. QFD, was originally developed in Japan in the 1970s for the automobile industry. According to Hofmeister (1991) the QFD methodology has been used in the food industry since 1987. (Benner et al., 2003) Subsequent studies confirmed that QFD can support the systematic design of food products (Viaene & Januszewska, 1999).

Two significant benefits have been identified when introducing QFD. First, a well-defined conceptual research phase can substantially reduce production costs. Second, through consumer segmentation and analysis, companies can increase potential market share when launching a new product (Viaene & Januszewska, 1999). In this context, QFD serves as a valuable tool to optimize the new product development process, ensuring that consumer expectations are addressed from concept to commercialization. The first documented QFD case study in the United States was in 1986, when Kelsey Hayes used the methodology to develop a coolant sensor (Chan & Wu, 2002). Early adopters included major companies such as 3M, AT&T, Baxter Healthcare, Budd, Chrysler, DEC, Ford Motor, General Motors, Goodyear, Hewlett-Packard, IBM, ITT, Kodak, Motorola, and NASA (Chan & Wu, 2002). Many other organizations have since applied QFD and reported substantial benefits, and its use continues to expand across various sectors.

While QFD has achieved widespread success in engineering and manufacturing, its potential within the food industry remains underexplored. This justifies its adaptation in the present study, which applies QFD to the development of a ready-to-eat taro product.

### **1.1.1. ISO 16355-1:2021**

ISO 16355-1:2021 (*Application of statistical and related methods to new technology and product development process*), promotes a systematic approach to support decision-making in product innovation (ISO, 2021). Within the context of QFD, ISO 16355-1:2021 is highly relevant because it formalizes many of the practices that QFD practitioners have applied since the methodology was first developed (Akao & Mazur, 2020). The standard encourages a systematic approach, integrating customer-driven data with statistical analysis to reduce uncertainty in new product development.

For the food industry, this standard represents an opportunity to increase methodological rigor in the adoption of QFD. It provides clear directions on how to structure customer requirements, define measurable target values, and evaluate risks. Although ISO 16355 has been mostly applied in engineering and manufacturing contexts, its principles can be adapted to food product development, where consumer preferences and sensory attributes play a decisive role (Jugulum & Samuel, 2021). In this sense, ISO 16355-1:2021 complements the QFD methodology by aligning it with international best practices for product innovation.

### **1.1.2. Recent Developments in QFD for the Food Industry**

Recent literature has connected QFD with the emerging paradigm of Quality 4.0, which combines traditional quality management with digital technologies and data-driven decision-making. Santoso et al. (2024) emphasized QFD as a key tool in this context, showing how it structures innovation processes that were previously intuitive, while Peres et al. (2025) demonstrated how digital quality systems in the food industry can integrate QFD within smart manufacturing and continuous improvement frameworks.

Beyond digitalization, several studies have explored hybrid and sustainability-oriented approaches. Tri Ummarta et al. (2024) combined QFD with fuzzy logic to support the development of coffee-based products, and Ishak et al. (2024) integrated QFD with axiomatic design in the valorization of soybean milling by products. Similarly, Mudgal et al. (2024) applied a QFD Kano model to sustainable packaging design, and Wirawan et al. (2024) used QFD to enhance packaging convenience and usability. Siwiec et al. (2025) further expanded the methodology by coupling QFD with Life Cycle Assessment (LCA) to connect quality planning with environmental impact analysis, while Wicaksono et al. (2025) applied QFD principles to cleaner-production strategies in food-service operations.

These recent contributions confirm that QFD is becoming increasingly integrated with data-driven, hybrid, and sustainability-focused frameworks, aligning with contemporary trends in food innovation and circular-economy practices. From healthier formulations to waste-reduction strategies, the methodology is proving adaptable to both consumer expectations and sustainability goals. This growing body of evidence supports the idea that QFD is moving beyond theory and establishing itself as a practical, cross-disciplinary tool for entrepreneurs and food companies (Fagnoli & De Minicis, 2023; Santoso et al., 2024; Peres et al., 2025; Wicaksono et al., 2025).

## **1.2. QFD Limitations**

Although QFD has shown considerable potential across industries, several limitations have been highlighted in the literature, particularly when applied to the food sector. Recognizing these constraints is essential to understanding both the challenges and opportunities for its adaptation. One of the most frequently mentioned issues is the incomplete application of the methodology. Most studies on QFD in the food sector stop at the HoQ, and few complete applications have been published (Benner et al., 2003; Cohen, 1995). Another limitation is the scarcity of case studies. Companies are often reluctant to share detailed experiences for competitive reasons, which makes empirical validation difficult and leaves researchers with only partial accounts (Benner et al., 2003).

These limitations explain why QFD remains underutilized in the food sector. However, they also highlight the importance of further practical applications. By adapting the methodology to food-specific requirements, it is

possible to demonstrate its potential and provide entrepreneurs with a structured tool for innovation. The present study follows this rationale by applying QFD to the development of a ready-to-eat taro (*Colocasia esculenta*) product to illustrate both the challenges and the benefits of the approach.

### **1.3. House of Quality**

The methodology employs a series of matrices, the first and best-known being HoQ, which relates customer requirements to the technical characteristics of the product. QFD is not limited to this initial first matrix; it can also include others such as the product planning matrix, process planning matrix, and production planning matrix. HoQ represents the first stage of the QFD process. It serves as the starting point for product development by identifying and prioritizing customer needs (WHATs) and translating them into technical specifications (HOWs). In practice, HoQ facilitates communication across departments such as marketing, design, and production, ensuring that the final product reflects market expectations.

Although QFD comprises several stages, most publications and company practices tend to focus only on the HoQ (Viaene & Januszewska, 1999). Its relative simplicity, flexibility, and adaptability make it especially attractive for entrepreneurs and small businesses, even though more advanced matrices exist. For this reason, HoQ continues to represent a practical entry point for companies seeking to systematize product development without the complexity of later QFD phases.

### **1.4. Other Methodologies for the Development of New Products**

While QFD provides a structured framework for translating consumer requirements into technical specifications, it is not the only methodology supporting food product innovation. Over the last decades, several complementary approaches have been developed to enhance creativity, accelerate processes, and reduce market risk. Among them, Design Thinking emphasizes empathy with consumers and iterative problem-solving; the Stage-Gate model structures development into sequential stages with decision checkpoints; and the Lean Startup approach promotes rapid experimentation and validated learning.

Each of these methodologies brings unique strengths: Design Thinking fosters creativity, Stage-Gate ensures discipline and resource allocation, and Lean Startup increases agility and responsiveness to consumer feedback. When combined with QFD, they can create hybrid models that balance structured decision-making with flexibility and innovation. For this reason, a brief overview of these methodologies is presented below to contextualize the role of QFD within the broader landscape of new product development tools.

#### **1.4.1. Design Thinking**

Lastly, design thinking means creating new meanings. Product design is a sociotechnical endeavor that concerns both physical and social realities. According to the social constructionism theory, customers tend to assign social meanings to a product when interacting with the product. (Liu & Lu, 2020) Developing and enhancing innovative design-thinking skills is crucial in new product development. (Liu & Lu, 2020) QFD is one of the most widely adopted design methods (Liu & Lu, 2020) a combination of methods of Design Thinking and QFD can provide advantages in building products or services that align with customer needs and desires with a creative, innovative, and scalable approach. (Koswara & Alifin, 2024). The approach of Design Thinking and QFD can help understand user needs deeply and come up with innovative solutions that meet customer needs (Koswara & Alifin, 2024).

The iterative processes of Design Thinking validate identified needs and potential solutions before they are formalized in QFD. Ideation sessions generate a broader array of quality characteristics (HOWs) to meet customer requirements, which are then prioritized through QFD structured matrices. Engaging multidisciplinary teams is essential as they bring diverse perspectives throughout both methodologies. This integration leverages the human-centered focus of Design Thinking to define customer needs and apply QFD to translate those needs into specific product and process requirements, ultimately fostering a more innovative approach to product development.

### 1.4.2. Stage-Gate Model

Companies in the food sector adopt different approaches, methods, and strategies for developing new products. For example, convenience food manufacturers often apply the Stage-Gate model or milestone-based models, which generally consist of phases such as idea exploration, business case development, product testing, evaluation, and launch (Azanedo et al., 2020).

The Stage-Gate model is recognized as a structured idea-to-launch system, serving as both a conceptual and operational roadmap for managing the NPD process and increasing its effectiveness and efficiency (Cooper, 2008). This model can be compared to a sports playbook, where each play is defined to drive the project sequentially and under control, ensuring that risks are reduced and strategic decisions are taken at critical checkpoints (Cooper, 2008). The classic system involves five stages and five gates, including an initial discovery phase and a post-launch review (Cooper, 2008; Cooper et al., 2002).

#### 1.4.2.1. The States

The innovation process can be visualized as a sequence of stages, each consisting of a set of recommended activities designed to move the project forward to the next gate. Key characteristics of the stages (Cooper, 2008):

- Each stage aims to reduce uncertainties and risks by gathering information.
- The cost of each stage is higher than the previous one, representing incremental commitments but also a progressive reduction of uncertainty.
- Activities are carried out in a parallel and multidisciplinary manner, involving teams from different areas (marketing, research and development, engineering, production).
- There are no ownership stages assigned to departments — all functions contribute at every phase, promoting a holistic perspective of product development.

#### 1.4.2.2. The Gates

After each stage, the project passes through a gate — a decision point (go/kill/hold/recycle) that determines whether it should move forward, be terminated, or adjusted. The structure of each gate includes three main elements (Cooper, 2008):

1. Deliverables — tangible results presented by the team at the gate, corresponding to the activities completed in the previous stage.

2. Evaluation criteria — the parameters for decision-making, including:

- Must-meet criteria (eliminary checklist items that discard unfeasible projects);
- Should-meet criteria (scoring criteria that allow prioritization among projects).

3. Outputs — the decision taken (Go/Kill/Hold/Recycle), accompanied by an approved action plan for the next stage, including assigned resources, deadlines, and deliverables.

Thus, gates act as quality and strategic management checkpoints, ensuring that the company's resources are invested only in the most promising projects aligned with business goals.

## 1.5. Lean Startup

The Lean Startup methodology is increasingly recognized as a valuable framework for innovation and entrepreneurship. According to Blank & Eckhardt (2024), the Lean Startup can be best understood as an application of the scientific methodology to entrepreneurship. It emphasizes experimentation, iterative development, and validated learning, rather than relying on lengthy planning cycles and assumptions.

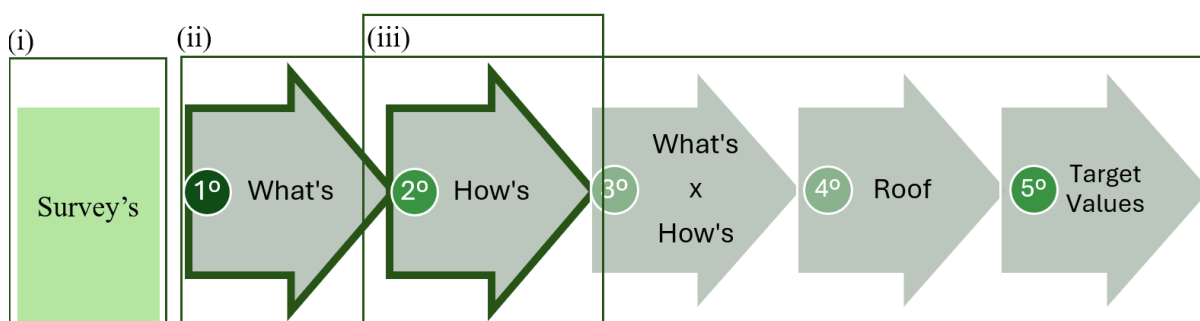
In the context of NPD, Lean Startup promotes the creation of a minimum viable product (MVP) that allows entrepreneurs to test hypotheses directly with customers. Feedback collected from these early interactions guides further product iterations, ensuring that development is grounded in real market needs and reducing the

risk of failure. By incorporating Lean Startup principles, the QFD methodology can become more agile, customer-centric, and adaptable, enabling companies to develop products that better meet market expectations with greater efficiency. This integration offers the potential to align QFD's structured, systematic approach with Lean Startup's flexibility and rapid learning cycles, resulting in a more effective innovative process.

## 2. Methods

This study employed a mixed-method approach, combining a literature review with a practical application of the QFD methodology. The process focused on the development of a ready-to-eat taro (*Colocasia esculenta*) product, using consumer data as the foundation for building HoQ. The methodology involved three main stages: (i) identification of consumer requirements through surveys, (ii) translation of these requirements into technical characteristics, and (iii) construction of the HoQ to guide product planning. The following workflow illustrates the methodological steps followed in this study, from the literature review to the final conclusions.

**Figure 1:** Methodological workflow of the study (author's elaboration).



## 3. Results — House of Quality

The first step in the first HoQ is to identify the customers' requirements. To achieve this, surveys were conducted to understand the consumers' needs, as well as their importance and relevance. Customers' requirements were rated on a scale of 1 to 5. A total of 24 responses were collected through online surveys, between 3<sup>rd</sup> and 6<sup>th</sup> February 2025.

### 3.1. Consumer's Requirements (Whats) or "Voice of Customer"

The construction of HoQ begins with the identification of consumer demands, commonly referred to as the (Whats) (Benner et al., 2003), the (Whats) were identified through an online survey. The results confirmed the importance of attributes such as taste, health, and convenience, which are in line with broader innovation trends in the agri-food sector. Respondents evaluated factors such as taste, convenience, texture, health, sustainability, allergen-free options, and origin certification on a five-point Likert scale. Results revealed that taste (mean score 4.8/5), health (4.2/5), and convenience (3.9/5) were the most valued attributes. These findings are consistent with previous studies emphasizing consumer preference for healthier and more practical food options (Stewart-Knox & Mitchell, 2003; Costa et al. 2006)

This first stage focuses on VoC, a structured list of product attributes that must be fulfilled. Establishing the VoC is considered the most critical step in QFD projects (Costa et al., 2000). Incorporating consumer requirements early in the NPD process has been recognized as a decisive success factor (van Kleef et al., 2005), since consumer research is relatively inexpensive compared to the potential cost of market failure. At this stage of the HoQ, the QFD team must ensure a clear understanding of what consumers demand from the product and how these demands align with the company's strategic objectives (Costa et al., 2000). This involves capturing both qualitative dimensions (what consumers value in general) and quantitative dimensions (the relative importance of each attribute) (Viaene & Januszewska, 1999). Such a structured identification of consumer requirements forms the foundation for subsequent translation into technical specifications in HoQ. Figure 2 presents the ranked list of consumer requirements (Whats) and their relative importance.

**Figure 2:** Consumer's requirements (author's elaboration).



Whats — “Voice of the Customer”	
Convenience	5
Taste	5
Healthy	4
Allergen free (Gluten/ Lactose free)	2
Origin Certificates (IGP/ Organic)	3
Sustainability	3
Texture	4

The results confirmed that taste, health, and convenience (ready-to-eat) were the most valued attributes, followed by texture and sustainability-related factors such as certified origin and allergen-free claims. These findings are consistent with previous studies emphasizing consumer preference for healthier, more practical, and trustworthy food options (Stewart-Knox & Mitchell, 2003; Costa et al., 2006; van Kleef et al., 2005). Moreover, evidence from innovation challenges such as ECOTROPHELIA Portugal reinforces this alignment, with finalist products most frequently highlighting convenience, health, and tradition, particularly within categories such as snacks (34.1 %), desserts (17.1 %), and ready meals (12.2 %) (Cardoso & Oliveira, 2021).

### 3.2. Product’s Requirements (Hows)

The (HOWs) represent the technical characteristics established to meet the consumer requirements identified in the survey. For the ready-to-eat taro (*Colocasia esculenta*) product, these technical specifications were defined to ensure safety, quality, and alignment with consumer expectations. They include: **(i) preparation time**, with the product designed to be ready to eat in  $\leq 5$  minutes and ensuring  $\text{pH} < 4.5$  and a minimum shelf life of  $\geq 30$  days; **(ii) taste evaluation**, requiring a minimum sensory acceptance score of  $\geq 80\%$ ; **(iii) Low Sugar/Fat content**, limiting sugar to  $< 0.5$  g/100 g, fat to  $< 1.5$  g/100 g, and sodium to  $< 120$  mg per portion; **(iv) allergen-free**, formulation, verified through laboratory testing for gluten and lactose; **(v) certified suppliers**, ensuring ingredient traceability, IGP origin verification, and compliance with “*Produto da Madeira*” certification; **(vi) sustainability**, including raw materials sourced from certified organic producers and the use of recyclable or biodegradable packaging; and **(vii) selection of taro cultivar**, guaranteeing stable sensory characteristics and consistent quality across batches. These technical specifications summarize the product requirements that guide formulation, processing, and quality control in the development of the ready-to-eat taro (*Colocasia esculenta*) product. **Figure 3** presents the technical requirements (HOWs) identified for this product.

**Figure 3:** Product’s requirements (author’s elaboration).

Hows
<b>(i) Preparation time</b> Product ready to eat ( $\leq 5$ minutes) $\text{pH} < 4.5$ ; Shelf life $\geq 30$ days
<b>(ii) Taste Evaluation</b> Minimum sensory acceptance score of $\geq 80\%$ . Controlled cooking temperature/time
<b>(iii) Low Sugar/Fat content</b> Nutritional Targets: sugar $< 0.5$ g/100g; fat $< 1.5$ g/100g; sodium $< 120$ mg/portion
<b>(iv) Allergen free</b> Gluten/ Lactose free Validated allergen-free formulation/ Laboratory verification



<p><b>(v) Certified suppliers</b>                  Certified suppliers ensuring traceability, IGP origin verification, and compliance with the “<i>Produto da Madeira</i>” certification.</p>
<p><b>(vi) Sustainability</b>                  Selection of raw materials from certified organic producers; use of recyclable/ biodegradable packaging;</p>
<p><b>(vii) Selected taro cultivar</b>                  Use of a taro cultivar with stable sensory characteristics and consistent quality across batches.</p>

### 3.3. Matrix — Relationship Whats x Hows

The relationship matrix connects consumer requirements (Whats) with technical requirements (Hows), enabling the identification and prioritization of actions with the greatest impact on consumer satisfaction (Bech et al., 1997). Each relationship was classified as strong, medium, or weak according to the scoring system proposed by Benner et al. (2003), where strong = 9, medium = 3, and weak = 1.

**Figure 4:** Relationship between the Whats and Hows (author’s elaboration).

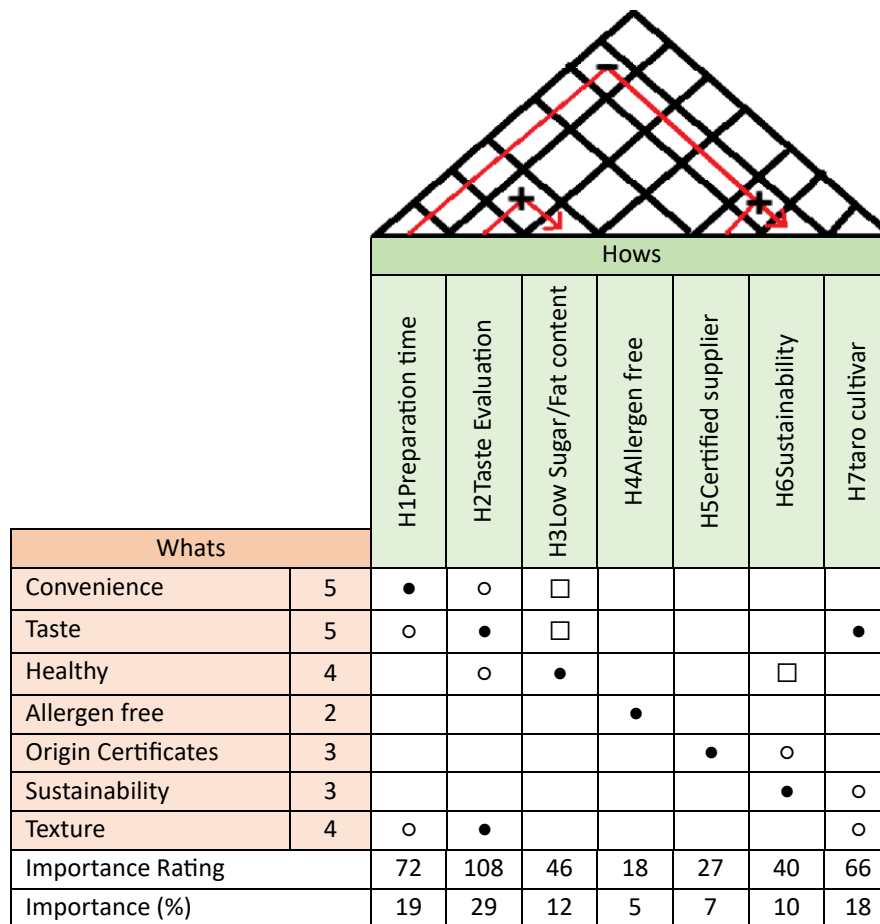
● (9)	Strong Relationship
○ (3)	Medium Relationship
□ (1)	Weak Relationship

Based on this scale, the relationship matrix was constructed to connect consumer demands with technical specifications. This matrix constitutes the core of the HoQ, as it visualizes how strongly each consumer requirement is supported by the defined technical parameters. Beyond highlighting direct relationships, the matrix also acts as a diagnostic tool, as blank rows or columns indicate either that a consumer requirement has not been adequately translated into a technical specification, or that a technical feature does not respond to any identified consumer need (Benner et al., 2003). Although some authors describe the four-phase QFD approach, most food industry applications focus primarily on this first matrix, the HoQ, as it provides essential insights into trade-off decisions and product improvement opportunities (Benner et al., 2003).

Results revealed strong relationships between: (i) convenience and preparation time; (ii) taste and both taste evaluation and taro cultivar; (iii) health and low sugar/fat content; and (iv) texture and taste evaluation. Figure 5 illustrates the relationship matrix between (Whats) and (Hows), highlighting strong, medium, and weak correlations.



Figure 5: Matrix: relationship Whats x Hows (author’s elaboration).



Once the first HoQ has been constructed, it is possible to extend the analysis by developing additional matrices, such as process planning or production planning matrices, to further support decision-making throughout product development. However, in practice, many development teams limit themselves to the initial HoQ.

### 3.4. Roof of the HoQ

The roof of the HoQ represents the correlation matrix, which identifies positive and negative interdependencies among the technical requirements (HOWs) (Benner et al., 2003). These correlations indicate where actions may support or conflict with one another during product development. In this study, positive correlations were observed between taste evaluation and low sugar/fat content, as well as between certified suppliers and sustainability. These synergies suggest that improvements in one parameter can reinforce the other, strengthening the overall product concept. Conversely, a negative correlation was identified between preparation time and sustainability, indicating a potential trade-off between achieving quick preparation and maintaining environmentally responsible production practices. Recognizing these correlations is essential for balancing product attributes and anticipating conflicts during development (Cohen, 1995). Figure 6 presents the correlation matrix (roof) of the HoQ, showing the positive and negative interactions among the HOWs.



Figure 6: Roof of the HoQ (author’s elaboration).

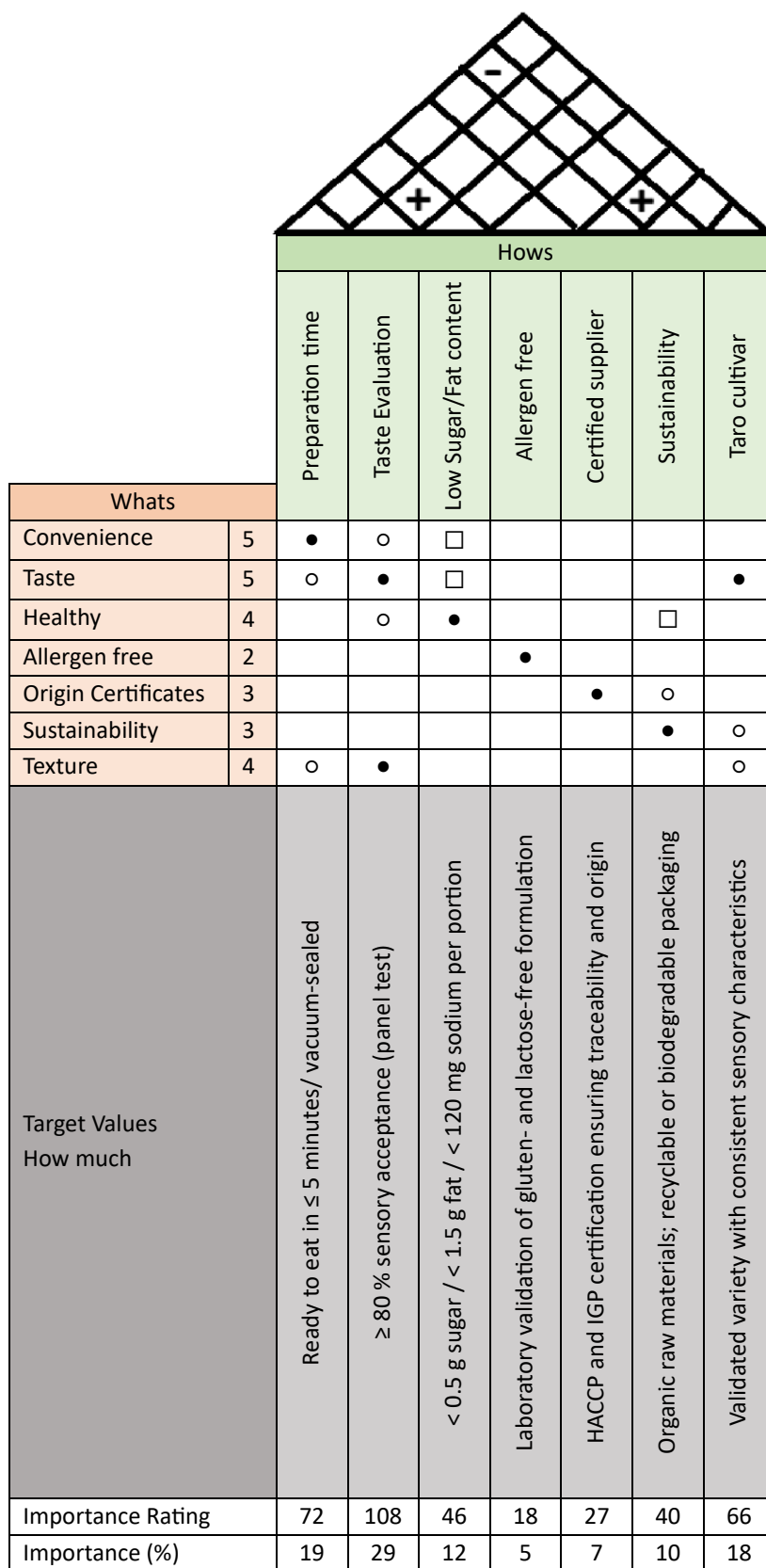
Whats		Hows						
		Preparation time	Taste Evaluation	Low Sugar/Fat content	Allergen free	Certified supplier	Sustainability	Taro cultivar
Convenience	5	●	○	□				
Taste	5	○	●	□				●
Healthy	4		○	●			□	
Allergen free	2				●			
Origin Certificates	3					●	○	
Sustainability	3						●	○
Texture	4	○	●					○
Importance Rating		72	108	46	18	27	40	66
Importance (%)		19	29	12	5	7	10	18

### 3.5. Target Values How Much

Target values were established for each technical requirement to ensure alignment between product specifications and consumer expectations. The cooking process was optimized so that, once packaged, the product can be reheated and ready to eat within ≤ 5 minutes, ensuring convenience while maintaining taste and texture. Shelf life was set at a minimum of 30 days under refrigerated storage, supported by vacuum packaging to guarantee microbiological stability. Nutritional targets were defined as sugar < 0.5 g/100 g, fat < 1.5 g/100 g, and sodium < 120 mg per portion, in line with industry standards for healthy products. Additional targets included laboratory validation of allergen-free formulation (gluten and lactose), supplier certification under HACCP and IGP schemes to ensure traceability and origin integrity, and the use of a validated taro cultivar to guarantee batch-to-batch sensory consistency. Sustainability objectives were addressed through the selection of organic raw materials and the adoption of recyclable or biodegradable packaging solutions. These quantitative benchmarks represent the How Muchs of the HoQ and provide measurable goals for product development, supporting analysis, optimization, and consistency in meeting consumer expectations (Benner et al., 2003). Figure 7 presents the complete HoQ for the ready-to-eat taro (*Colocasia esculenta*) product, integrating consumer requirements (WHATs), technical requirements (HOWs), correlations, and corresponding target values.



Figure 7: Complete HoQ for the ready-to-eat taro (*Colocasia esculenta*) product (author’s elaboration).



## 4. Discussion

The application of the QFD methodology to the development of a ready-to-eat taro (*Colocasia esculenta*) product proved effective in aligning technical specifications with consumer requirements. HoQ facilitated the translation of consumer preferences, such as taste, convenience, and health, into measurable targets, including nutritional composition, shelf life, and packaging solutions. At the same time, the process revealed challenges typical of the food industry, such as balancing technical feasibility with consumer expectations and managing trade-offs between sensory quality and nutrient preservation.

These results mirror innovation trends observed in initiatives like ECOTROPHELIA Portugal, where finalist products have consistently emphasized convenience, health, and tradition. Snacks (34.1%), desserts (17.1%), and ready meals (12.2%) dominated submissions, with common features including bioactive compounds (34.2%), reduced sugar/fat content (19.0%), and gluten/lactose-free formulations (19.0%) (Cardoso & Oliveira, 2021). The emphasis on health attributes aligns with industry-wide efforts to improve nutritional profiles through sugar and fat reduction (Cardoso & Oliveira, 2021). Previous research also indicates that reduced-fat products tend to achieve stronger market performance, likely because they respond directly to consumer health concerns and retailer strategies (Stewart-Knox & Mitchell, 2003).

From a managerial perspective, integrating QFD into NPD requires organizational preparation. Training is essential for marketing, research and development, and production teams to understand the logic of the HoQ and interpret consumer data effectively. While initial applications are time and resource intensive, subsequent use becomes more efficient once routines and templates are established (Benner et al., 2003). For small and medium sized enterprises, the main challenge is the opportunity cost of skilled human resources; however, the potential reduction in market failure risk and improved alignment with consumer needs typically outweigh the initial investment.

Therefore, companies should adopt a phased approach to implementation:

- **Pilot phase** — small scale projects to build capacity and achieve quick wins.
- **Integration phase** — systematic use of the HoQ within NPD processes by cross functional teams.
- **Consolidation phase** — expansion to additional QFD matrices (e.g., process or production planning), ensuring continuous improvement.

This study also presents limitations. The sample was small ( $n = 24$ ), limiting generalizability. Moreover, the methodology was applied in a conceptual framework rather than an industrial context, meaning that practical constraints such as production costs, supply chain variability, and regulatory requirements were not fully tested. Future research should therefore validate the methodology in real industrial settings and explore hybrid approaches combining QFD with complementary tools such as Design Thinking, Stage-Gate, or Lean Startup.

### 4.1. Opportunities

Despite these challenges, the adaptation of QFD to the food sector offers several opportunities. First, it enables companies to systematically integrate consumer insights into product development, thereby increasing the likelihood of market success and reducing failure rates. Second, it fosters cross-functional collaboration by structuring communication between marketing, research and development, and production an area where small and medium sized enterprises often face difficulties.

QFD also supports the development of healthier and more sustainable food products, addressing regulatory pressures and consumer expectations regarding nutrition, allergen-free options, and environmental impact. By aligning with these market trends, QFD serves not only as a development tool but also as a means of strategic differentiation. Finally, its relatively low financial cost compared to other innovation frameworks makes QFD accessible to entrepreneurs in emerging markets, democratizing structured product development and allowing smaller companies to compete more effectively.

## 5. Conclusions

This study demonstrated how QFD can be applied to the development of a ready-to-eat taro (*Colocasia esculenta*) product, systematically translating consumer requirements into technical specifications through the HoQ. The final HoQ confirmed that consumer priorities can be effectively converted into engineering attributes, proving the usefulness of QFD in food product development. These findings align with recent research highlighting QFD's relevance for innovation in food and packaging design (Indraswari et al., 2024; Mudgal et al., 2024; Peres et al., 2025). Furthermore, defining measurable technical targets supports the transition towards data-driven quality management in line with Quality 4.0 principles (Santoso et al., 2024).

This work also advances the literature by addressing a ready-to-eat root-based product (taro) with explicit microbiological and nutritional parameters, and by embedding regional certification “*Produto da Madeira*” within the HOW “Certified suppliers” (IGP). This strengthens the link between QFD, traceability, and territorial identity—dimensions rarely explored in recent studies (Siwiec et al., 2025; Wicaksono et al., 2025).

From a managerial perspective, QFD enhances the alignment between innovation and consumer expectations—particularly regarding taste, convenience, health, and sustainability. Although implementation requires investment in training, time, and cross-functional teamwork, these costs are offset by long-term benefits such as reduced risk of market failure and increased consumer trust. For entrepreneurs and SMEs, QFD represents a structured yet flexible framework for consumer-driven innovation.

Some limitations must nevertheless be acknowledged. The small sample size and the conceptual rather than industrial application restrict the generalizability of the findings. Future research should extend this analysis to industrial environments and explore hybrid approaches combining QFD with methodologies such as Design Thinking, Stage-Gate, or Lean Startup. In addition, integrating QFD with tools like Life Cycle Assessment (LCA), IoT-based monitoring, and data analytics could reinforce its alignment with the Quality 4.0 paradigm and support measurable sustainability performance.

In conclusion, QFD—through the systematic integration of WHATs and HOWs—offers both theoretical contributions to food innovation literature and practical guidance for companies. Its adaptation to the food sector represents not only a methodological framework but also a strategic pathway for building consumer-driven, sustainable, and competitive innovations. Ultimately, QFD's adaptation to food entrepreneurship represents more than a technical exercise: it redefines innovation as the measurable translation of human needs into sustainable, market-viable solutions.

## References

- Akao, Y., & Mazur, G. H. (2020). The leading edge in QFD: Past, present and future. *International Journal of Quality & Reliability Management*, 37(2), 451–463.
- Azanedo, L., Garcia-Garcia, G., Stone, J., & Rahimifard, S. (2020). An overview of current challenges in new food product development. *Sustainability*, 12(8), 3364.
- Bech, A., Hansen, M., & Wienberg, L. (1997). Application of house of quality in translation of consumer needs into sensory attributes measurable by descriptive sensory analysis. *Food Quality and Preference*, 8(5–6), 329–348.
- Benner, M., Linnemann, A., Jogen, W., & Folstar, P. (2003). Quality function deployment (QFD) – Can it be used to develop food products? *Food Quality and Preference*, 14(4), 327–339.
- Blank, S., & Eckhardt, J. T. (2024). The lean startup as an actionable theory of entrepreneurship. *Journal of Management*, 50(8), 3012–3034.
- Cardoso, E. L., & Oliveira, L. (2021). *Ecotrophelia Portugal (2017–2020): Análise de conteúdo de um concurso para promoção do empreendedorismo académico e da inovação alimentar*.



- Chan, L. K., & Wu, M. L. (2002). Quality function deployment: A literature review. *European Journal of Operational Research*, 143(3), 463–497.
- Cohen, L. (1995). *Quality function deployment: How to make QFD work for you*. Addison-Wesley.
- Cooper, R. G. (2008). Perspective: The stage-gate® idea-to-launch process—Update, what’s new, and nexgen systems. *Journal of Product Innovation Management*, 25(3), 213–232.
- Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2002). Optimizing the stage-gate process: What best-practice companies do—II. *Research-Technology Management*, 45(6), 43–49.
- Costa, A. I. A., Dekker, M., & Jongen, W. M. F. (2000). Quality function deployment in the food industry: A review. *Trends in Food Science & Technology*, 11(9–10), 306–314.
- Costa, A. I., & Jongen, W. M. F. (2006). New insights into consumer-led food product development. *Trends in Food Science & Technology*, 17(8), 457–465.
- Fargnoli, M., & De Minicis, M. (2023). Applying QFD in smart product-service system design. *International Journal of Product Development*, 28(3–4), 241–258.
- Grimsby, S. (2024). Knowledge bases, innovation and sustainability—When tradition meets novelty in the food industry. *Trends in Food Science & Technology*, 144, 104307.
- Hofmeister, G. (1991). Quality function deployment in food industry product development. *Food Technology*, 45(6), 77–81.
- Indraswari, T., Widodo, E., & Rahayu, S. (2024). Application of quality function deployment in chocolate beverage design. *AIP Conference Proceedings*, 3125(1), 020013.
- International Organization for Standardization. (2021). *ISO 16355-1:2021 – Applications of statistical and related methods to new technology and product development process — Part 1: General principles and perspectives of quality function deployment (QFD)*. ISO.
- Ishak, A., Ginting, R., & Siallagan, S. (2024). Application of quality function deployment (QFD) and axiomatic design method for product design: Study case compost waste product. *Journal of Achievements in Materials and Manufacturing Engineering*, 122(1).
- Jugulum, R., & Samuel, P. (2021). *Design for lean Six Sigma: A holistic approach to design and innovation*. Wiley.
- Koswara, R., & Alifin, F. I. (2024). A user-oriented UI/UX application design using the integration of quality function deployment (QFD) and design thinking methods. *MOTIVECTION: Journal of Mechanical, Electrical and Industrial Engineering*, 6(1), 85–100.
- Liu, A., & Lu, S. (2020). Functional design framework for innovative design thinking in product development. *CIRP Journal of Manufacturing Science and Technology*, 30, 105–117.
- Mudgal, S., Kumar, R., & Singh, V. (2024). Combining QFD and Kano model for sustainable packaging design. *Journal of Cleaner Production*, 445, 143872.
- Peres, P., Silva, R., & Mendes, A. (2025). Quality 4.0 in the food industry: Integration of digital technologies in quality management. *Foods*, 14(2), 256.
- Pop, C., Frunză, G., & Pop, I. M. (2020). Application of QFD methodology (house of quality) for production of fruit ice cream. *Scientific Papers. Series D. Animal Science*, 63(1), 53–60.



- Santoso, I., Rau, H., Choirun, A. U., Aprilianto, H. C., Lestari, K., A'yuniah, S., & Kusumaningtyas, O. W. (2024). Application of QFD in sustainable new product development in the agro-industrial sector: A systematic literature review. *International Journal of Sustainable Engineering*, *17*(1), 926–944.
- Santoso, R., Putra, A., & Nugroho, D. (2024). Integrating QFD for sustainability-oriented product development. *International Journal of Quality and Reliability Management*, *41*(6), 1254–1271.
- Siddiqui, S. A., Zannou, O., Karim, I., Kasmianti, Awad, N. M., Gołaszewski, J., Heinz, V., & Smetana, S. (2022). Avoiding food neophobia and increasing consumer acceptance of new food trends—A decade of research. *Sustainability*, *14*(16), 10391.
- Siwec, A., Nowak, M., & Bartosz, K. (2025). Integrating QFD and life-cycle assessment (LCA) to link product quality and environmental impact. *Sustainability*, *17*(1), 112.
- Stewart-Knox, B., & Mitchell, P. (2003). What separates the winners from the losers in new food product development? *Trends in Food Science & Technology*, *14*(1–2), 58–64.
- Tri Ummarta, I., Santoso, I., Pranowo, D., & Choirun, A. U. (2024). Utilizing coffee bean subgrade quality by designing product development using integrated kansei words and fuzzy QFD. *Cogent Food & Agriculture*, *10*(1), 2427319.
- Tri Ummarta, T., Susanto, H., & Kusuma, E. (2024). Integration of QFD and fuzzy logic for the development of coffee-based products. *AIP Conference Proceedings*, *3125*(1), 020012.
- Van Kleef, E., Van Trijp, H. C., & Luning, P. (2005). Consumer research in the early stages of new product development: A critical review of methods and techniques. *Food Quality and Preference*, *16*(3), 181–201.
- Viaene, J., & Januszewska, R. (1999). Quality function deployment in the chocolate industry. *Food Quality and Preference*, *10*(4–5), 377–385.
- Wicaksono, R., Hartono, S., & Pradana, Y. (2025). Quality Function Deployment for cleaner production in food service operations. *Journal of Cleaner Production*, *448*, 143901.
- Wirawan, M., Putri, E., & Rahmawati, T. (2024). Packaging redesign using Quality Function Deployment for fried food products. *E-Journal Trisakti Industrial Engineering*, *9*(2), 77–85.

## Appendices

Survey, the survey was carried out between the 3<sup>rd</sup> and 6<sup>th</sup> of February, the survey was answered by 24 people online.

- When buying food products, what importance do you attach to the factor: **Allergens free**

(1) Nothing important 10 responses

(2) Unimportant 4 responses

(3) Moderately Important 3 responses

(4) Important 2 responses

(5) Very important 5 responses

Total:  $60 = (10 \times 1) + (2 \times 4) + (3 \times 3) + (4 \times 2) + (5 \times 5)$

- When buying food products, what importance do you attach to the factor: **Convenience**

(1) Nothing important 1 responses

(2) Unimportant 0 responses

(3) Moderately Important 5 responses

(4) Important 11 responses

(5) Very important 7 responses

Total:  $95 = (1 \times 1) + (2 \times 0) + (3 \times 5) + (4 \times 11) + (5 \times 7)$

- When buying food products, what importance do you attach to the factor: **Texture**



(1) Nothing important 0 responses  
 (2) Unimportant 0 responses  
 (3) Moderately Important 9 responses  
 (4) Important 7 responses  
 (5) Very important 8 responses  
 Total:  $95=(1\times 0)+(2\times 0)+(3\times 9)+(4\times 7)+(5\times 8)$

- When buying food products, what importance do you attach to the factor: **Taste**

(1) Nothing important 0 responses  
 (2) Unimportant 0 responses  
 (3) Moderately Important 0 responses  
 (4) Important 3 responses  
 (5) Very important 21 responses  
 Total:  $117=(1\times 0)+(2\times 0)+(3\times 0)+(4\times 3)+(5\times 21)$

- When buying food products, what importance do you attach to the factor: **Origin Certificate**

(1) Nothing important 10 responses  
 (2) Unimportant 4 responses  
 (3) Moderately Important 3 responses  
 (4) Important 2 responses  
 (5) Very important 5 responses  
 Total:  $60=(1\times 10)+(2\times 4)+(3\times 3)+(4\times 2)+(5\times 5)$

- When buying food products, what importance do you attach to the factor: **Healthy**

(1) Nothing important 0 responses  
 (2) Unimportant 1 responses  
 (3) Moderately Important 3 responses  
 (4) Important 9 responses  
 (5) Very important 11 responses  
 Total:  $102=(1\times 0)+(2\times 1)+(3\times 3)+(4\times 9)+(5\times 11)$

- When buying food products, what importance do you attach to the factor: **Sustainability**

(1) Nothing important 1 responses  
 (2) Unimportant 2 responses  
 (3) Moderately Important 11 responses  
 (4) Important 7 responses  
 (5) Very important 3 responses  
 Total:  $81=(1\times 1)+(2\times 2)+(3\times 11)+(4\times 7)+(5\times 3)$

Importance (rates)			
Taste	117/24	4,8	<b>5</b>
Healthy	102/24	4,2	<b>4</b>
Convenience	95/24	3,9	<b>4</b>
Texture	95/24	3,9	<b>4</b>
Sustainability	81/24	3,3	<b>3</b>
Origin Certificate	60/24	2,5	<b>2</b>



---

### Ethical Statement

---

**Conflict of Interest:** Nothing to declare. **Funding:** Nothing to declare. **Peer Review:** Double-blind.



All content from *JER—Journal of Entrepreneurial Researchers* is licensed under [Creative Commons](#), unless otherwise specified and in the case of content retrieved from other bibliographic sources.