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Technological Innovation Strategy in Fish Farming: Application of a Technological Maturity Tool

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HIGHLIGHTS

- TRL aids project development in food science, focusing on fish technology.
- Project impacts on society can be assessed through TRL evaluation.
- TRL measures maturity of fish products in academic research projects.

Abstract: This research developed a tool based on the TRL (Technology Readiness Level) metric to characterize the levels of scientific and technological maturity of fish products. The study was based on a descriptive and exploratory research, using a case study and data collection through the application of questionnaires containing semi-structured questions and analysis of examples of referenced material. A TRL calculator model was proposed, adapted to the food segment with emphasis on fish technology. The tool was applied in five projects in the area of fish technology and the results were evaluated through the application of four methodological proposals. The results indicated that the best model for the use of the tool in the food context in fish technology was the proposal developed in this work, efficiently demonstrating the degree of maturity of the projects evaluated.

Keywords: Scientific innovation; level of technological readiness; fish; technology transfer.

INTRODUCTION

In the food industry, innovation has gained great prominence, being increasingly recognized by academic institutions, companies and market professionals as a determining factor of organizational success, considering it relevant in the creation of value and capture of competitive advantages, in addition to differentiating itself from the competition, regardless of its size and the sector to which it belongs [1,2].

Fish is among the four most consumed animal protein sources in the world. It is responsible for about 17% of all protein consumed by humans and represented, in 2018, an *apparent per capita consumption* of

20.5 kg/inhabitant/year. However, in 2020, there was a lower consumption estimate than in 2019 (20.2kg kg/inhabitant/year) [3].

In Brazil, the last fisheries bulletin released by the then Ministry of Fisheries and Aquaculture estimated a production of around 637,884,000 tons [4,5]. In 2021, the aquaculture sector recorded a fishing potential of 841,005,000 tons of farmed fish (tilapia, native fish, and other species), according to data published by the Brazilian Fisheries Association [6]. Compared to the 2020 production, there was an increase of 4.7% in this production, highlighting the relevance of fishing activity in national agribusiness. Even with these data, the national fish consumption (10 kg/per catch/year) is still lower than the world consumption, mentioned above [7].

Currently, the construction of incentive programs for the implementation of innovation to meet the needs of society, as well as the stimulus to competitiveness to remain active in the market, has undergone a great advance, with this it can be said that the government has a great interest in supporting the implementation of innovation in companies [9]. Therefore, the interactions between the Institutes of Science and Technology (ICT's) and with private companies constitute a primordial mechanism to enable the development of inventions based on academic research [8].

A metric has already been applied as a mechanism for measuring technological maturity by actors in technological science systems in the United States of America, Europe and, more recently, in Brazil. This is the Technology Readiness Level (TRL), developed by the National Aeronautics and Space Administration (NASA), updated by ISO 16290:2015 [9,10]. Evaluation methods consist of quantifying the levels of consolidation of research and products [11].

In this context, the present work proposes the elaboration of a tool in the area of Fish Technology, based on the TRL model mentioned, to determine the degree of technological maturity of products developed by academic research projects in the large area of Food Science and Technology analyzed through the application of four methodological proposals. In this way, it will be possible to assess the technological maturity of the proposed innovations and the existing opportunities in the market.

Making it possible to understand the types of difficulties experienced during each stage and, thus, provide more inputs with solutions to expand the number of Research, Development and Innovation (RD&I) Projects with the capacity to reach the Brazilian market.

MATERIAL AND METHODS

Universe, Population and Research Instrument

The Quantitative Approach of this study followed studies by [12]. highlighting the need to characterize and evaluate a target population by means of a questionnaire to identify which types of elements are directly linked to the problem, based on information on the theme of maturity in technology-based scientific projects, observing new visions or confirmations of practices usually already known. The methodology covers fundamentals of technological innovation, contextualization and application of the TRL tool related to the development of innovative products/technologies. Given the perceived importance of identifying phases and maturity in the technological development of academic projects in the area of food technology with emphasis on fish.

Obtaining and Adapting the Questionnaire for the Food Segment

The data collection on the selected academic projects was carried out based on the technological maturity tools developed by [13] and the Technological Institute of Aeronautics, supported by NBR ISO 16290:2015 [11].

It was observed the identification of factors related to functionality and activities considered essential for the development of the projects and that could serve as support for the development of the questionnaire applied in the food segment in the area of fish technology, in view of the need to meet the market trends regarding the development of products of greater convenience and healthiness.

Initially, a questionnaire was adapted under the criteria of NBR ISO 16290:2015, considering the proposal of a calculator presented by the study [13] and by the Technological Institute of Aeronautics, proposing a scale of technological maturity levels based on the TRL metric [11].

The questionnaire was composed of nine levels in order to allow users to bring to light specific and essential information about a given technological project. For the adaptation of the questionnaire, each element was analyzed, together with the advisors and researchers of the area of interest in question, who constitute the levels of the instrument, being detailed and discussed through reading and writing based on the available literature. In view of this, factors were aligned that facilitate the modification of the need for adjustments in the context of academic projects in the food segment.

In addition to adequacy, values between 0 and 5 points were assigned to the questionnaire to indicate the degree of adherence among the elements of the instrument.

Application of the Questionnaire between Projects in the Food Segment

The researchers and their respective projects were selected and identified according to the technology evaluated, through an electronic form with the respective free and informed consent form. The application of the questionnaire was carried out via Google Forms®, with the help of the videoconferencing platform Google Meet® for possible clarifications, as well as the Free and Informed Consent Form (ICF) to the interviewees. At the end of the application of the questionnaire among the selected projects, the data generated were summarized for the construction of the research path and alignment of the data obtained.

Treatment and Analysis of Results

Data collection was carried out through document analysis, where the answers collected by each proposal were carried out through the observation of the development of the projects regarding the application of the tool.

Thus, for the extraction of the results, 4 proposals were used for the methodological framework: 1) proposal according to NBR ISO 16290:2015 [11], since the proposal analyzed elements considered essential between the levels of the tool; 2) proposal based on the TRL calculator model based on the study of [13], where the results were verified from a linear model of sequential phase development; 3) weighting of the proposal taking into account the functional criticality of the elements of the tool, taking into account elements of the work of [14,15] and 4) proposal suggested by the author, considering elements of previous proposals and weighting of weights between elements and life cycle of the tool. Thus, to evaluate the influence of the elements contained in the questionnaire, observing the similarities of the answers between the projects and that could identify their respective levels of maturity.

Identification of different possible situations in the condition of technological development in a project

Characteristics of the project cycle and its relationship with possible situations in the academic context were considered, observing that the tool was adapted to meet the needs of research projects developed in the academic environment. Table 2 shows these different possible situations that characterize these conditions.

Table 1. Technological situation and development of the projects assessed

Situations in technological development	• The project presents its maturity level in a complete (complete) way, answering all the elements (questionnaire); or at least corresponding to a minimum considered satisfactory. • The project presents its level of maturity in a not full way, but with the transfer and applicability of the technology possible and viable. • Despite not fully meeting a certain level of maturity, the project cannot be prevented from carrying out its continuity in technological development, even if it does not guarantee its contemplation of the elements (essential and non-essential) constituent of the respective levels.

Source: Own authorship

Methodological proposal for the application of the tool considering essential elements between the levels of the tool

The levels of the TRL tool have activities considered essential, which define the objective that is intended to be achieved at each level of the tool. Thus, based on the number of elements evaluated at the levels of the questionnaire applied, a percentage was generated that considered the representation of what was completed in terms of compliance applied. The level was considered achieved from the contemplation of all essential activities carried out in accordance with ISO NBR 16290:2015 [11].

Methodological proposal for the application of the tool considering the TRL Calculator

The questions were analyzed according to the adequacy of the TRL questionnaire in the context of the study, taking into account the level and percentage of compliance with the elements of the tool groups being higher than 85% and conditions established in the ABNT ISO NBR 16290:2015 standard. The aspects of the proposal of the "TRL Calculator" raised by the study of [13] were framed in the model in the concepts of NBR 16290:2015 [11], establishing a tolerance for compliance at each level of the tool so that the technology is considered qualified for the next higher level, which considered the representation of what was accomplished in terms of compliance that are related to the levels of the instrument.

Methodological proposal for the application of the tool considering the influence of technological development on the project life cycle

The third approach considered the application of weights between elements considered functional, according to the elements of the questionnaire adapted for the food segment, considering a component of the work of [14,15].

A three-level measure was proposed, considering the Functional Criticality Factors (FCF), with the condition of identifying elements in which they are related to functionality and elements considered essential activities for technological development between the levels of the tool.

According to (Table 3), from the identification of these elements, weights were assigned between the levels of the tool and the segment of the projects evaluated was considered with greater relevance, together with the NBR 16290:2015 standard [11], as a degree of importance within each level of the tool in relation to the increase in the maturity of the technology,

Table 2. Critical Value of the Functionality of the Projects

Critical Value	Definition
3	• The condition has a fundamental need for the maturation and core functionality of the projects evaluated. No alternative or replacement is required.
2	• The condition plays a vital role in the core functionality of the projects. However, a workaround may be needed to better inform the projects by applying technologies that can be replaced by current ones, where they can be an acceptable penalty.
1	• The condition is improving in terms of project performance and other functionalities of the development process. However, there are several alternative technologies that can be substitutes and incur a minimal penalty.

Castiron: [14,15]

Methodological proposal suggested by the author for the application of the tool, considering its importance in the influence of technological development in the life cycle of the project – use of weights between the elements and levels of the life cycle of technological projects.

Proposal four, developed by the author, took into account the criticality factors identified in the previous section. The influence of these elements on the life cycle levels of technological projects is implemented. Remembering that the levels of tools are categorically formed from technological development. Table 4 shows the values implemented in the division of the groups in relation to the life cycle, taking into account values from 1 to 4.

Table 3. Quotation values on the influence of the life cycle

TRL Level	Multiplier Factor – Life Cycle
TRL1	1
TRL2	1
TRL3	2
TRL4	2
TRL5	2
TRL6	2
TRL7	3
TRL8	3
TRL9	4

Proposal to create an index of the relationship between the technological maturity and the development of the project in its life cycle, considering the risk and investment factors.

An analysis of the relationship between the technological maturity and the respective development of the projects between the levels of the tool's life cycle was established, taking into account the levels of investment risk of the project regarding its application.

The Adherent Technological Development Index (IDTA) refers to a relationship between the actual and ideal Indicator of the project, considering the investment and work applied to the project so far, and the existing technological risk for the continuity and implementation of that technology or product built after analysis of the methodological proposals applied to the 5 projects. The construction of the models could be verified according to equations 1, 2, 3 and 4 developed by the author, for the variables characteristics of the product or process resulting from each technology and segment.

$$Td = \Sigma\ (Ci \times d) \tag{1}$$

$$Fi = R\ \mathrm{D}\ T \tag{2}$$

$$Ft = \Sigma\ (Rt)\ \delta\ \Sigma\ (Ci \times d) \tag{3}$$

$$Id = Ft\ (ideal)/Ft(real) \tag{4}$$

Where, i = 1 to 9; Td – Work invested in technological development; Ci — Investment at each level of the TRL; d – f($N_{TRL)}$ (research workforce at each level) Elements of the questionnaire; Ft – Technological adhesion applicator; Rt — Present technological risk. The risk ranges from 0 (no risk), i.e., the chance of success is maximum, to 1 (maximum risk), signaling a minimum possibility of success in the technological implementation; Id — Index of adherent technological development; Ft (ideal) - Values that reflect ideal or plausible situations for the TRL level; and, Ft (actual) – Determined from the model.

Thus, Td is all the effort made for the constitution and employability of the technology employed, that is, all the work invested in technological development. The CI is related to the demand required for the TRL to be met, meeting each investment at the TRL level. f(NTRL) the direction that the research must establish to fulfill the requirement within the applied TRL. Rt is linked to the probability of occurrence of chemical, physical and/or environmental damage between industry-environment-society. Id related to efficiency and how the project adheres to the tool, referring to a relationship between the indicator of the actual project with the ideal, considering the investment and work applied to the project so far, and the existing technological risk for the continuity and implementation of that technology or product.

RESULTS

Result of the implementation of the proposal considering essential elements between levels of the tool

The approach took into account that the level of TRL could be defined when a project effectively achieved all the activities considered essential for each level of the tool. The lowest level of TRL with all essential activities completed is the grade of the tool indicated for this approach. Table 5 shows the levels and elements achieved in each of the five projects analyzed, under the conditions established in the ISO NBR 16290:2015 standard [11].

Table 4. Level of maturity of the projects taking into account essential elements of the TRL tool

TRL	Project A	Project B	Project C	Project D	Project E
1	X	X	X	X	-
2	X	X	X	-	-
3	X	X	X	-	-
4	X	X	X	-	-
5	-	-	-	-	-
6	-	-	X	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
TRL Level	**4**	**4**	**4**	**1**	**1**

The model was established to indicate the level of maturity of the projects, considering that each level has activities considered essential and, thus, meeting the objective of each level of the tool in the criteria of the established proposal. It is important to emphasize that all the elements for this approach are important for the maturation of the technology, but the activities taken as essences that are highlighted by ABNT ISO 16290:2015 [11], are indispensable for each level of technological development

The ABNT NBR ISO 16290:2015 standard does not define minimum frequency requirements for carrying out the technological maturity assessment [11]. The way to carry out the evaluation is at the discretion of the mediator who will apply the methodology. Table 5 describes the scope of each project on the conditions for identifying the key elements. It was identified that project C did not meet the elements of TRL 5, despite meeting the conditions to achieve higher TRL.

The NBR approach is not influenced by the scope of the project, since it follows the influence of activities considered essential, regardless of the branch of technology applied. Therefore, anticipating and managing the development along with the applicability of a new technology requires knowledge of essential pillars for the execution of the project, such as performance, budget, and schedule, this directly implies the initial experimental planning of the project for its success in the future [16].

In view of the conditions imposed in the methodology of this study (Table 2), it is established that project C managed to reach level 6 of the tool, despite the absence of the elements considered essential stipulated by ABNT ISO NBR 16290:2015 for this proposal. Since, despite not fully reaching a certain level of maturity (TRL Level 5), the project cannot be prevented from carrying out its continuity in technological development, even without ensuring its contemplation of the (essential and non-essential) constituent elements of the respective levels. The conditions were established, given the need to align the methodological proposals established in this study, based on the extraction of the results among the projects evaluated at the time of application of the tool.

The other projects evaluated in the proposal of this study were defined according to the table above this chapter, considering that gradually, with the increase in the levels of the tool, there was non-compliance with elements considered essential according to the established standard. They also did not meet the criteria established in this project (Table 2), which are necessary for the maturation of the projects evaluated.

The core activities described between each level of the tool are considered specific to each level of the tool and are relevant to any type of technology. NBR ISO 16290:2015, published by the Brazilian Association of Technical Standards (ABNT), focuses on spatial applications, but its text admits that the scale is used in other fields of activities, such as, for example, the information technology sector [11].

The adequacy of the scale between the requirements of the ABNT ISO 16290:2015 standard for other sectors, defines as a first step in the assessment of technological maturity the identification of the element/technology that will be measured, which may or may not be a component of a larger system. Once this is done, the next step is to define the performance requirements of the component at each level of the scale, as shown in the following table [11]. Thus, the development of a specific tool for the food segment can improve performance between the levels established within ABNT ISO NBR 16290:2015 for academic projects in the area of food engineering, science and technology.

Results of the application of the tool considering the TRL calculator model

The aspects of the "TRL Calculator" proposal raised by [13] were framed in the model of concepts among the elements considered as essences as established in the ABNT ISO NBR 16290:2015 standard [11]. In this approach, the degree of maturity achieved in each project was always the lowest on a full-scale scale (Table 6), taking into account the level and percentage of adherence to the elements of the tool groups higher than 85%, which considered the representation of what was completed in terms of compliance that are related to the levels of the tool.

Table 5. Level of maturity achieved by the projects under the conditions established by the TRL calculator

	TRL Score by Project									
	Project A		**Project B**		**Project C**		**Project D**		**Project E**	
TRL	Cal. TRL	NBR ISO	Cal. TRL	NBR ISO	Cal. TRL	NBR ISO	Cal. TRL	NBR ISO	Cal. TRL	NBR ISO
1	98%	X	100%	X	76%	X	51%	X	89%	-
2	93%	X	89%	X	78%	X	62%	-	89%	-
3	98%	X	100%	X	54%	X	86%	-	94%	-
4	90%	X	86%	X	50%	X	52%	-	82%	-
5	92%	-	66%	-	56%	-	0%	-	84%	-
6	100%	-	51%	-	86%	X	0%	-	91%	-
7	20%	-	0%	-	11%	-	0%	-	67%	-
8	17%	-	0%	-	0%	-	0%	-	0%	-
9	17%	-	15%	-	17%	-	13%	-	17%	-
Level TRL	**4**		**4**		**1**		**1**		**1**	

The projects carried out by A and B complied with the cycle of basic and applied research, according to the criteria defined by the TRL calculator method of the studies of [13]. The projects carried out by C and D did not reach the stipulated level of 85% in terms of conformity of the tool elements. On the other hand, Project E, despite meeting the conformities of the elements by the tool, did not meet the conditions established by ABNT ISO NBR 16290:2015. The conditions established regarding the essential elements, there is no minimum percentage of frequency for carrying out the technological maturity assessment. Evidencing the loss of necessary information between TRLs of lower levels due to the lack of integration of the acceptable margin of conformity of the elements.

The evaluated projects had a gradual increase between the levels of basic and applied research, although the projects of C, D and E did not meet the demands suggested by the methodological proposal used. It is worth mentioning that for the suggested calculation method, the TRL of the project could be established at the next level if it met the requirements of superiority conformities referring to 85% identity of the previous levels and obtaining the elements considered essential defined by ABNT ISO 16290:2015 between the levels of the tool. Whereas each level of the tool has its evolving functionality and need within each group established within it.

This model established, in a classificatory way, the evaluation process for the establishment and progression of the levels among the TRL's achieved. The proposal idealized by this model is a compression of the TRL potential achieved by the projects. However, difficulties are encountered in absorbing and establishing specific criteria required for academia in the field of fish technology. In this sense, the visualization of projects that have a certain pre-established field of action (research vision) and another with execution deficit (market vision) becomes necessary for further evolution.

The proposal considered the methodology of [13], but in view of the need to evaluate projects resulting from academic research and in the context of food science and technology, it was necessary to establish criteria that, based on the conditions observed in each project evaluated, would better classify it in terms of its technological maturity.

Knowing that the method developed by the studies of [13,11] has an approach originally directed to the aerospace sector segment, it was understood the need to make considerations about elements of the tool through situations observed between the projects as a relevant factor to classify the technological maturity among the projects that make up the development of this work.

The approach that took into account the proposal of the calculator [13], despite referencing a level in the projects, still loses information according to the need of the tool. This is due to the fact that the obligation of a level is only obtained when all tasks related to these levels have been completed in accordance with the conditions established in the proposal. In this way, the project may miss useful information in the maturation of the technology by neglecting the completed activities of levels above the level considered completed.

In addition, in this proposal, the projects were evaluated addressing all the elements of the base tool and making the necessary modifications for the area of fish technology. Highlighting that the proposal can differentiate or modify its result at the level of a TRL, considering ABNT ISO NBR 16290:2015.

The contextualization and interpretation of the results obtained by the TRL's define the innovation purpose of the project, including other factors such as market scarcity and competitiveness involving the emergence of new technologies and products that underlie the power of innovation [17].

Thus, the LRT level of a given project was classified by the authors of this study (Table 7), using the indicators found in the survey of project situations when submitted to the TRL questionnaire (Table 2), serving as documentary evidence to assess the context of the food segment. In addition to properties in the context of the study of the projects, observing the adequacy of the elements of the questionnaire on the projects evaluated on a continuous basis, determining which TRL would be established.

Table 6. Maturity level of the projects based on the information generated by the application of the TRL tool on the TRL calculator proposal

	Project A	Project B	Project C	Project D	Project E
TRL Level	6	5	4	3	6

Projects A and B complied with the cycle of basic and applied research, according to the criteria defined by the TRL calculator method, although it did not meet the conditions of the NBR, there was an understanding of growth up to levels 6 and 5, respectively, being used as a factor to determine the maturity levels according to the conditions exposed in (Table 2).

The project (C), despite not meeting the conditions of 85% of conformity between the elements of basic and applied research, it was possible to observe the conditions of the essential elements between the TRL and a significant increase between the validation of the projects, from the TRL (5; 6) that served as support to determine a level of TRL 4, in view of its increasing development under the conditions of the NBR ISO and conditions described (Table 2) in the methodology of this study.

Having a situation contrary to the project of C, the project E, despite meeting the conformities of the elements of the tool, did not meet the conditions established by ISO NBR 16290:2015 essential elements of the tool, but the conformity of the elements as a whole (TRL, 6) was considered based on the conditions of the TRL calculator questionnaire [13], thus avoiding the loss of necessary information between TRLs of lower levels due to the lack of integration of the margin acceptable conformity of the elements.

It was possible to observe that projects C, D and E presented difficulties to reach their level of maturity in a full way, however, the transfer and applicability of the technology was possible and viable, evidencing the need to incorporate conditions to reach the level of TRL in a way directed to the context of the study. The questions that did not adhere to the TRL's of basic and applied research served as a support point to visualize the main difficulties of the projects for a possible future solution of advancement to a higher level. The verification of maturity levels aims to ensure, in the context of innovation, the best relationship between factors such as course, risk and success in the market [22].

Result of the application of the tool considering its importance in the influence of technological development between the elements of the tool – use of weights between the elements of the tool

For this proposal, components of the authors were used [14,15], considering that the context of the methodology used among the authors was not used for this study. Where weights were weighted between the elements of the instrument, based on the conditions established in (Table 3), given the need to align factors of greater relevance to the food segment. These weights of functional criticalities were considered according to the elements of the questionnaire adapted for the food segment together with the NBR 16290:2015 standard, as a degree of importance within each element on the levels of the tool in relation to the increase in the maturity of the technology. The standard, on the other hand, is the main one that regulates the tool in Brazil.

The PCF approach informs the complete percentage of all levels of the TRL for each project, evaluating in a more targeted way for the context of the research addressed (food segment), making an analogy of how much would be necessary for a project to reach a full level of maturity in the tool. Whereas, in order to reach a level, the percentage of compliance of the elements of the tool groups is equal to or greater than 85%.

The PCF proposal was developed based on the components found in the authors' studies [14,15], there was a direction to the context of the study, given the association of weights between the elements of the tool, according to the need to develop the projects in terms of functionality. (Table 8) shows the performance of each project in relation to the performance between each element of each level of the TRL tool.

Table 7. Level of maturity achieved between projects on the application of weights between elements of the TRL tool.

TRL Level	Project A	Project B	Project C	Project D	Project E
1	96%	100%	78%	45%	89%
2	92%	94%	88%	66%	93%
3	99%	100%	40%	80%	94%
4	87%	88%	37%	43%	84%
5	95%	63%	61%	0%	83%
6	98%	45%	88%	0%	91%
7	22%	0%	6%	0%	64%
8	16%	0%	0%	0%	0%
9	16%	17%	19%	15%	19%
TRL Project	**6**	**4**	**1**	**1**	**3**

The PCF approach considers all levels of the tool with the same weight, regardless of whether they are larger or smaller, taking into account the need for the level of the tool in view of the stipulated criteria of greatest interest for the adopted segment. Thus, it should be noted that the activities of the higher levels of TRL have similar weight to the lower levels of technological maturity.

A's project reached the TRL levels related to experimental development, defined with elements responsible for proof of concept, verification and demonstration of the technology developed in a relevant environment for technological maturation.

Projects B and E fulfilled the cycle of basic and applied research, considering the percentage of 85% compliance of the elements of the tool. Projects C and D, despite not meeting the conditions of 85%

conformity between the elements of TRL1, it was possible to observe an increase between the validation of the projects (Table 8) and the later levels of the tool. Highlighting the loss of important information between the development of the project.

Despite the indispensability of implementing a percentage of compliance between the levels of the TRL tool, given the need to standardize the tool among the elements served. It is notorious that the condition of stipulating a percentage of 85% to define a level of technological maturity in relation to the elements, loses information considered essential for the maturation of the projects, considering that some developed projects do not necessarily need to execute their technologies from basic research.

In view of the definitions of the levels of technological maturity described in this approach, the conditions were applied (Table 2), given the need to adapt the situations found in the analyzed projects to the proposal, giving a degree of importance to the need for the projects (Table 9) according to the conditions of their development.

Table 8. Maturity level of the projects based on the information generated by the application of the TRL tool, on the proposal for applying weights between the elements of the tool

	Project A	Project B	Project C	Project D	Project E
TRL Level	6	4	2	3	6

It should be noted that projects A and B did not have significant changes between the conditions imposed (Table 2) for this proposal, but it is important to discuss the need to understand the needs to reach higher levels, understanding their respective percentages of completeness that can help in the maturation of the projects about what is being done and what needs to be done to reach greater maturity.

Projects C and D did not fully reach a certain level of maturity, even so, they were not prevented from carrying out their continuity in technological development, even if they did not guarantee their contemplation as to the constituent elements of the respective levels. Thus, the loss of necessary information between TRLs of lower levels is avoided due to the lack of integration of the acceptable margin of conformity of the elements.

Project E fulfilled the necessary conditions for experimental development, even with the need for a solution to better support the project, with the transfer and applicability of the technology.

It is notorious the increase in the need for application and use of tools that can validate academic projects by government agencies and educational institutions regarding the validation of projects developed in academia. The study of [18] highlights the need to apply the use of the technological maturity tool in products and technologies under development in higher education and Science and Technology institutions, from the perspective of the positive effects on the quality of processes and assistance in the tasks of modernization of practices related to innovation.

Result of the application of the tool, considering its importance in influencing the technological development of the project – use of weights between the elements and levels of the life cycle of technological projects.

The development of this proposal was influenced by the previous proposals presented in this work, given the need to develop a method that would meet the needs of the study context. Indicators were developed between the elements of the tool and the life cycle (Table 4) that represent each level of the TRL tool, in order to define it for each project evaluated, in order to outline mechanisms aimed at the food segment, aligned with the factors related to the need of the context of the projects evaluated and the conditions that best respond to them.

The criteria of the proposal considered that the parameters stipulated by the other proposals took as reference other methodologies, not considering that the analyzed projects had their development linked to research in the academic field. The parameters were defined based on the need for deeper visualization and to drive academic projects to the market in terms of the segment of interest, since it is difficult for proposals to delegate their research to achieve higher levels of validation according to the TRL tool.

The weighted approach model considered the need to meet the demand for projects (Table 10) in the food segment with emphasis on fish technology (with academic participation), with suggestions that could align factors related to need and functionality. This suggestion aligned the weight values to the levels of the tool's life cycle, leading to criteria that could be applied to fish technology, which would be a way to determine that TRL1 would have equal significance to TRL9, intrinsically evaluating each element of the instrument according to the need of the proposal.

Table 9. Level of maturity achieved by the academic projects on the conditions established in the proposal for the application of weights between the elements of the tool and the life cycle of the TRL.

TRL Level	Project A	Project B	Project C	Project D	Project E
1	96%	100%	78%	45%	89%
2	92%	94%	88%	66%	93%
3	99%	100%	40%	80%	94%
4	87%	88%	37%	43%	84%
5	95%	63%	61%	0%	83%
6	98%	45%	88%	0%	91%
7	22%	0%	6%	0%	64%
8	16%	0%	0%	0%	0%
9	16%	17%	19%	15%	19%
TRL Project	**6**	**4**	**1**	**1**	**3**

The model developed by the author considers an activity of greater relevance to the context of the study, compared to the other proposals that do not take into account elements of interest to the technology, causing loss of information that would be of greater interest for the development of the projects evaluated. Tools with TRL-based foundations are constantly developed with adaptations related to the areas to which the projects relate. Each tool developed has adjusted descriptions at each level of the TRL, helping the creators of the projects [19]

The direction of the proposal was aligned with the conditions for the improvement of the projects developed for the fish area, in view of the need to contribute to the reduction of validation errors, with regard to its application in the face of the needs of the consumer market. In addition to configuring weighting factors between the cycles of the tool with the elements of each level, the results were found (Table 11), based on the criteria stipulated for the context of the study (Table 2) that adapted the tool to the academic context.

Table 10. Level of maturity of academic projects based on the information generated by the application of the TRL tool, the proposal for the application of weights, the elements and the life cycle of the TRL tool.

	Project A	Project B	Project C	Project D	Project E
TRL Level	6	4	2	3	6

There was no difference between the levels of the TRL of the previous proposal (model 3), but it is worth mentioning the need to consider information regarding the functionality and approach of the elements considered essential for the development of the tool, considering factors related to the technological segment of the projects evaluated, through the levels of their development.

The precision of the criteria established in this proposal also has the potential to catalyze information necessary for the maturation of technologies between projects and identify opportunities for technological development through the targeting of elements between the levels of the tool, supporting a continuous maturation of efforts between food science and technology into innovation widespread in the market that generates significant economic results.

Proposal to create an index of the relationship between the technological maturity and the development of the project in its life cycle, considering the risk and investment factors

In order to better direct the tool to the academic context, given the inconsistencies of the evaluated works, in view of the conformity of the elements between the levels of the tool, a model was identified (proposal developed by the author) and the adherent development index was applied, to which the projects were submitted and analyzed, considering intrinsic and extrinsic factors that affect their development and/or execution.

The score was obtained (Table 12) by the investment for the development of each project, conditions established in the proposal for the development of each project, taking into account the conformity of the weighted elements to the levels of the TRL tool, and the use of equations (1, 2, 3 and 4) gradually to evaluate the efforts applied in line with the work developed during the TRL evaluations. demonstrating the current situation of technological maturity of the project, aligning the requirements of each level regarding the level of technological maturity, directed proportionally to the factor of the project via intrinsic and extrinsic characteristics. The risks in the development of each evaluated project were considered zero, and it was understood that this work did not develop risk factors for the evaluation of the projects based on the conditions applied among the proposals developed.

Table 11. Sum of efforts, investments and adherence rate for each academic project considering the weighted values according to the number of elements of the instrument

Projects	Investment	Sum d	Risk	DTA Indicator	Adherence Rate
One	30000	56,27	0	1688237,06	56%
B	32000	42,83	0	1370619,48	46%
C	34000	35,57	0	1209526,10	40%
D	30000	20,96	0	628700,44	21%
And	31000	57,78	0	1791038,50	60%
Ideal	30000	100	0	3000000	100%

It is noted that projects A, B and E obtained the highest values among the conditions imposed for the elaboration of the index. The project adherence profile corresponds to a relevant score in the technological maturity index of a project, where the current situation of the project is demonstrated according to the requirements of each condition imposed, reflecting how mature the technology that the market needs is.

Specimens C and D showed the lowest proportions when compared to the 5 projects evaluated. The application of the level of adherence is directly linked to the intrinsic characteristics of the projects, considering that lower scores will require an improvement action plan in the short, medium and long term in order to improve their technological development.

Studies carried out by [21], sought to analyze, critical success factors of academic projects, which have financial support from training agencies, in order to know the levels of application and importance of these projects that receive financial support, the data were collected through an applied questionnaire and summarized by the level of importance where values of (1 - 39.99%), Projects of little importance and low application (40 - 59.99%) would be of medium importance and medium application, and (60 - 100%) of high importance and high application. Thus, comparing the adhesion values with those found here, it can be seen that the minimum would be considered "initial" (project D) and the maximum as "improved" (project E). Thus, the higher the maturity, the shorter the delay, the lower the cost overrun, the higher the percentage of execution of the planned scope and the greater the success of the projects.

In view of the results of the table (Table 12), the relevance of the application of the technological maturity tool in academic projects is clear, in view of the need to address contents related to management, strategies, analysis of the internal and external environment of the project, qualitative and quantitative aspects related to the evaluated project that can guarantee from survival to competitive advantage in the current market.

DISCUSSION

The creation and application of the instrument in a questionnaire model enabled the validation of the aspects that cover food science and technology and improved the analysis of the proposals to identify the level of maturity among the academic projects, in addition to providing information on what measures should be carried out for the progress of the activities developed in the academic context.

The results of the application of the questionnaire and their respective percentages regarding completeness can help several universities to identify the monitoring of the progress of their projects and the designation for better maturity of the proposals developed.

It was possible to identify a great difficulty among the projects to advance in the face of the levels of experimental development, industrialization, production and commercialization of the products among the four proposals suggested by this study. This information can be extracted by educational institutions and used to outline a better direction that solves problems related to technological development that can help and define the projects developed in the academic field.

Some considerations were pointed out regarding the help of technological risks during its scientific basis between basic and applied research, and when the levels of technological readiness under analysis are still at lower levels, it becomes possible to redirect the development of the technology and techniques chosen to obtain the result. While in the higher TRL, the project tends to undergo only improvements until the desired technological maturity is reached.

It is worth mentioning that the development of a project does not necessarily go through all phases when it comes to the development of a product or process. In some cases, projects involve improvements in products and processes and some of the existing knowledge can start in later phases, such as experimental development, for example.

Thus, based on the factors analyzed by the questionnaire to be filled out, the technology collaborator in the projects developed by the graduate programs can define goals and, subsequently, identify risks present during the development of the products. Thus, demonstrating that the tool proves to be effective for risk management and maturation of technological products developed by academia.

The graduate responsible for the development of the project will be able to measure the maturity of the technology, contributing to its evolution and reducing the risk of a lower degree of maturity and lower risk of implementation when compared to technologies of lower levels. The results were obtained by means of extraction and summarization in *Microsoft Excel*®, for each proposal analyzed, generating the average of the percentages of responses of the projects among the established models.

When analyzing the approach, we can see that the application of essential elements on the levels of the tool ended up being limited in the sense of calculating the level of technological maturity of the projects, since it only considers which level was reached if all the activities related to this level are completed. In addition, the proposal is not influenced by the scope of the project, since it follows the influence of activities considered essential, regardless of the branch of applied technology.

As for the TRL Calculator model, limitations were found in the sense of identifying the level of technological maturity, considering that the level was only reached if all activities considered essential according to NBR 16290:20415 were completed, in addition to the percentage factor of 85% between the elements, defined in this work proposal as the limit to consider a level completed. It is worth mentioning that the model was developed for the aerospace engineering segment, thus being redirected to another area, which could make data extraction difficult.

When the model was applied to the projects, it was found that the PCF approach generated satisfactory results in the evaluation of the conformity of the elements contained in each level, considering that the elements were directed to the context of the work, since it is considered that a level would be reached if the recommended percentage among the activities related to it was completed. It is important to highlight that the completion rate must be reasonable, considering that the absence of the fee results in the loss of relevant information for the maturation of the projects to the next level.

Despite the direction, the proposal loses information that is important to highlight, regarding the need to evaluate the elements according to the level of the tool, reaching the understanding that the higher its level of maturity, the lower the risks of validating the project in a real system.

The proposal of weight in view of the needs of the food segment together with the levels of the life cycle of the TRL tool proved to be effective, identifying factors that are related to the academic projects of this segment, which could be analyzed for decision-making in view of the need for evolution of academic projects for implementation in society.

The weight-based approach proved to be the most flexible with regard to the analysis of the maturity level of the projects developed in the area of fish technology. Thus, evidencing that the concepts addressed in relation to the other proposals would be the absence of lost reports among the criteria and the evidence that the evaluation is more adaptable for projects in technical areas.

The results of the suggestions for the weight-based approach model developed by the author were analyzed using data generated in *the Microsoft Excel® program,* where for each criterion used for this model, the conditions that best directed to the context of the study were used. Therefore, check the efficiency percentage of 85% to consider an activity completed. Thus, it makes it possible to quantify the accuracy of the results obtained and to define the conditions that best suit the needs of the projects regarding the analysis of the adherent development index.

The Adherent Technological Development Index (IDTA) analyzed a relationship between the indicators of the real development of the projects and the ideal, based on the results found in the proposal defined by the author. The development of the project, investment and work applied so far were considered, as well as the existing technological risk for the continuity and implementation of that technology or product, allowing to quantify the accuracy of the results obtained and define the criterion that best suits the needs of the projects regarding its application in a real system.

Thus, the model would be recommended for the food segment aiming at the inclusion of weights directed to this planning between the life cycle of the tool and its elements contained in each of its levels. However, in addition to assigning criteria that can meet the needs of academic research in the face of the TRL tool, however, for another area, a new evaluation would be recommended according to the interest of the research.

In order to better disseminate the objective proposed by these projects, training is recommended for employees of educational institutions, so that they understand the need for the tool and its use in the academic context so that it can be disseminated in the most varied areas of research, teaching, extension and innovation.

These trainings can be done through courses, congresses, lectures with partnerships with agencies that already use the tool for better guidance in the development of projects. In this sense, government entities are spreading the need for the application and use of tools that can validate academic projects, recently leading to the publication of MCTI Ordinance No. 6,449, of October 17, 2022, by the Ministry of Science, Technology and Innovations, which institutes a technological maturity calculator based on TRL [20].

As for the prospects for increasing TRL in academic projects in the area of fish technology, in the last two decades, more than 7,000 studies have shown the use of emerging technologies to transform fish muscle into a new product for human consumption and more than 2,000 have shown the use of fermentation processes to transform discarded solid waste into silage for animal feed. However, the research was carried out on a laboratory scale, i.e., basic and applied research (TRL 1, 2 and 3).

When developing a new product or by-product in a pilot plant, the manufacturing process can be evaluated and controlled, making it possible to plan and define the steps, kinetic and operational parameters that directly affect the production process and the basic functionalities of the product, similar to the industrial process, but on a smaller scale. Thus, the project will have the flexibility to test and evaluate all process conditions.

Despite the challenges, the application of the TRL tool can ensure product validation in the laboratory sector and, subsequently, in an operational environment, reaching the industrial scale. For the TRL 4, 5, 6 and 7 scales, the actions will be focused on the production of the prototype product, evaluating the effects of processing, calculating the capital and operating costs of the process. In this way, regularizing the product from the perspective of industrial inspection and testing the product in the market. However, it is known that going through the "valley of death" in the demonstration phase of product prototype development is the biggest challenge to overcome. The need to carry out the tests in a demonstration plant and the capital costs make the research inaccessible to ICTs. For entrepreneurs, it would be a risk to invest in basic and applied research without the process being qualified and finalized and the chances of the product reaching the market being proven.

The implementation of a demonstration pilot plant for the development of the new product allows the integration between the Company x ICT's x the Government and the strengthening of the fish production chain. Product development, controlled process, execution of the production flowchart, operational reports, describing and documenting the results, estimated operating and capital costs for the small and medium producer and the implementation of the product in the market (TRL 8 and 9).

CONCLUSION

The present research concluded the proposed development objective of proposing a tool based on the TRL (Technology Readiness Level) for the food sector with emphasis on fish technology, addressing technical, economic, political-legal aspects based on NBR ISO 16290:2015 and the tools developed by the TRL calculator and the Technological Institute of Aeronautics.

It was possible to evaluate the technological maturity of academic projects in the area of Food Science and Technology with emphasis on Fish Technology. This evaluation was carried out through four different approaches, concluding that the last proposal, developed by the author, proved to be more appropriate to the context of the study.

It was also possible to understand how the evolution occurs in the development of a technology based on the elements of each level of the TRL tool. This information can be used to discuss future progress alternatives regarding its application in real production systems.

This article refers to several activities that still need to be carried out for the enrichment and maturation of the assessment instrument. The first of them is precisely to analyze other projects in the area of Food Science and Technology in order to understand the need for the tool for the context of the food segment based on academic studies.

The creation of the instrument made it possible to validate the aspects that cover food science and technology in the activities listed in the questionnaire with more professionals in the area, thus aiming at a greater consonance of the questionnaire with the reality of the sector. Finally, the adherence index applied during the development of the tool made it possible to relate factors considered determinant to enable the continuity of an analyzed project, in its respective life cycle of technological maturity.

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