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Priority technologies and innovations in the fishing agribusiness by the year 2032. Foresight study through the Delphi method[1]

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Abstract

Introduction. This paper is presented in the framework of the project "Alternatives for the use of by-products derived from fishing agribusiness", Universidad del Cauca, through the research group: Harvesting of Byproducts and Agro-industrial Residues, ASUBAGROIN, which aims at the development and implementation of technologies and innovations for the use of by-products generated by the fishery activity, in order to improve research and innovation capacities in that specific subsector. **Objective.** The purpose of this paper is to prioritize innovations in fish by-products by consulting experts to identify innovation, technology and knowledge management activities for the institutions involved in the sector. **Materials and methods.** The methodology consisted in the application of the Delphi method through a structured and anonymous survey with national and international experts on topics related to the fish farming industry, using a questionnaire of 143 items divided in five groups, in order to choose priority topics. **Results.** The questionnaires were filled out by 37 experts from Colombia, Brazil, the United States, Mexico and Uruguay; a total of 54 priority themes were obtained, corresponding to 38% of the topics presented. Among the topics of greatest consensus and mode are the formulation of concentrated foods, partial substitution of fishmeal, extrusion of concentrated foods, Omega-3 rich oil, probiotics, bioaccumulation, microalgae of fish processing wastewater, technological appropriation, technological evaluation, measurement of intellectual capital, innovation processes, and technological strategies. **Conclusions.** One of the main contributions of the study is the benefit for current players in the fish innovation system and new ones, such as technology development centers and new ventures, since they will have a route map of innovations on which to focus their investments and project initiatives.

Key words: delphi, fishing agribusiness, priority technologies, experts, consensus.

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Tecnologías prioritarias e innovaciones del sector pesquero para el año 2032. Estudo de prospectiva por el método Delphi

Resumen

Introducción. Este artículo se presenta en el marco del proyecto "Alternativas para el uso de subproductos derivados de la agroindustria piscícola", Universidad del Cauca, a través del grupo de investigación "Aprovechamiento de Subproductos, Residuos y Desechos Agroindustriales", ASUBAGROIN, relacionado con la aplicación de tecnologías e innovaciones para el uso de los subproductos generados por la actividad piscícola, con el fin de mejorar las capacidades de investigación e innovación en ese subsector específico. **Objetivo.** El propósito de este artículo es priorizar innovaciones en subproductos piscícolas a través de consulta a expertos, así como actividades de gestión de innovación, tecnología y conocimiento para las instituciones pertenecientes al sector. **Materiales y métodos.** La metodología utilizada consiste en la aplicación del método Delphi, a través de consulta anónima y estructurada a expertos nacionales e internacionales en temas relacionados con la industria piscícola, con un cuestionario de 143 ítems en 5 grupos, para elegir los temas prioritarios. **Resultados.** Los cuestionarios fueron diligenciados por 37 expertos de Colombia, Brasil, Estados Unidos, México y Uruguay; un total de 54 temas prioritarios fueron obtenidos correspondiente al 38 % de los temas presentados. Entre los temas de mayor consenso y moda están la formulación de alimentos concentrados, sustitución parcial de harina de pescado, extrusión de alimentos concentrados, aceite rico en Omega-3, probióticos, bioacumulación, microalgas de aguas residuales de procesamiento de pescado, apropiación tecnológica, evaluación tecnológica, medición de capital intelectual, proceso de innovación y estrategias tecnológicas. **Conclusiones.** Uno de las principales contribuciones del estudio está relacionada con los actuales actores del sistema de innovación piscícola y de los nuevos, tales como centros de desarrollo tecnológico y nuevos emprendimientos, ya que ellos tendrán un mapa de ruta de innovaciones sobre las cuales enfocar sus inversiones e iniciativas de proyectos.

Palabras clave: delphi, agroindustria piscícola, tecnologías prioritarias, expertos, consenso.

Tecnologias prioritárias e inovações no setor pesqueiro para o ano 2032. Estudo de prospectiva através do método Delphi

Resumo

Introdução. Este artigo se apresenta no marco do projeto "Alternativas para o uso de subprodutos derivados da agroindústria piscícola", Universidad del Cauca, através do grupo de investigação "Aproveitamento de Subprodutos, Resíduos e lixo Agroindustriais", ASUBAGROIN, relacionado com a aplicação de tecnologias e inovações para o uso dos subprodutos gerados pela atividade piscícola, com o fim de melhorar as capacidades de investigação e inovação nesse subsetor específico. **Objetivo.** O propósito deste artigo é priorizar inovações em subprodutos piscícolas através de consulta a especialistas, assim como atividades de gestão de inovação, tecnologia e conhecimento para as instituições pertencentes ao setor. **Materiais e métodos.** A metodologia utilizada consiste na aplicação do método Delphi, através de consulta anônima e estruturada a especialistas nacionais e internacionais em assuntos relacionados com a indústria piscícola, com um questionário de 143 itens em 5 grupos, para eleger os assuntos prioritários. **Resultados.** Os questionários foram diligenciados por 37 especialistas da Colômbia, Brasil, Estados Unidos, México e Uruguai; um total de 54 assuntos prioritários foram obtidos correspondente a 38 % dos assuntos apresentados. Entre os assuntos de maior consenso e moda estão a formulação de alimentos concentrados, substituição parcial de farinha de peixe, extrusão de alimentos concentrados, aceite rico em Omega-3, probióticos, bio-acumulação, microalgas de águas residuais de processamento de peixe, apropriação tecnológica, avaliação tecnológica, medição de capital intelectual, processo de inovação e estratégias tecnológicas. **Conclusões.** Um das principais contribuições do estudo está relacionada com os atuais atores do sistema de inovação piscícola e dos novos, tais como centros de desenvolvimento tecnológico e novos empreendimentos, já que eles terão um mapa de rota de inovações sobre as quais enfocar seus investimentos e iniciativas de projetos.

Palavras chave: delphi, agroindústria piscícola, tecnologias prioritárias, especialistas, consenso.

Introduction

This research work was developed in the framework of the project "Alternatives for the use of by-products derived from fishing agribusiness" from Universidad del Cauca, through the research group: Harvesting of Byproducts and Agro-industrial Residues, ASUBAGROIN. This research group aims at the development and implementation of technologies and innovations for the use of by-products generated by the fishery activity, in order to improve research and innovation capacities in that specific subsector.

One of the components of the project deals with the prioritization and identification of technological innovations, technologies, and technology, innovation and knowledge management activities related to fish by-products in Colombia in the year 2032. This led to a specific foresight study through the application of the Delphi method, with the participation of experts from Colombia and other countries, with experience in this subsector.

This article presents the results of the application of the Delphi method during two rounds on topics such technologies and innovations, and aspects related to technology, innovation and knowledge management, which are a priority in the fishing agribusiness (with emphasis on byproducts that can be obtained from trout and tilapia). The study was conducted through an anonymous survey with experts in five groups: animal feeding, processes, functional products, biodiversity and bioprocesses, and technology, innovation and knowledge management. Firstly, the paper reviews the antecedents on the applications of this method, its conceptualization and main characteristics; next it presents the methodology used in the two rounds, the statistical analysis used, and the results on the common themes in both rounds with a high mode, 4 or 5, and a high percentage of consensus. Finally, it presents the result analysis, discussion and conclusions sections.

Theoretical framework

Fishing and aquaculture in Colombia represent two important sectors of food production for domestic consumption and exports, and they are two multipliers of local economy that contribute to overcoming poverty in rural areas. The country has an important potential for the development of aquaculture, which is based on a great continental and marine water richness, an adequate climate for the cultivation of species, and a wide range of aquatic organisms capable of domestication (AUNAP, 2014).

Fish farming in Colombia brings together multiple economic agents involved in the different activities for production and marketing of the final and intermediate goods in the value chain. These activities are related to fingerling production, fish raising and fattening, fish processing and marketing channels (Espinal, Martínez & González, 2005).

In the fishing chain several problems arise, one of which has to do with production, as it is made in ponds or water mirrors for subsistence fish farming. Other issues that arise in the sub-sector are related to the use of by-products of the fish farming industry, since it is sensitive to a reduction of the purchasing power of the people. Fish farmers are faced with problems of public order, given that most of the raw materials for the production of the concentrates are imported (Ministerio de Agricultura y Desarrollo Rural, 2011).

From the technological point of view, the obtaining of fish derivatives with high or medium technological level is almost nil. The technology applied in the production and commercial management of the fishing resources is deficient, and there is no transformation or handling of byproducts of the Aquaculture industry such as viscera, skins, scales, and heads, among others. These byproducts represent about 12% of the total weight of the production but there is no generation of commercial by-products, except for some sausages and charcuteries; and applications from biotechnology remain scarce (Ministerio de Agricultura y Desarrollo Rural, 2012).

The mentioned problems, accompanied by a scarce or no application of technological management tools, as in the case of foresight studies, do not show an encouraging scenario or evidence of improvement alternatives when marketing products and byproducts at national level. As a matter of fact, the bets on technological innovations in by-products in the fishing sector are not clear, so that specific foresight studies using the Delphi method could help decision-makers set bets on technologies, technological innovations and technology and innovation management activities that can be adopted by stakeholders in the fishing sector.

Foresight is a science that sets its goal in the development of tools to plan knowledge of the future.

Gastón Berger (1967), one of the founders of the discipline, defines it as "the science that studies the future to understand and be able to influence it; although sometimes the term futurology refers to other disciplines not based on the scientific method".

According to Jordi Sierra (1992), it is defined as "the science that studies the future to understand and be able to influence it. Although in fact it is, paradoxically, a science without object that moves between the need to predict what can happen and the desire to

invent the best possible future. Although becoming cannot be accurately predicted, we can imagine our preferred tomorrow".

In turn, Luke Georghiou (1996) describes foresight as "a systematic means of assessing scientific and technological developments that could have a strong impact on industrial competitiveness, wealth creation and quality of life".

With the contribution from these concepts and many more scholars it can be claimed that foresight is a science that sets its goal in the development and use of tools to know and plan the future, with high risks. It is the foresight of the future with the aim of implementing timely actions in the present, leading us to situations that are longed for and not fortuitous.

In this sense, there are groups of thinkers who have aligned themselves under this concept. Within the schools of foresight is the Anglo-Saxon approach, for which the Delphi method constitutes its core tool. This method presents its own characteristics and differentiates the Anglo-Saxon school from others, such as the French, with emphasis on scenarios, and the Australian, which is more related to social perspective.

The Delphi concept

Linstone and Turoff, quoted by Landeta (2006), define the Delphi concept as the "method of structuring a group communication process that is effective in allowing a group of individuals, as a whole, to address a complex problem".

Valdés (1999) and Moráguez (2001), quoted by Moráguez (2006), explain that the Delphi method consists in the systematic use of the intuitive judgment of a group of experts to obtain a consensus of informed opinions. It is essential that these opinions are not manipulated or influenced by the criteria of some other experts.

This technique seeks to get specialists to agree on a problem raised. The method is based, then, on the principle of collective intelligence, which tries to achieve a consensus of opinions expressed individually by a group of people carefully selected as experts qualified in the subject, by means of successive iteration of a feedback questionnaire with the average results of the previous round, with the application of statistical calculations (Linstone and Turoff, 2002; Powell, 2003).

As for Delphi features, it is a systematic and interactive method that relies on a panel of independent experts, using a number of expert opinions in anonymous communication with feedback; it is a flexible consensus-building tool in which judgments are summarized and resubmitted in order to refine the problem across a wide range of fields (Helmer & Rescher, 1959). According to Rowe and Wright (1999), Delphi has four important characteristics: anonymity, interaction, controlled feedback, and statistical aggregation of a group of responses.

Method process

The three major phases of the Delphi method can be seen in Figure 1.

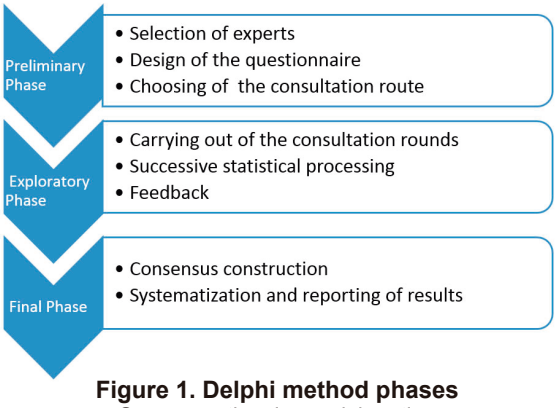

Figure 1. Delphi method phases
Source: authors' own elaboration

Origins of the method

Nielsen and Thangadurai (2007) mention that the Delphi method began in 1940. According to Landeta (2006) and Dalkey and Helmer (1963), its origin is attributed to the RAND Corporation (Research and Development) in the late 1940's in Santa Monica, in a study that was published twelve years later. The method originated from a Cold War study to identify potential U.S. industrial targets and their vulnerability to Soviet munitions (Fletcher & Marchildon, 2014; Rowe & Wright, 1999; Linstone & Turoff, 1975).

According to Castelló and Callejo (2000), Delphi is a method that has been used in national exercises of technological foresight; it began to be used by Japan in its five-year prospective exercises in order to define the country's long-term growth direction.

For Abend (2002, p. 32), "the Delphi method proposes a question and invites the opinion or solution from a group of highly qualified experts. The process is conducted anonymously".

The Delphi method has had applications in many sectors around the world, with a marked emphasis on foresight studies in technology and innovation (Van der Duin, 2006; Castelló & Callejo, 2000). However, since its beginnings in the 1940's, it has undergone changes in its methodology to such an extent that the applications presented in recent years correspond more to a "modified Delphi", characterized by anonymity, the presentation of different alternatives to consensuses and a smaller number of rounds, among other aspects (Cabero, 2013).

Several applications of Delphi studies around the world, with their purposes, country of origin and number of experts, can be observed in Zartha (2014). There are notable applications in Spain in the pharmaceutical sector, probiotics, social sciences and information and communication technologies; in the United Kingdom, in web 2.0; in Finland, in predicting market variables and CO_2 emissions; in Canada, in health and carpal tunnel syndrome; in France, in influenza epidemics; and in the United States, in e-commerce, the Millennium project, developing leadership profiles of new products and online education.

Among the Delphi studies analyzed in Colombia we find works on engineering teaching, biodegradable packaging, nutrition and food policies, sustainable production plans in natural parks, the Colombian electricity sector, the leather sector, footwear and leather goods, the agricultural sector, and construction activities, among others. The analysis of some of the applications of the method in Colombia is presented in Table 1:

Table 1. **Applications of the Delphi Method in Colombia**

Author	Country or organization	Title and purpose	Number of rounds used	Number of experts	Statistical index used or suggested
Diego Hernández, Jorge Ibáñez, Yuleidys Ortiz, Luz H Soto	COLOMBIA Universidad Nacional Abierta y a Distancia UNAD, Bogotá.	Foresight study for the design of strategies that contribute to the formulation of sustainable production plans in Colombia's natural parks by the year 2020.	Not mentioned	Not mentioned	Not mentioned
Carlos Eduardo Niño Castellanos, Benjamín Andrés Manjarrez Zárate	COLOMBIA Universidad Nacional Abierta y a Distancia UNAD Bogotá	Foresight and strategic plan for the civil works construction company MOVITEC Ltda, for the year 2023.	Not mentioned	Not mentioned	Not mentioned
Mauricio Díaz Escorcia, Santiago Hernando Parra Guerrero, Iván Guillermo Salavarrieta Díaz	COLOMBIA Universidad del Rosario, Bogotá	Foresight study of the conditions of the Colombian labor market for graduates of the Administration Faculty of Universidad del Rosario for 2017.	Not mentioned	Not mentioned	Not mentioned
Jhon Wilder Zartha, Clara Marcela Mosquera, John Jairo Escobar, Wilder Perdomo, Héctor Estrada Cadavid, Ricardo Llerena	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Foresight study methodology for a basic university science center by the year 2020.	3	29 mathematicians, 35 physicists and 26 chemists	Mode, consensus percentage
Jhon Wilder Zartha, Gloria Liliana Vélez, Luis Jaime Gutiérrez, Juan Felipe Herrera	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Foresight study for the faculty of Computer Engineering of Pontifical Bolivarian University by the year 2015.	3	30 in the first round, 29 in the second round, and 26 in the third round	Mode, consensus percentage
Jhon Wilder Zartha, Diego Andrés Flórez Londoño, Hader Vladimir Martinez, Juan Felipe Herrera	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Thematic foresight study of Mechanical Engineering in Colombia by the year 2020.	3	35	Mode, consensus percentage

Author	Country or organization	Title and purpose	Number of rounds used	Number of experts	Statistical index used or suggested
Jhon Wilder Zartha Sossa, Juan Carlos Morales, Raúl Valencia, Hader Vladimir Martínez	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Profile of the Textile Engineer for 2015. Foresight study.	3	50	Mode, consensus percentage
Jhon Wilder Zartha Sossa, Iván Zapata Sierra, Santiago Quintero Ramírez, Juan Felipe Herrera	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Strategic foresight in Industrial Engineering by the year 2020.	2	34	Mode, consensus percentage
John Fernando Vargas Buitrago, Jhon Wilder Zartha Sossa,	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Foresight study of the telecommunications sector by the year 2015.	3	28 in the first round, 18 in the second round, and 21 in the third round	Mode, consensus percentage
Jhon Wilder Zartha Sossa, German Urrea Quiroga	COLOMBIA Universidad Pontificia Bolivariana, Medellín	Education in Aeronautical Engineering in Colombia (2015).	3	17 in the first round, 12 in the second round, and 5 in the third round	Mode, consensus percentage

Source: authors' own elaboration

Regarding the limitations of the method, these are related to the scarce application of new statistical parameters; several studies have shown little rigor in the use of these indicators, such as Amanatidou (2011), Chuang, Chia and Wong (2013), Castelló and Callejo (2000), Cancelo, Neyro and Baquero (2014), Chang, Huang and Lin (2000). Other works only use some combination of some statistical parameters, such as mode, average, median, and standard deviation (Wakefield & Watson, 2013; Cabero, 2013; Moore, 2011; Zeedick, 2012).

Rowe and Wright (1999) found other weaknesses, such as surface analysis of responses and poor rigor in expert selection. Kauko and Palmroos (2014) recognize the little emphasis or detail in data analysis between rounds. Fletcher and Marchildon (2014) refer to the low number of specifications for selecting the winning variables. Cancelo, Neyro and Baquero (2014) criticize the fact that the method is used only for past analysis and not for estimating future data. Debin et al. (2013) and Zeedick (2012) mention the apparent lack of use of indicators to measure the level of participants' expertise.

Creange and Careyron (2013) present results with only one round. As for the importance of conducting a post-poll questioning whether the panelists took into account the responses of others and how many of them contributed comments, Kauko and Palmroos (2014) draw attention to using panels of panelists or interest groups – stakeholders (Hussler et al., 2011, quoted by Kauko & Palmroos, 2014). Another type of gap is related to the number of panelists; Rowe and Wright (2001) mention that a range between 5 and 20 people is sufficient.

Materials and methods

A structured, anonymous, and reiterated consultation was carried out with national and international experts on themes related to the fishing agribusiness by the year 2032. The themes are: animal feeding, processes, functional products, biodiversity and bioprocesses, and innovation, technology and knowledge management. This query was performed using the Delphi method. The questionnaire consisted of 143 items, in which each expert contributed by choosing the information that they considered pertinent in each of the thematic areas.

The methodology included the following phases:

Identification of the need or purpose

This activity established the need or purpose of the foresight study and the contributions that could be generated to the macro-project "Alternatives for the use of by-products derived from agro-industry fishery - ALTPEZ".

Selection of the monitor team

The monitor team should be made up of people with the capacity to study and investigate the issue in question, and it is desirable to establish specializations in the functions to be performed by each of the group members. The monitor team was selected from the members of the research macro-project ALTPEZ from Universidad del Cauca. A methodological team was also chosen to be part of the monitor team, following Konow and Pérez (1990). This methodological team consists of one or more experts in the Delphi Method and complements the group of thematic experts in the monitor team.

The functions of the monitor team are:

- Define the objectives pursued with the Delphi exercise.
- Gather and consolidate the initial information for the study of the subject in question.
- Define the panelist selection criteria.
- Conduct the study of the subject according to the objective.
- Prepare a detailed work plan of the activities and a timetable for the exercise.
- Design the questionnaires.
- Design methods for tabulation and evaluation of the information obtained through the questionnaires. This includes defining the criteria that will determine who can be the experts and how the consensus will be measured.
- Distribute and collect the questionnaires.

Expert profile

The profile of the experts was defined as follows: Professionals, academics and researchers in the field of fish by-products, preferably graduated from Engineering programs such as process, chemical, agro-industrial, and food and biological engineering, who meet the following requirements:

Academics and Researchers:

- Bachelors of Science in Engineering
- Master's degree or Ph.D. in the aforementioned areas

Entrepreneurs and experts from the public and private sector and interface entities (technological development centers, productivity centers, business incubators, science and technology parks, among others) that meet the following requirements:

- Experts with solid experience in the business and / or public sector, preferably with more than 10 years of experience.

Number of experts

A total of 147 e-mails were sent, 115 of which were effective. 37 experts answered both rounds.

Construction of the technological / thematic / innovation tree

For the construction of the first-round questionnaire, it was necessary to carry out technological surveillance on the existing topics, technologies and innovations at a national and international level. To do this, the following search equation was constructed: [TITLE-ABS- 1 (waste OR residues OR by products OR derivatives))]. This equation was monitored in databases specialized in scientific articles such as Scopus and in patents in Freepatens on line with the aim of extracting the themes, innovations and technologies that were included in the format of the first Delphi round.

Construction of the first Delphi Round

With the topics selected from the technological tree, 5 groups were defined, each with their respective themes. In total 143 items were defined.

Results

Objective group

The invitation with the Delphi first-round questionnaire was sent by email to 147 national and international experts from companies in the productive sector, universities, government, public and private sector, among other organizations. 27 email deliveries failed and 5 people responded that they did not have experience in the field, for a total of 115 effective emails.

Answers

The first-round questionnaire was completed by 37 national and international experts who filled out the surveys and sent their responses. This allowed to have the opinion of experts from other countries, especially those with academic, business or research experience in fish by-products or in the two fish species that were the focus of the research (trout and tilapia). Table 2 shows the number of participants by nationality.

Table 2. **Number of participants by nationality**

Nationality	N° of Participants
Colombia	31
Brazil	1
U.S.	1
Mexico	3
Uruguay	1

Source: authors' own elaboration

Definition of the priority groups

With the average consensus percentage per group of topics, it was then established that a topic would be considered as a priority in the first round if it had a consensus percentage higher than the average of the thematic group, and a modal value greater than or equal to 4 or 5. With respect to the ratings, the modal value is the most repeated rating within the number of responses.

Subjects with a modal value of less than or equal to 2 and with a percentage higher than the group average were classified as non-priority in the first Delphi round. The other subjects that did not fulfill the previous conditions were considered subjects in discussion.

The classification gave rise to three groups of topics:

- Priority issues (PI)
- Topics under discussion (TUD)
- Non-Priority Topics (NPT)

Results of the first Delphi round

After the statistical analyses were performed according to the method mentioned in the methodology, we found:

- Priority issues: 57
- Topics under discussion: 0
- Non-Priority Topics: 86

These topics are described in the questionnaire of the second Delphi round. Table 3 presents the priority themes in each group:

Table 3. **Priority themes in eachv group**

1. Animal feeding
Pellets of fish silage
Feeders for partial replacement of fishmeal
Feeders for fish feeding
Ensilage of fish viscera
Antioxidants
Omega 3 fatty acids
Probiotics
Zootechnical parameters
Formulation of concentrated foods
2. Processes
Extrusion of concentrated foods
Diets
Temperature
Residence time
Determination of humidity
Quality of raw materials
Apparent digestibility
Coefficient of apparent digestibility
Plant Design
Machine classification by physical characteristics
Filleting machine
Vacuum packing machine
Freezing tunnel
Washing equipment
Packaging equipment
Fish silage equipment
Freezers
Coolers
3. Functional products
Oil rich in omega-3
Fish oil
Oil from fish waste
Collagen
Probiotics
4. Biodiversity and bioprocesses
Hydrolyzed fish protein
Protein extraction
Bio-conservation
Bio-oils
Fish oil
Probiotics
Fish processing wastewater microalgae
5. Technology, innovation and knowledge management
Technology assessment
Technological appropriation
Group memory
Community practice
Content management

Creation of technology-based companies
Competitiveness
National Technological Strategies
The triple helix of University-Industry-Government relationships
Evaluation of innovation and technology projects
Technology project plans
Portfolio of R + D + i projects
Innovation processes
Innovation systems
Evaluation of R & D
Collaboration networks
Quality certifications of concentrate plants
Foresight studies

Source: authors' own elaboration

Data sheet

- Topics: 143
- Clusters: 5
- Questionnaires sent: 86
- Questionnaires answered: 37

The percentage of participation by experts' nationality can be observed in figure 2.

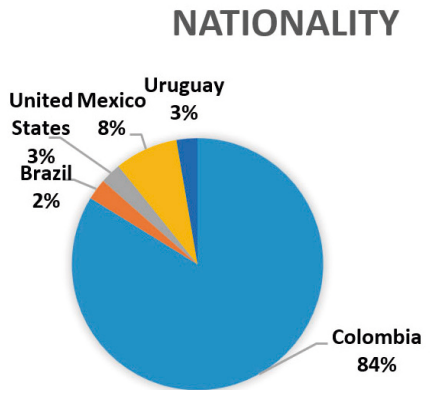

Figure 2. **Expert nationality**
Source: authors' own elaboration

As can be seen, the nationality of the experts who answered the first Delphi round is: Colombia, 84%; Mexico, 8%; U.S., 3%; Uruguay, 3%; and Brazil, 2%.

Second round

Priority themes

In total, 54 priority themes corresponding to 38 % of the topics presented in the Delphi method were obtained. Table 4 shows the Delphi results in the first and second rounds.

Table 4. **Delphi method results of the first and second rounds**

	1. ANIMAL FEEDING	% Consensus R1	Average % Consensus R1	Decision R1	% Consensus R2	Average % Consensus R2	Decision R2
1.1	Pellets of fish silage	38%	35%	Priority	30%	35%	Discussion
1.2	Fish fillet flour	30%		Discussion	43%		Priority
1.3	Flour of by-products for feeding in poultry	35%		Discussion	35%		Discussion
1.4	Feeders for partial replacement of fishmeal	46%		**Priority**	43%		**Priority**
1.5	Feeders for fish feeding	43%		Priority	35%		Discussion
1.6	Fish waste silage oil	27%		Discussion	32%		Discussion
1.7	Fish silage	32%		Discussion	41%		Discussion
1.8	Chemical ensiling of fish waste	30%		Discussion	32%		Discussion
1.9	Biological ensiling of fishery waste	30%		Discussion	41%		Discussion
1.10	Biochemical ensiling of fish	27%		Discussion	32%		Discussion
1.11	Ensilage of fish viscera	38%		Priority	35%		Discussion
1.12	Acid ensiling	27%		Discussion	27%		Discussion
1.13	Silage treated with formic acid	27%		Discussion	32%		Discussion
1.14	Silage treated with sulfuric acid	30%		Discussion	32%		Discussion
1.15	Self-fertilizing silage	22%		Discussion	24%		Discussion
1.16	Antioxidants	35%		Priority	32%		Discussion
1.17	Lipids	32%		Discussion	32%		Discussion

1.18	Tocopherols	32%		Discussion	35%		Discussion
1.19	Omega 3 fatty acids	41%		**Priority**	38%		**Priority**
1.20	Probiotics	46%		**Priority**	41%		**Priority**
1.21	Zootechnical parameters	41%		Priority	30%		Discussion
1.22	Formulation of concentrated foods	**56%**		**Priority**	**50%**		**Priority**
	SUGGESTIONS		Biofloc for fish feeding				**42%**
			Precision fish farming				32%
			Genetically made males or genetically made females				11%
	2. PROCESSES	**% Consensus R1**	**Average % Consensus R1**	**Decision R1**	**% Consensus R2**	**Average % Consensus R2**	**Decision R2**
2.1	Extrusion of concentrated foods	38%	29%	**Priority**	32%	30%	**Priority**
2.2	Double screw extrusion	22%		Discussion	24%		Discussion
2.3	Single screw extrusion	27%		Discussion	32%		Discussion
2.6	Fur harness - Tanning	30%		Discussion	43%		Discussion
2.10	Oxidation	30%		Discussion	35%		Discussion
2.11	Preservation of by-products with organic acids	27%		Discussion	27%		Discussion
2.13	Obtaining gourmet products from viscera	22%		Discussion	32%		Discussion
	Process parameters						
2.15	Physical properties	27%		Discussion	30%		*Priority*
2.16	Subsistence allowance	43%		**Priority**	43%		**Priority**
2.17	Temperature	41%		**Priority**	38%		**Priority**
2.18	Residence time	35%		**Priority**	32%		**Priority**
2.19	Determination of humidity	35%		**Priority**	35%		**Priority**
2.23	Textural properties	27%		Discussion	27%		Discussion
2.24	Quality of raw materials	**54%**		**Priority**	51%		**Priority**
2.26	Apparent digestibility	49%		**Priority**	46%		**Priority**
2.28	Enzyme modification	30%		**Priority**	30%		**Priority**
2.29	Coefficient of apparent digestibility	51%		**Priority**	49%		**Priority**
	Machines and equipment						
2.30	Plant design	49%		**Priority**	46%		**Priority**
2.31	Classification of machines by their physical characteristics	32%		Priority	27%		Discussion
2.32	Headless machines	24%		Discussion	24%		Discussion
2.33	Hoppers for waste storage	30%		Discussion	30%		Discussion
2.34	Rotary drum for washing	32%		Discussion	32%		Discussion
2.35	Gutting machines	30%		**Priority**	30%		**Priority**
2.36	Filleting machine	38%		**Priority**	32%		**Priority**
2.37	Vacuum packing machine	32%		**Priority**	30%		**Priority**
2.38	Freezing tunnel	35%		**Priority**	32%		**Priority**
2.39	Reception equipment	27%		Discussion	27%		Discussion
2.40	Agglomeration equipment	27%		Discussion	27%		Discussion
2.43	Washing equipment	30%		Priority	27%		Discussion
2.44	Equipment for peeling (“skinning”)	27%		Discussion	27%		Discussion
2.45	Conditioning equipment	24%		Discussion	24%		Discussion
2.46	Packaging equipment	32%		**Priority**	32%		**Priority**
2.47	Fish silage equipment	30%		Priority	27%		Discussion
2.48	Pelletizers	27%		Discussion	27%		Discussion
2.49	Blenders	24%		Discussion	24%		Discussion
2.50	Mixing bowls	24%		Discussion	24%		Discussion

2.51	Freezers	35%		**Priority**	32%		**Priority**
2.52	Dryers	27%		Discussion	27%		Discussion
2.53	Coolers	30%		**Priority**	30%		**Priority**
2.54	Stirrers	24%		Discussion	24%		Discussion
2.55	Mills	30%		**Priority**	30%		**Priority**
	SUGGESTIONS		Equipment and containers for the packaging of oils and gourmet products				0%
			Process line design				21%
			Fast and slow freezing				11%
	3. FUNCTIONAL PRODUCTS	**% Consensus R1**	**Average % Consensus R1**	**Decision R1**	**% Consensus R2**	**Average % Consensus R2**	**Decision R2**
3.1	Omega-3 rich oil	**51%**	34%	**Priority**	51%	35%	**Priority**
3.2	Fish oil	43%		**Priority**	38%		**Priority**
3.3	Refined fish oil	30%		Discussion	30%		Discussion
3.4	Oil from fish waste	35%		Priority	32%		Discussion
3.5	Fish hydrolysates	24%		Discussion	35%		Priority
3.6	Freeze-dried products	30%		Discussion	30%		Discussion
3.7	Collagen	41%		**Priority**	38%		**Priority**
3.8	Proteases	32%		Discussion	35%		Priority
3.10	Active peptides	24%		Discussion	30%		Discussion
3.11	Hyaluronic acid	30%		Discussion	32%		Discussion
3.12	Chitin	24%		Discussion	32%		Discussion
3.13	Probiotics	**51%**		**Priority**	43%		**Priority**
	SUGGESTIONS		Extraction of enzymes for in vitro digestibility studies				16%
			Phospholipids				11%
	4. BIODIVERSITY AND BIO-PROCESSES	**% Consensus R1**	**Average % Consensus R1**	**Decision R1**	**% Consen-sus R2**	**Average % Consensus R2**	**Decision R2**
4.1	Hydrolyzed fish protein	35%	29%	Priority	27%	30%	Discussion
4.2	Protein extraction	32%		**Priority**	**30%**		**Priority**
4.3	Bio-conservation	41%		**Priority**	**38%**		**Priority**
4.4	Bio-oils	32%		Priority	27%		Discussion
4.5	Fish oil	32%		**Priority**	32%		**Priority**
4.6	Trypsin from fish waste	24%		Discussion	27%		Discussion
4.7	Probiotics	46%		**Priority**	41%		**Priority**
4.8	Bioaccumulation	27%		Discussion	35%		Priority
	Other topics related to bioprocesses						
4.14	Fish processing wastewater microalgae	32%		**Priority**	32%		**Priority**
4.15	Microalgae of sewage (Food)	30%		**Priority**	41%		**Priority**
	SUGGESTION		Copepods for larval feed-ing				**32%**
	5. TECHNOLOGY, INNOVATION AND KNOWLEDGE MANAGEMENT	**% Consensus R1**	**Average % Consensus R1**	**Decision R1**	**% Consen-sus R2**	**Average % Consensus R2**	**Decision R2**
	Technological foresight and simulation						
5.1	Theory of decisions	27%	35%	Discussion	30%	35%	Discussion
5.2	Dynamic of systems	32%		Discussion	32%		Discussion
	Technological foresight and technological surveillance						
5.3	Competitive intelligence	32%		Discussion	46%		Priority
5.4	Technology maps	30%		Discussion	35%		Discussion
5.7	Social networking analysis	24%		Discussion	24%		Discussion

	Technology transfer						
5.8	Technology assessment	41%		**Priority**	38%		**Priority**
5.9	Technological appropriation	46%		**Priority**	43%		**Priority**
	Knowledge management						
5.10	Measuring intellectual capital	30%		Discussion	38%		Priority
5.11	Group memory	38%		Priority	27%		Discussion
5.12	Technology-based knowledge	30%		Discussion	32%		Discussion
5.13	Organizational knowledge	32%		Discussion	32%		Discussion
5.14	Modeling of the knowledge flow	30%		Discussion	30%		Discussion
5.15	Organizational intelligence	27%		Discussion	30%		Discussion
5.16	Mental maps	27%		Discussion	35%		Discussion
5.17	Conceptual maps	27%		Discussion	30%		Discussion
5.19	Community practice	41%		Priority	35%		Discussion
5.20	Content management	35%		Priority	32%		Discussion
5.21	Collaborative management	27%		Discussion	24%		Discussion
5.22	E-learning applications	30%		Discussion	35%		Discussion
5.23	Diagnosis of knowledge capacities	32%		Discussion	32%		Discussion
	Science and technology policy						
5.25	Creation of technology-based companies	43%		**Priority**	**43%**		**Priority**
5.26	Competitiveness	49%		**Priority**	**43%**		**Priority**
5.27	National technological strategies	41%		**Priority**	**38%**		**Priority**
5.28	The triple helix of University-Industry-Government relationships	**54%**		**Priority**	**51%**		**Priority**
	Management						
5.29	Technological strategies	35%		**Priority**	43%		**Priority**
5.30	Evaluation of projects in innovation and technology	49%		**Priority**	49%		**Priority**
5.31	Technology project plan	41%		**Priority**	41%		**Priority**
5.32	Portfolio of R + D + i projects	43%		**Priority**	41%		**Priority**
5.33	Innovation processes	49%		**Priority**	49%		**Priority**
5.34	Innovation systems	41%		Priority	32%		Discussion
5.35	Evaluation of R & D	38%		Priority	35%		Discussion
5.36	Collaboration networks	41%		**Priority**	41%		**Priority**
5.37	Quality certifications of concentrate plants	43%		**Priority**	41%		**Priority**
5.38	Foresight studies	38%		Priority	35%		Discussion
	SUGGESTION		Social Innovation				16%

Source: authors' own elaboration

Results analysis

The number of experts who answered the two rounds were 37. According to previous works in Colombia and the world, some Delphi studies with a smaller number of experts have been observed. Internationally there are studies with 10, 15, 7, 30, and 32 experts (Wakefield & Watson, 2013); 10 experts (Kauko & Palmroos, 2014); 24 and 20 experts (Liimatainen et al., 2014); 32 experts (Creange & Careyron, 2013); and 14 experts (Landeta, 2006). In Colombia, the studies of Velásquez and Castro (2013) and Zartha et al. (2015a; 2015b) were performed with 26 and 30 experts, respectively.

It must be highlighted that the exercise included two rounds to avoid "experts' fatigue" and for the generation of results in times that allow to align this study with bets on planning or strategic direction. The three rounds were actually articulated and assembled into two rounds in the present study. This was achieved by allowing to attach justifications or comments to the initial 143 items in the first round (something that in previous exercises was only done

in the second round and thus forced a third survey). In this way, in the second round experts could already have arguments for and against, and the change-of-item activity could be done in the same second round. In previous years, Zartha (2015a; 2015b) had done three rounds to obtain the same results; this prolonged the process, with the additional consequence of not having the same number of experts in the third round as in the first.

Highlighting the importance of issues discussed in the first round but which were considered by the same experts in the second and last round is one of the aspects that is neglected in the results analysis of the Delphi method. This helps to counter criticism of the method in terms of the insufficient round-to-round analysis mentioned by Kauko and Palmroos (2014). On this aspect, as regards the issues that were discussed in the first and second rounds of the present study and which were prioritized, we have the following: fish silage meal, in the group ANIMAL FEEDING; physical properties, in the group PROCESSES, in the sub-group Process Parameters; fish hydrolysate and proteases, in the group FUNCTIONAL PRODUCTS; bioaccumulation, in the group BIODIVERSITY AND BIOPROCESSES; competitive intelligence, in the sub-cluster technological foresight and technological surveillance; and measurement of intellectual capital in the sub-group knowledge management. Finally, in the cluster of innovation, technology and knowledge management, it is important to take into account the themes / technologies / innovations for possible bets at an industrial level both in Colombia and in those regions that generate or want to take advantage of fish related products where investment priorities are desired.

Continuing with the analysis between rounds, the following are topics that were prioritized in the first round and discussed in the second round: pellets of fish silage, feeders for fish feeding, silage ensilage of fish, antioxidants and zootechnical parameters, in the group ANIMAL FEEDING; classification of machines by physical characteristics, washing equipment and fish silage equipment, in the machines and equipment sub-group of the group PROCESSES; oil from fish waste, from the group FUNCTIONAL PRODUCTS; hydrolyzed fish protein and bio-oils, from the group BIODIVERSITY AND BIOPROCESSES; group memory, community practice and content management, in the knowledge management sub-group, and innovation systems, R & D evaluation and foresight studies, in the management sub-group, from the group INNOVATION, TECHNOLOGY AND KNOWLEDGE MANAGEMENT. It is important to clarify that the second round gave the experts the opportunity to validate or change their ratings based on the justifications given by the experts, so the result of round two is the final result. Therefore, from the point of view of the experts surveyed, these themes / technologies / innovations do not become the bet or priority for companies or institutions that want to promote these issues.

The topics that were common in the first and second round (total number of topics) are the first bets for companies or future research and technological development centers that want to recommend and generate new productive projects in regions with a fishery orientation and with potential in value-added generation in fish by-products. These topics are detailed in Table 5 in the Decision R1 and Decision R2 columns with the term “priority”.

Discussion

In each of the five groups, no group averages were obtained in upper quartiles, (for example at 75% and 100% consensus). The average consensus percentages for each of the 5 groups were: 35 %, 30 %, 35 %, 30 % and 35 %, respectively. However, if there had been an increase in the number of experts, there would be no guarantee of obtaining higher consensus percentages by group. This phenomenon has also been evidenced in previous foresight studies on biodegradable packaging (Zartha et al, 2015), and on water, education and health (Fundación Ciudad del Saber, 2017), among others.

Several topics, technologies or innovations have a high mode and a high consensus percentage (compared to the average consensus of their group) and therefore, were presented as the winning or priority topics. However, the choice of specific bets by the actors (or agents) of the fish innovation system are in the light of several criteria, such as: previous technological capabilities, availability of resources, strategic plans of each region, human talent training, barriers to the chosen innovation strategy, and the lifecycle phase of the chosen technology, among others.

Before choosing a topic as a bet, it is advisable to carry out technological surveillance and competitive intelligence studies in depth. This can help avoid overcharging in the chosen strategy or project. For example, before prioritizing a specific fish innovation, projects must be generated and investment agreements must be made according to the particular technology phase (emerging, incoming, key, mature or declining), the appropriate monitoring and investment strategy should be analyzed (monitoring only, selective investment, non-overinvestment) and the right moment to exercise a mechanism of technological and intellectual property should be defined (before or after the inflection point). All these elements can be known for a specific technology or

innovation according to previous studies carried out by Hernández et al. (2016), Aguilar et al. (2012), Grajales et al. (2016) and Zartha et al. (2016). The sector of fishing and its derivatives should review the recent study by Zartha et al. (2017) on probiotics, hydrolyzed protein, and animal feed.

Foresight studies have several approaches: French, Anglo-Saxon, Italian, Australian, or specific methodological approaches. The two strongest schools in the world are the French school with an emphasis on cross-impact matrices -the MICMAC cross- (Godet, 1993), and the Anglo-Saxon school based on expert consultation, of which the Delphi method is the main exponent. The use of experts has great advantages when it comes to prioritizing bets in a concrete manner at the level of technologies, innovations and new businesses. This last school was the one used in this study; however, future research in the fishing sector could take into account the French school, which could lead to an image of the future with a path to recoup (which constitutes a definition of "scenario"). The present research results contribute in particular to identifying and prioritizing innovations, technologies and activities in innovation, technology and knowledge management, that is to say, the paths on how to arrive at a future image of by-products of the fishing sector in Colombia.

Finally, the themes in the group of innovation, technology, and knowledge management deserve a special analysis, since items such as the university-industry-government relationship, evaluation of innovation and technology projects, innovation processes, competitive intelligence, and technology appropriation, are modal values of high consensus rates. This indicates they are aspects to be considered by existing organizations in the fish sector and by future institutions such as technological development centers and other interface entities.

Conclusions

The number of experts used in the two Delphi rounds agreed with ranges chosen by other foresight studies using the Delphi method in Colombia and in other countries.

The Delphi study showed possible bets at the level of themes in the chosen groups: animal feeding, processes, functional products, biodiversity and bioprocesses. These issues related to innovations and technologies can constitute routes or trajectories for regions of several countries in terms of decision making, which will allow to construct a future scenario through the creation of start-ups, investment centers, new product development projects and projects to materialize innovations in fish by-products.

In the management cluster of innovation, technology and knowledge, the themes that won in the two rounds became foci for university transfer offices, consulting firms and interface entities such as CDT fish technology development centers. These issues are related to knowledge management technologies so it will be necessary that the innovations and priority technologies become reality in the regions where the use of fish by-products is a real bet.

A total of 54 priority themes were obtained. In the first four groups related to technologies and innovations, some of the items chosen as priorities were: formulation of concentrated foods and feedstuffs, partial substitution of fish meal, extrusion of concentrated foods, oil rich in omega 3, probiotics, bioaccumulation and microalgae of fish processing wastewater. In the innovation, technology and knowledge management group, the topics with the greatest consensus were: technological appropriation, technological evaluation, measurement of intellectual capital, processes of innovation and technological strategies.

The results obtained constitute an approach to the routes, trajectories or paths that must be traveled from 2016 to 2032 according to the answers from the experts consulted. However, given the existence of other foresight schools such as the French school, it is advisable to complement these concrete bets with a rigorous scenario analysis containing PEST-EL analysis (political, economic, social, technological, environmental and legal), cross-impact matrices, key variables, and possible, probable and desirable scenarios in the fish sector.

The bets on technologies and innovations in this study should be reviewed taking into account the previous resources and capabilities in the region or organization in which they are to be implemented. It is important to review if they currently have the technological capabilities, absorption capacities, availability of resources, clear strategic direction, and human talent, and identify the types of barriers they have. Finally, the winning themes also constitute an invitation to think about the near future for building the necessary capacities to make the topics prioritized in this research become a reality.

The technologies and innovations presented as priorities may be subject to specific complementary studies involving different types of surveillance. This can help decision makers in the fishing sector make decisions with less uncertainty, especially in terms of technology lifecycle, inflection points, monitoring, investment strategies, and timing to

apply mechanisms of technological and intellectual property.

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