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EDITORIAL

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Identifying agri-food research priorities for Spain - 2017 results

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Abstract

Among other functions, the INIA is involved in national and international cooperation in the field of agri-food research. The process of identifying and classifying gaps in our knowledge forms an essential part of this effort. This article describes that process, the tools and the materials used to achieve the final objective, namely, the identification of research priorities in the Spanish agri-food sector in order to deal with the societal challenges posed by society and the stakeholders involved. These challenges, within the context of the bioeconomy, are the sustainability of primary and forestry production systems, the safety and quality of food and bioproducts as well as the competitiveness of farmers and companies in this sector. It is necessary to optimize resource management and means of production along with improved efficiency to guarantee sustainability throughout the value chain process. The main goal, under the current scenario of climate change, is to develop models which lead to a balance between food quality and production costs (competitiveness and economic sustainability), ecosystem conservation and mitigation of the environmental impacts (environmental sustainability) while maintaining the population in rural areas (social sustainability). These models will be based on new technology in both intensive and extensive production systems. They should support the improvement and valuation of traditional products together with the formulation and development of foods with new functionalities and quality while at the same time ensuring safety. As well as satisfying consumer demand, improved knowledge must lead to a more efficient use of our own resources and by-products within the framework of a circular economy, including the development of bioproducts, eco-innovation and eco-design.

Additional keywords: foresight, sustainability, efficiency, competitiveness, climate change.

Abbreviations used: AHW (Animal Health and Welfare); AKIS (Agrarian Knowledge and Innovation Systems); CCAA (Autonomous Regions); ICT (Information and Communication Technologies); MAS (Marker-Assisted Selection); QTL (Quantitative Trait Locus); R&D&I (Research, Development and Innovation); SCAR (Standing Committee on Agricultural Research).

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Introduction

As regards agrarian research, it is normal practice to set research goals differentiated into three stages (Hanson *et al.*, 1977): identification and classification of knowledge gaps, estimation of available knowledge level and classification of priorities.

The Statute of the Spanish National Institute for Agricultural and Food Research and Technology (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, INIA) (BOE, 2000) states among its functions that of promoting national and international cooperation in the field of agriculture and food research, particularly among the Autonomous Communities of Spain as well as to foster, develop and coordinate strategic actions for scientific and technological research in accordance with the directives of the State Plans for Scientific and Technological Research and Innovation.

The course of actions anticipated in order to fulfill these functions includes foresight studies concerning the advances and novel orientations of agri-food technical research and development, its organization and management.

In this framework, the "The Strategic Plan of the INIA 2014-2017" identified research coordination as a strategic area which includes foresight exercises among the actions to be developed. The main objective of these exercises was to identify the research needs (the scope

of action covering agricultural, aquacultural and forestry production, as well as the activities associated with the transformation of the products of each), especially regarding adaptation to climate change, contributing to its mitigation, environmental, economic and social sustainability in the context of globalized markets.

The research priorities identified form the basis for policy decision making in research plans and programs, both at national or international level. Funding research schemes, and subsequent individual calls at both levels, take into consideration this information in order to establish specific challenges and identify the scope and expected impacts in each area.

Priority identification methodology

Establishing research priorities, for example using a top down strategy, is normal practice in European framework programmes (Andrée, 2009) as an internal decision making strategy in the European Commission. This is in line with a strategy in which, having identified the general challenges, priorities are addressed through mapping of capacities in order to identify research priorities, as stated in an internal document of the Office of the Chief Scientist of the Australian Government (2012).

The approach used to establish the research priorities varies. Kaplan *et al.* (2013) reviewed it for use in the field of healthcare, and identified two large groups of possibilities: those which use analysis techniques based on quantitative epidemiological, clinical or financial data; and those which use interpretative evaluations based on consensus of opinion among groups of specialists. We have based our work on this latter group.

The data obtained to carry out this work were based on the activities developed by the management teams of the INIA foresight and coordination programmes between 2014 and 2017. These were organized into the following groups:

● *Permanent analysis of research project results* financed through public calls for proposals, identifying new areas of knowledge, the development of which can affect, either directly or indirectly, the entire agri-food sector or some of its subsectors. Fifty one coordination and monitoring meetings were held to address emerging issues of particular importance for the Spanish agri-food sectors, along with the transfer of research findings in areas of particular interest to certain sectors.

● *Periodic meetings and workshops with different sectors and administrations*, aimed at identifying deficiencies which limit the development and competitivity of our production sectors, from primary production to industrial processing and commercialization. Information has been gathered during the period from:

• 40 technical meetings with agri-food, forestry and biochemistry sector technological platforms, as well as with groups fostering innovation. In many of these we have participated in devising their strategic schedules for research and innovation.

• 55 workshops with organizations and associations representing the Spanish agricultural sector.

• 74 meetings with different Spanish administrations, especially those responsible for agriculture and the environment, as well as with representatives from the field of public health.

● *Sectorial actions in specific areas of knowledge.* In complex fields, such as plant health, horticulture, porcine or ovine meat production, a team of specialized researchers analyzed and evaluated the possibilities for knowledge generation. They contrasted them later with the opinions of technicians, organizations and private companies in each field in order to achieve a consensus on the challenges which must be addressed in the coming years. Nine sectorial and foresight actions have been developed with the participation of more than 70 researchers and 50 representatives from different sectors and companies.

● *Public-private collaboration forums.* One-day forums open to the public and focusing on specific areas have been organized with the aim of promoting interaction; seeking synergies and points of convergence among the different players involved in research and innovation. Researchers participated, presenting their lines of work and main results, along with companies, cooperatives and associations of different types, identifying their research needs in specific areas and issues. At the end of these forums, conclusions are agreed on among the organizers and representatives of the parties attending. Twenty eight forums have been held over the period considered, with the participation of more than 500 researchers, 300 companies and associations along with 2500 attendees.

Both the sectorial actions and the forums have allowed us to advance towards the development of integral research projects, specialized according to sectors of production, which respond to the needs identified through a multidisciplinary, collaborative approach with public sector (public research organisms and universities) as well as private sector (technological centers, companies, associations and platforms etc.) participation. The ultimate goal is to contribute to increasing the competitiveness of the Spanish agri-food sector through innovation and in turn favor the incorporation of tools aimed at achieving market differentiation, the reduction of production costs and improved efficiency.

● *Participation in international foresight activities* conducted within the framework of international activities of the INIA. In this period we highlight the following activities:

• 54 meetings of the *Standing Committee on Agricultural Research (SCAR)*, including meetings of the Steering Committee and different Workgroups, among others: Food Chain (*Food Systems*), Agrarian Knowledge and Innovation Systems (AKIS), Animal Health and Welfare (AHW), Forest Research and Innovation (Forest) and Animal Production (SAP).

• 12 meetings of the *Food Security and Climate Change Joint Programming Initiative* FACCE-JPI, both of its governing body and other specific meetings in order to draw up a strategic agenda and put it into practice.

• 6 meetings of the Ibero-American Institutes of Agrarian Research.

• 10 meetings of the Governing Board of the Regional Agricultural Technology Fund FONTAGRO.

• 6 meetings of the Partnership for Research and Innovation in the Mediterranean Area, (PRIMA), Horizon Program 2020 initiative, based on article 185, for Mediterranean countries.

• 8 meetings of the Animal Task Force Initiative.

• 3 meetings of the Global Research Alliance on Agricultural Greenhouse Gases.

• 5 meetings of the Agricultural Chief Scientists organized in the framework of the G20 annual meetings.

● *Planning of agri-food research annual priorities* to be considered in the calls for funding of research projects in the framework of the Spanish INIA-CCAA (Spanish Autonomous Regions) system. These priorities are subjected to the opinion of the Agricultural Research Coordination Board, comprising regional Spanish administrations responsible for agri-food research, together with the INIA and the Ministry for Agriculture and Fisheries, Food and the Environment. Each year, the foresight work carried out was submitted for analysis, consideration and contributions from the board.

Conclusions and priorities were compiled and discussed to provide a base document. This provided the basis for the 2017-2020 revision of the Societal Challenge 2, Bioeconomy, in the "State Plan for Scientific and Technical Research and Innovation".

The aim of this proposal was to address the objectives of the State Plan: stimulate R&D&i orientated towards the challenges faced by our society. As stated in the Plan, it is necessary to direct the scientific research carried out in universities, public research organisms and private companies towards resolving the current and future necessities of our society in accordance with the challenges defined in the Spanish Strategy for Science, Technology and Innovation 2013-2020. These challenges have been reformulated or updated in the Spanish and European Bioeconomy Strategies in the "Horizon 2020" Programme as well as in the "Food 2020-2030" and "European Circular Economy" strategies. In all cases the ultimate goal was to promote the integration of knowledge in order to adapt, advance and transform the results of research into products and services for society in the agri-food sectors.

Base document of research priorities

The criterion used was to utilize the framework of priorities set out in the "State Plan for Scientific and Technical Research and Innovation" (2017-2020) for the social challenge 2 (Bioeconomy: sustainability of primary production and forestry systems, food safety and quality, productive, sustainable agricultural activity, sustainability of natural resources, marine and maritime research and bioproducts). Based on this criterion, the needs identified were grouped into six main areas:

I. Conservation and sustainable integrated management of agroecological systems and of agroforestry, genetic, hydrological and fishing resources.

II. Improvement in the competitiveness and environmental, economic and social sustainability of agricultural, livestock, forestry, fishing and aquacultural production.

III. Food safety and quality.

IV. Development of intelligent production systems, processes and technology as well as food and agricultural industry control.

V. Development of biofuels and bioproducts.

VI. Eco-innovation and eco-design.

I. Conservation and sustainable management

This section includes the search for, and adoption of, advanced solutions for the conservation and integral sustainable management of natural resources. Agroecological systems and agroforestry, genetic, hydrological and fishery resources are considered. The effects of climate change and mitigation of these effects, the use of renewable energy sources, the preservation and promotion of biodiversity, along with models of sustainability in water use, agriculture, extensive and smallholder livestock farming and fishing were discussed. The following needs and areas of action were identified:

● As regards the adaptation of production systems to climate change, mitigating its effects and preserving the level of biodiversity:

• Define practices to mitigate the effects of climate change through agricultural or silvicultural practices which reduce the emission of greenhouse gases and other pollutants, including fertilization management and improved efficiency in the use of nitrogen.

• Develop production simulation models under new climatic scenarios.

• Evaluate the impact of global change on the occurrence of plagues, diseases and their vectors as well as weeds, both with regard to vegetal, animal or forestry production.

• Evaluate the measures for adapting to climate change in agro-livestock systems and ecosystems, including genetic improvements aimed at resilience and adaptation, together with greater understanding of the physiology of adaptation. Seed coating technology will be evaluated as an adaptation technique.

• Analyze changes in the biodiversity of agricultural and forestry ecosystems, along with tools to avoid reduction in biodiversity and fight against invasive species.

• Carry out an evaluation into the risk of change in forest vegetation as a result of progressive substitution of species or due to the drastic loss of the current vegetation through severe episodes of tree mortality.

• Progress in the introduction and management of new species with environmental and nutritional advantages.

● In order to improve the management and use of soils suitable for agriculture and forestry:

• Integral management of soils in each of the agroecosystems present in Spain: measures of fertility, soil protection and restoration, reduction of erosion and degradation, mitigation and adaptation to climate change through carbon fixation in agricultural and forestry soils, decontamination of soils, or preventive and curative measures aimed at improving the health of agricultural and forestry soils.

• Improved productivity through good soil working practices, plant cover, nitrogen-fixing organisms, soil structure and organic material.

• Reduce carbon and hydrological footprints in general and in each of the ecosystems in Spain.

• Manage the biological component of the soil, including microbiomes, for purposes of health, fertility and decontamination, bearing in mind the impact on greenhouse gas emissions.

● In terms of improvements in the management and use of water for irrigation and controlling the environmental impact of irrigation:

• Model hydrological needs according to the crop, improving water and energy use efficiency.

• Develop strategies for irrigation at plot level through irrigation agronomy.

• Improve water quality, diagnostics and support for irrigation management in irrigation communities, precision irrigation based on sensors, use of ICTs interoperability of remote controls, use of drones and artificial vision systems in irrigation communities.

• Incorporate automation in the different systems and agricultural utilization of hydrological resources, as well as in pollution control.

• Improve energy efficiency and use of renewable energy in irrigation as well as analyzing the policies of the Water Framework Directive.

● As regards prevention and management of forest fires:

• Adaptive planning and management, prevention strategies including agro-pastoral alternatives.

• Forest fire extinction and recovery of the systems in accordance with post-fire protocols.

● In the area of conservation and use of genetic resources of interest in agriculture, livestock, forestry and microbes:

• New strategies for characterization, multiplication and conservation “in situ” and “ex situ” to guarantee the health of the collections.

• Methods for conserving germoplasm along with the associated documentation and technology permitting the conservation of agricultural genetic material, reducing the associated costs.

• Structuring the conservation of microbial genetic resources of interest for the food chain and kept in publicly accessible collections.

● A need has been identified to create and manage a database of raw research data to promote meta-analyses facilitating the adaptation of our agricultural systems to climate change and contribute to mitigating its effects, especially as regards:

• The creation, maintenance and consolidation of a data repository to gather all the available information in order to model and simulate the behavior of our agricultural, forestry, livestock and microbial genetic resources under different climatic scenarios.

• The use of data available in existing databases to generate new knowledge.

II. Competitiveness and sustainability

This group includes the needs associated with improving competitiveness and environmental, economic and social sustainability of agricultural, livestock, forestry, fishing and aquacultural production systems.

The introduction of processes and technology which lead to an increase in efficiency and sustainable intensification of production were considered. The most important constraints are: adapting to climate change, preserving ecological systems and addressing prevention, protection against and control of plagues and diseases or introduction of new crops and species. The following areas were considered:

- New technologies applicable to the agricultural, forestry and agri-food sectors:
  - Generation of new knowledge is necessary in the area of ICTs applied to these sectors; satellite development, artificial vision, sensors, remote controls, remote detection systems, management and decision-making support systems applicable to the agri-food and forestry sectors and especially to the management of inputs in the agricultural sector.
  - Robotization of processes which are suited to automation. In particular, the early detection of symptoms of biotic and abiotic crop damage.
  - The mechanization of labor intensive tasks such as the characterization of crop response to different types of stress, harvesting of fruit and vegetables, olives, grapes or pine nuts, or tasks which may be hazardous for workers such as applying pesticides.

- Sustainable intensification of agricultural and forestry operations is one of the necessary steps to improving competitiveness and preserving the natural capital:
  - Integral improvement in the profitability of intensive agricultural and forestry operations by reducing unit costs along with homogeneity and quality of the final product adapted to the demand.
  - Development of new materials, structures and climatic management and control systems.
  - Soil or substrate preparation systems.
  - Improvement in water use efficiency, especially in the case of water with a high salt content, more efficient use of energy and of fertilizers, including recycling of byproducts and agri-food residues.
  - Analysis of the physiological basis of factors determining production, including the response of plants to biotic and abiotic stress, pollination needs, the fruition process or grafting compatibility, the relationship between pre-harvest management and homogeneity of the final products.
  - The incorporation of new materials, sensors, robots, precision equipment and ICTs, to achieve integral and integrated management of the operations.
  - Obtaining technical, economic and environmental indices which allow us to identify and reduce the emission of greenhouse gases, carbon footprint and hydrological footprint, or identify and increase biodiversity.

- The sustainability of extensive agricultural operations deserves special attention in this agro-climatic context, attempting to:
  - Increase productivity and final product quality in extensive agricultural operations with agricultural or forest species, whether domestic or foreign, improved or recovered.
  - Improve soil management, particularly organic material, microbiomes, nutrient dynamics, fertilization (fertirrigation, sensorics, and maps) and humidity.
  - Improve sowing and cultivation methods, adapted to the climatic conditions.
  - Efficiently manage water and energy in the case of irrigation, low input agriculture and mechanized technology.
  - Development and incorporation of technical, economic, environmental and biodiversity indices which allow the current situation as well as future scenarios with extreme meteorological phenomena to be modelled.

- Biotechnology and genetic improvement for obtaining new plant varieties both for human and animal consumption:
  - Improvement in response to biotic and abiotic stress and adaptation to the client and end consumer.
  - Identifying the genes and QTLs associated with characteristics of interest, development of appropriate molecular markers for the purpose of marker-assisted selection (MAS), prioritizing the widespread use of biotechnology and "omics" technology, genotypic and phenotypic technology, employing bioinformatic technology to integrate all the available information.
  - Obtaining plant material based on the use of new technology (ZFN, ODM, RdDM, cisgenesis, intragenesis, inverse generation or agroinfiltration, genome editing, synthesis biology).
  - Improvement in the varieties of legumes and protein crops to increase their productivity and homogeneity, adapting them to the new climatic scenarios, along with the necessity to mechanize their cultivation and harvesting, control of antinutritional factors, incorporating improvements in the processing quality and digestibility, as well as identifying and characterizing the functional components. The aim is to develop varieties and clones capable of competing with other protein sources and facilitate their integration in crop rotation as part of our agroecological systems.

- Integrated control of plagues, diseases and weeds in response to the demands of society both as regards food safety and mitigation of environmental impacts:

• Generate knowledge on the biotic relationships in agricultural and forestry ecosystems, including the relationships between cultivated plants and phytophages, pathogens and weeds; the relationships between these and their natural enemies and antagonists; and the multitrophic relationships which affect the health of crops and forest stands.

• Identify and assess their parameters and manage the factors which reduce or worsen the problem of plagues, diseases or weeds so that they can be taken into account in integrated control programmes; functional biodiversity in agricultural and forestry ecosystems as part of the integrated control.

• Focus specifically on emergence of plagues, diseases or weeds through evaluation and design of risk maps for the introduction and establishment of systems to detect, diagnose and monitor populations, along with the development of economic, social and environmental impact indicators.

• Monitor resistance to phytosanitary products and seek alternatives, evaluating the effectiveness and efficiency of different phytosanitary defense measures as alternatives to phytosanitary products.

• In the priority identification process our sector considers the following as strategic plagues, diseases and weeds: *Ceratitis capitata*, *Drosophila suzukii, Aonidiella* and *Candidatus liberibacter* and their vectors in citrus fruits and horticultural crops, the Apple snail in rice, *Monilinia fructicola* in stone fruits, *Verticillium dahliae* and *Xylella fastidiosa* in olive, Petri disease and other wood fungi, *Plasmopara viticola* and *Uncinula necator* in vines, *Xanthomonas arboricola* in stone fruit and almond, *Erwinia amylovora* in pip fruit, the *Tomato leaf curl New Delhi virus* (ToLCNDV), the *Tomato torrado virus* (ToTV), the *Cucumber mosaic virus* (CMV), the *Pepper vein yellow virus* (PeVYV), *Bromus* and *Lolium spp*. in winter cereals; *Leptochloa* spp. and *Echinochloa* spp. in rice, *Rhynchophorus ferrugineus* (red palm weevil), *Gonipterus scutellatus* (eucalyptus snout beetle), *Coraebus undatus* (cork beetle), *Bursaphelenchus xylophilus* (pine wilt nematode), *Fusarium circinatum* (pitch canker), decline in holm oak and cork oak; *Micosphaerella narwae* in persimmon fruit; *Dryocosmus kuriphilus* in chestnut; and white flies.

● In livestock farms, sustainable intensification and its development was also considered strategic:

• Management and environmental control of installations and equipment aimed at improving economic and environmental efficiency as well as animal welfare.

• Sustainable management of livestock fecal waste, including the reduction of ammonia emissions during the entire production process.

• Improvement in feed efficiency through food adapted to different genotypes, use of alternative raw materials, relationships between feeding strategies-diets-greenhouse gas emissions.

• Animal welfare indicators and strategies.

• Optimization of water consumption and quality on livestock farms as well as improved energy efficiency.

• Incorporation of precision techniques and ICTs applied to livestock.

• Identification and quantification of biomarkers as well as obtaining technical, economic and environmental indices which can be used for modeling, identifying and reducing greenhouse gas emissions, carbon footprint and hydrological footprint, or increasing biodiversity.

• Orientating production towards improved quality and homogeneity of final products (meat, milk, eggs, honey, wool or leather and hides).

● The incorporation of sustainability in extensive livestock farming in order to maintain competitiveness:

• Integral improvements in productivity through: integral strategies for reproductive management, improved efficiency of feed resources, pasture, forage or byproducts, prevention and control of diseases.

• Reduction of environmental impacts.

• Compilation of technical, economic, welfare and environmental sustainability indices for modeling, valuation of ecosystem services and use in the framework of new genomic-based genetic improvement systems.

● Biotechnology, genetic improvement and reproduction:

• Incorporation of biotechnology, omics technology, particularly genomics, genome editing and predictive biology that contributes to boosting the efficiency of the selection profiles.

• Improved output and adaptation of our production systems to the new climate change scenarios (rusticity, drought and extreme temperatures, particularly heat, resistance to disease and parasites), taking into account the welfare of the animals.

• Identification of the characteristics related to feed efficiency and adaptation to the demands of the client and end consumer (homogeneity, meat quality, milk composition, honey quality).

• The search for genes, markers or genomic regions involved in functional sustainability (fertility, immune systems, use and replacement of body stores) which allow a high production level to be maintained without a decline in the resilience of the animals in highly selected populations according to their productive characteristics (balance between functionality and productivity).

• Further our understanding of animal microbiomes, particularly digestive ones, with two fundamental

objectives: improve the health of farm animals and increase the efficiency of food use, both traditional and new types. In the case of ruminants, a further objective is the reduction of methane emissions.

● Integral control of diseases, syndromes and other threats is essential not only to improve the welfare of the animals and productive efficiency, but also to reduce costs or to keep the options open for markets abroad. In the priority identification process the following were deemed necessary:

• Development of rapid, precise diagnostic techniques, both "in situ" (field diagnosis) and in the laboratory, using rapid confirmation technology.

• Availability of alternative vaccines for all types of attack, placing particular emphasis on DIVA (Differentiating Infected from Vaccinated Animals) strategies for diseases etc. with repercussions for public health, profitability or access to market.

• Development of epidemiological monitoring models, as well as risk analysis and management, both at farm and national level.

• Updating of studies on acquired resistance, the search for new molecules and the development of integral alternatives (genetic resistance, management, food, vaccination and manipulation of digestive system microbes) to the use of antibiotics in livestock production.

• Diseases and threats identified as priorities are: toxoplasmosis, salmonellosis, brucellosis, tuberculosis, blue tongue, West Nile virus, Rift Valley fever virus, African horse sickness and other emerging vectorial diseases, viral hemorrhagic disease and porcine reproductive and respiratory syndrome (PRRS), flu, laringotracheitis and mycoplasmosis in poultry, new strains of viral hemorrhagic disease, mucoid enteritis and myxomatosis in rabbits, fish disease and parasites and zoonotic enteropathogens. Pathogens and threats associated with professional apiculture (*Vespa velutina* [Asian hornet], bee-eaters) were also included.

● Aspects have also been identified in the field of aquaculture:

• Food and nutrition: re-define the nutritional requirements of crop species in order to optimize feed, the use of byproducts, waste and other alternative raw materials.

• Management of the life cycle, genetics and physiology: genetic improvement and breeding selection, cryopreservation of genetic resources and selected lines, control of the proportion of each sex and early puberty, improvement in scientific and technical understanding of new species.

• Engineering and management aspects such as the development of off-shore systems, improved biomass estimation techniques and real-time average weight, automation of processes, optimization of economic and environmental efficiency of recirculation systems as well as the reduction in fish escapes.

• Quality, traceability and safety of food products, with the development of new products and services, improvements in marketing, transformation of the image of the sector and knowledge of the market and consumers.

• Integration of productive systems with the environment through improved waste treatment in fresh-water fish farms and determination of the assimilation capacity of marine ecosystems, promotion of integrated multi-trophic aquaculture (AMTI), and risk analysis of the effects of climate change on farmed species and systems.

• Management of populations of marine and estuarine species to generate new food sources, concentrating on ecosystem management.

• Animal health and welfare, considering progress in health management as essential; prophylaxis and health control, detection, diagnosis and quantification of pathologies, treatments and incorporation indices of animal welfare and stress in the main species farmed.

• Economic and social aspects are important, especially improved governance and intelligence of markets.

● All the technology derived from the new areas of knowledge proposed above is applicable to any system of production. However, given its particular relevance to our markets, we highlight the necessity to expand our knowledge on organic agriculture, livestock farming and aquaculture. In this regard it is considered necessary to:

• Enhance production systems using currently available as well as new technology to maximize final production and homogeneity of products from organic farms.

• Develop plague, disease and weed control strategies in organic agriculture, livestock farming and aquaculture using management and cultivation techniques and through the evaluation of natural extracts to control the causative agents.

III. Safety, quality and new types of food

As regards food quality and safety, we included the development of safe foods along with other functional and nutraceutical developments. Conservation processes which improve safety, nutritional quality and shelf life of food products as well as systems for the

detection of risks and fraud, were considered. Research into the relationships between food and health and nutrigenetics is also important for our society.

● The development of new types of food or alteration of existing food by incorporating functionalities demanded by the consumer can be important elements in improving competitiveness:

• The generation of new knowledge on the functionality of the active components of food, both traditional and new generation, allowing innovation in new foods, enriched or fortified with active components from the food chain.

• Continued reduction in components which are not recommendable for certain sectors of the population (fat, cholesterol, salt, lactose), and the formation *in situ* of functional compounds (antihypertensive peptides, antimicrobials etc.).

• Advances in the supplements with microorganisms and functional compounds (probiotics, prebiotics, functional fatty acids, etc.), specially aimed at improving the functioning of the human microbiomes.

• Development of hypoallergenic products.

• Incorporate new raw materials with nutritional and environmental advantages for human and animal foodstuffs.

• Promote the generation of knowledge with regard to diet and health in order to advance towards a more healthy nutrition, including genetic and metabolic markers along with new bioactive and neutraceutic compounds, bearing in mind the role of microbiota in health. Advances in available information on diet and health should be accompanied by integration, accessibility and compatibility in order to promote the use of these advances through new information processing technology.

● The quality and shelf-life of animal products is essential to fulfill demand and improve the efficiency of the chain, reducing food residues and waste through management of the production chain:

• Generating knowledge aimed at lengthening the shelf-life of foods made from animal products, maintaining their homogeneity and commercial quality, integrating management techniques for animal feed (antioxidants), movement, transport, stunning and slaughtering of animals along with carcass dressing and subsequent manipulation, processing, classification of products and preservation (cold chain, gases and intelligent packaging) to the retail outlet.

• Research aimed at improving strategies for the control of pathogens of particular relevance to public health: *Staphilococus aureus, Salmonella spp*., Hepatitis E virus, *Toxoplasma gondii*, enterohemorrhagic and enterotoxigenic *Escherichia coli*, thermotolerant *Campylobacter spp*., micotoxins and red mite. In parallel, carcass decontamination technology is necessary along with improvements in the management of the meat maturation process.

• In the case of dairy products it is necessary to advance in the determination and use of biogenic amine levels as an indicator of the quality of milk and dairy products. As regards the reduction of amines in the end product, it is necessary to develop methods to prevent their formation from the milk to the processes of elaboration (selection of ferments which do not produce them), maturation and conservation of cheeses.

• Similarly, it is necessary to improve technology aimed at detection and control of fraud, using analytical tools to quantify the composition of the food, as well as to differentiate between production methods. The use of additives for food preservation must also be addressed.

• The development of intelligent packaging would facilitate all the above mentioned activities.

● Improved shelf-life, quality and extension of the yearly period during which fruits and vegetables and products of vegetal origin in general are available must be achieved through integral management of the value chain:

• Strategies aimed at lengthening the shelf-life of fruit and vegetables, maintaining their homogeneity and commercial quality throughout the food chain, incorporating techniques for crop management, integral control of plagues and diseases, mechanized optimum moment harvesting, manipulation, transport and commercialization. Another approach to lengthening the shelf-life is to develop new so-called fourth and fifth range products.

• Control of diseases and post-harvest physiopathies.

• The development and transfer of knowledge which allows the industry to find the most efficient methods of preservation, processing and transport.

• The development of technology to seek alternatives to the use of sulphites in wine.

● Development of new foods, aimed at satisfying the demands of society for proteins, both for human and animal consumption, focusing particularly on the production of algae and insects.

● To complete this section, it is considered necessary to address new food risk management strategies, developing research projects in the following areas:

• Creation and management of information banks covering the entire chain, incorporating studies on the efficiency and adaptation of the sectors.

• Strategies for the communication of risks to all the different stages of the chain as well as to the consumer.

• Quantitative risk analysis and development of alternative risk management options applied to biological and chemical risks throughout the vegetal and animal food chain.

• Generation of methodologies including integral food safety models and rapid detection techniques.

• Development of industry self-evaluation models.

IV. Food and agroindustrial production and control

The development of systems, processes and technology for intelligent food and agroindustrial production and control is another substantial area of interest for which the foresight exercise has been carried out. This area includes the elaboration, transformation and preservation of foodstuff, forestry and fishing products along with the development of new value chains for processes, organization, commercialization etc. All of this contributes to social and environmental sustainability through efficient use of raw materials, minimization of waste, valuation of by-products and increased energy efficiency. This area includes economic, social and environmental optimization of the food chain, taking into consideration a range of aspects which are dealt with below.

● As regards the valuation and use of by-products as well as agri-food and forestry residues:

• Reducing the volume of by-products and residues generated not only in primary production but also in forestry and food industry, in the area of pre-transformation processes and concentration of residues at the place where they are generated.

• Developing techniques and treatments which allow the recovery of nutrients (nitrogen, phosphorous, etc.) and viable economic valuation of final by-products from which the active ingredients are extracted.

• Generating bioproducts: raw materials used in human as well as animal foodstuff or in pharmaceutical or cosmetic products, biofumigation, fertilizers, and basic molecules for the development of industrial processes, bioplastics and raw material for the generation of bioenergy both for industrial use or self-consumption. Particular attention will be dedicated to the generation of technology for cereal straw management, forest biomass, herbaceous lignocellulose, carcass hydrolysis and extraction of transformation agents (insects and others) as a source of protein.

● To make progress in the creation of new value chains in the area of agri-food and agroindustry it is necessary to:

• Develop new processes and technology applicable to the agri-food and forestry industries and to biorefineries, including production management and control systems and post-processing innovations.

• Promote ways to obtain new bioproducts and biofuels or bioenergy; the former aimed at bionutrition and bioprotection, particularly with regard to food and health and the development of new foods, functional ingredients, food supplements and other bioproducts with a differentiating market value.

● The competitiveness and transparency of the agrifood chain can be improved through R&D by:

• Studying the impacts associated with changes in agriculture and food policies in the European Union.

• Designing mechanisms which allow transparency of the agri-food chain (price transmission, contracts…).

• Analyzing the factors which determine the competitiveness of agri-food products outside the country.

• Seeking indicators of the balance between primary production and industry to reduce the imbalance among different stages of the chain and contribute added value to the products.

• Studying trends in food consumption and consumer behavior.

• New labelling models, including the composition, nutritional value and environmental impact of the product.

• Improving energy efficiency in the different stages of the food chain.

V. Bioproducts

The development of bioproducts, using residues from the agri-food and forestry value chains as raw materials, or those specifically designed to obtain biomass, will allow us to change from an economy based on fossil fuels to one which is based on renewable resources within the framework of a sustainable, circular economy. Among these new products are those which are destined for the food chain, the pharmaceutical and cosmetics industry, chemical industry or energy production, considering second and third generation biofuels as new end products obtained from biological resources, and therefore contributing to the development of the bioeconomy. In this regard, it is necessary to further our knowledge in many fields, some of which we refer to below.

● Recovery of nutrients (nitrogen, phosphorous etc.) and economic valuation of end by-products of the agri-food industry from which the active ingredients are extracted as well as obtaining biomass and in turn, energy. This is a field which brings together several scientific disciplines (biochemistry, biotechnology, thermochemistry etc.), thus involving a multidisciplinary approach.

● The application of sustainable management in forest systems is an indispensable prerequisite in order for society to accept the development and exploitation of forest biomass to obtain bioproducts and thus promote the Bioeconomy. For this purpose it is vital to:

• Develop tools which allow sustainable and efficient management of systems and forest crops based on multiscale and/or multidisciplinary approaches.

• Make use of forests in accordance with the sustainability of production, control of plagues and diseases or resistance to abiotic agents.

• Reduce production costs and increase the generation of added value, as well as maximizing the utilization of wood and non-wood forest products, guaranteeing sustainability, adaptation and survival of natural or planted forest systems.

VI. Eco-innovation and ecodesign in the agri-food and forestry sectors

Eco-innovation and ecodesign permitting efficient, prolonged and integral use of raw materials, increased service life and reduced obsolescence along with a decrease in residues. These are the foundations of the circular economy and its application in all economic sectors. These aspects are key to the Spanish economy and the social and economic development of its regions. Eco-innovation must be aimed at providing new models for business, processes and products which incorporate new formats and materials such as bottling and packaging technology (active and intelligent). In this area of the circular economy, the objective of which is the preservation and recovery of natural capital, we have attempted to include all the aspects associated with the integral, sustainable development of the rural environment. To achieve these objectives it is essential to apply R&D&I strategies.

● Re-evaluation of all the production processes, from the design of raw material supply and transformation processes, to bottling and packaging, aiming to improve efficiency in the use of raw materials, water and energy as well as reducing inputs and residues. Again, this process requires the application of available knowledge as well as new knowledge obtained through public-private sector collaboration and the development of innovations in the following fields:

• Generation of methods including integral food safety models and development of rapid detection techniques for dangers and risks.

• Development and incorporation of industry 4.0 technology in the agri-food and forestry value chain as an integral control tool which will guarantee efficiency, sustainability and convenience for the consumer.

• Ecodesign of packaging to improve safety, traceability and competitiveness of the products

● The rural environment must be maintained by developing competitive economic activities which encourage young people to settle there, thus guaranteeing the preservation of natural capital demanded by society. This requires rural development strategies based on knowledge and innovation in the following areas:

• Communication and implementation of innovation in production sectors, generalized application of Best Available Techniques (BATs) in the agri-food sector, study of the factors which facilitate the adoption of technological innovation.

• Development of innovation indicators.

• Improvements in small-scale processing of products, particularly with regard to adaptation to current regulations and the development of quality marks.

• New business models and the associated possibilities. Development of short marketing chains, the implementation of ICTs to promote short channels for marketing local and seasonal products.

• Development of micro-logistic innovation techniques adapted to the market conditions. Shorter, more flexible chains.

• Development of innovative economic activities based on agri-food and forestry production

Conclusions

Setting out the research priorities for the Spanish agri-food value chain, through a foresight exercise, has allowed us to reach the following conclusions:

1. Active and permanent dialogue between the different players involved in agri-food research (researchers, production sectors and companies as well as the different administrative departments responsible for agricultural policy and research) is essential if we are to successfully address the challenges posed by society.

2. Participation in international forums discussions and initiatives allows policy makers to identify global priorities and to align them with the Spanish objectives.

At the same time, this participation facilitates the inclusion of specific issues and concerns associated with Spanish production systems within the objectives of European and Global agri-food research.

3. Sustainability is a major challenge to society. Food and forestry production systems should address this challenge by providing high quality, safe, healthy food and bioproducts. Bioeconomy development requires the application of knowledge leading to more efficient resource use within the framework of a circular economy.

4. Under the current scenario of climate change, both adaptation and mitigation are key concepts to be taken into account in agri-food research strategies, from the perspectives of the different disciplines and across the entire production chain.

5. To deal with these challenges we need to generate new knowledge. Multidisciplinary collaboration will allow us to optimize resource management, improve efficiency and guarantee sustainability. New management models will lead to a balance between food quality and production costs (competitiveness and economic sustainability), ecosystem conservation and mitigation of environmental impacts (environmental sustainability) while maintaining the population in rural areas (social sustainability).

6. Demand driven production will require the incorporation of new technology in both intensive and extensive food systems, where safety as well as price are important. However, demand will continue to increase for a diversity of healthy, high quality food, either of traditional origin or formulated with different functionalities.

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