



CATÓLICA
ESCOLA SUPERIOR DE BIOTECNOLOGIA

PORTO

**GENETICALLY MODIFIED FOOD AND HEALTH
PROFESSIONALS: KNOWLEDGE, PRACTICE AND
TRAINING NEEDS**

Thesis submitted to the Universidade Católica Portuguesa to attain the degree
of Ph.D. in Biotechnology with specialization in Food Science and
Engineering

By
Isabella Ribeiro de Figueiredo Vieira

January 2021



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Under the supervision of Professor Margarida Silva and co-supervision of
Professor Elisabete Pinto and Doctor Teresa Brandão

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Resumo

Desde 1996 têm sido aprovados uma série de alimentos transgênicos para alimentação humana e animal na União Europeia. Estes alimentos, alterados através de engenharia genética, têm sido questionados quanto às dimensões dos seus potenciais benefícios e riscos. Isto é especialmente relevante no caso da dimensão nutricional, onde os consumidores são confrontados com as decisões diárias sobre a melhor maneira de se alimentar. Neste contexto os profissionais de saúde acabam por ser chamados a intervir, mais cedo ou mais tarde, e responder no âmbito do seu contacto clínico a questões de opinião, atitude e ciência. Assim o objetivo deste trabalho foi avaliar o conhecimento e opinião dos nutricionistas e médicos sobre o tema dos alimentos transgênicos e a sua percepção de necessidades de formação, além de apresentar uma proposta de ensino desta temática. Nesta investigação foram utilizados métodos de diferentes naturezas. Combinaram-se dados de natureza qualitativa e quantitativa (questionário, entrevista, aula) a fim de possibilitar a compreensão e aprofundamento dos fenómenos envolvidos. Um questionário foi aplicado entre março e julho de 2016, com a participação de 248 nutricionistas e 278 médicos. O questionário foi validado e outras análises baseadas em estatísticas foram realizadas para obter perfis dos entrevistados em função das várias questões associadas aos alimentos geneticamente modificados. Foi também realizado um estudo piloto com a participação de 14 profissionais de saúde com o objetivo de estabelecer e avaliar um módulo de formação em alimentos transgênicos para o ensino superior de Ciências da Nutrição e Medicina.

Os resultados mostraram diferenças entre nutricionistas e médicos: nutricionistas revelam opiniões mais desfavoráveis sobre alimentos transgênicos e médicos tendem para posições mais neutras. Esta caracterização permite retratar em detalhe como é que esses profissionais percebem a temática dos alimentos transgênicos. Parece existir influências de idade, género e nível de formação, seja nas opiniões seja no conhecimento. Tanto nutricionistas como médicos apresentam conhecimento fraco relativamente aos alimentos transgênicos. Estes dados podem ser compreendidos à luz da ausência generalizada de módulos de ensino desta temática, quer nos cursos de graduação, pós-graduação ou formação contínua. Nutricionistas e médicos consideraram útil ter algum tipo de treino em alimentos transgênicos durante a formação universitária e profissional, mas suas opiniões divergem quanto ao formato e tipo de oferta. Sendo os nutricionistas especialistas na área

alimentar, a oferta pode ser tanto em disciplinas nucleares como optativas. Já para médicos a ampliação do conhecimento se daria de forma menos visível, como disciplinas suplementares ou *workshops*.

O formato de ensino multidisciplinar proposto nesta investigação deriva do reconhecimento da teia complexa que liga ciência e tecnologia à sociedade. A formação por esta abordagem prepara os profissionais para ser mais críticos, aptos a raciocinar, pesquisar e questionar, reconhecendo os limites do conhecimento e suas implicações na tomada de decisão perante incertezas e riscos de distribuição social desigual.

Os resultados deste trabalho contribuem para e acrescentam à literatura atual sobre o posicionamento dos profissionais de saúde face aos alimentos transgênicos, estabelecendo um referencial e abrindo a porta a questões adicionais a que importa responder.

Palavras chave: Alimentos geneticamente modificados, médicos, nutricionistas, formação

Abstract

Since 1996 there have been a number of transgenic foods approved for human and animal consumption in the European Union. These foods, altered through genetic engineering, have been questioned as to the dimensions of their potential benefits and risks. This is especially relevant in the case of the nutritional dimension, where consumers are confronted with daily decisions about how to feed themselves. In this context, health professionals are called upon to intervene, sooner or later, and respond in the context of their clinical contact to questions of opinion, attitude, and science. Thus, the objective of this work was to evaluate the knowledge and opinion of nutritionists and physicians on the subject of transgenic foods and their perception of training needs, in addition to presenting a proposal for teaching this subject matter. In this research a combination of methods was used. Data of a qualitative and quantitative (questionnaire, interview, and class) nature were combined in order to improve the breadth and depth of the study. A questionnaire was applied between March and July 2016 and 248 nutritionists and 278 physicians took part. The questionnaire was validated and additional statistically-based analyses were performed to gather respondent profiles according to the various issues surrounding genetically modified foods. Furthermore, a pilot study with the participation of 14 health professionals was carried out with the purpose of establishing and assessing a training module on transgenic foods for Nutritional Sciences and Medical Sciences higher education.

Overall results showed nutritionists more unfavorable opinions regarding genetically modified foods whereas physicians tend towards a more neutral view.

This characterization draws a detailed portrait of how these professionals perceive transgenic foods. Apparently age, gender, and level of education all influence both opinion and knowledge. Nutritionists and physicians have fairly low knowledge of transgenic foods. This situation can be better understood in the light of the virtual non-existence of teaching modules on this topic in Portugal, either in undergraduate or postgraduate degrees, including continuing education. Both nutritionists and physicians considered it useful to have some kind of training on transgenic foods during university and professional education but their opinion differed on the format and type of program. As food experts, transgenic food studies could become a part of regular or optional courses. For physicians

knowledge would desirably take shape through lesser offers, such as extra credit courses or workshops.

The format of multidisciplinary teaching proposed in this research is based on the recognition that a complex web connects science and technology with society. This is an approach that develops much needed critical thinking skills when knowledge limitations are involved in decision making during times of uncertainty and an uneven risk distribution across society.

Results of this research contribute to the current literature on the positioning of health professionals regarding transgenic foods, creating a reference point where now questions must now be equated and answered.

Keywords: genetically modified foods, medical doctors, nutritionists, training

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List of abbreviations

ANACOR - Correspondence analysis
CESPU - University Institute of Health Sciences-North
DNA - Deoxyribonucleic acid
EC – European Commission
EU - European Union
EFSA - European Food Safety Authority
GM – Genetically modified
GMF - Genetically modified food/foods
GMO - Genetically modified organism/organisms
KMO - Kaiser-Meyer-Olkin
MCA - Multiple correspondence analysis
NUTS II - Nomenclature of Territorial Units for statistical purposes
n – sample size
RNA - Ribonucleic acid
 r_{Spearman} - Spearman correlation coefficient
STS - Science, Technology and Society
TF - Transgenic food

Introduction

Project rationale and framework

Food biotechnology is a promising and developing field, but the translation of this science through the professional to the consumer remains a challenge - specifically the issue of transgenic food (TF). Nutritionists and physicians are perceived by the public as being the most reliable source for food and nutrition topics; however, they may not have enough knowledge about this emerging technology.

Thus, talking about TF in health, nutrition sciences and medicine is necessary because TFs have already been introduced into human food and there are doubts from the public about their impact on health and the environment. We are therefore faced with a socio-scientific issue in the face of obvious socially relevant controversies.

The present study arises from the interest in perceiving the training needs of health professionals in relation to TF issues. The questions that guided this investigation were the following:

- What knowledge and opinion do health professionals have about TF?
- What are the contents about TF which are relevant to health professionals?
- What kind of information is needed to understand and deal on a personal and professional level with TF?

These questions remain to be answered in scientific literature.

Objectives

The main objectives (O) of the thesis are:

- O1 – Characterization of the opinion, knowledge, and self-perception of the training needs of physicians and nutritionists in relation to GM foods.
- O2 – Identification of profiles that characterize the personal attitude and professional conduct of physicians and nutritionists about GM foods.
- O3 – Outline of the multidisciplinary training about GM foods and related issues focusing on the Science, Technology and Society approach.

Thesis structure and justification

This thesis is organized in 6 naturally interlinking chapters, as follows.

Chapter 1 reviews the literature on transgenic foods. It emphasizes issues of genetics, nutrition, health, ethics, environment, legislation, concerns and controversies.

Chapter 2 presents the construction and validation of the questionnaire to ascertain the knowledge, opinion and training of physicians and nutritionists regarding genetically modified foods.

Chapter 3 provides a characterization of the opinion, knowledge and perception of the training needs of Portuguese nutritionists in relation to genetically modified foods (GMF). The study tries to answer the hypotheses (H):

H 1 - Nutritionists do not have enough knowledge about TF.

H 2 - There is no unanimous opinion of nutritionists.

H 3 - There is a need for university education.

H 4 - The socio-demographic characteristics influence opinion, knowledge and / or training.

H 5 - There are different profiles of nutritionists.

Chapter 4 focus on the characterization of the opinion, knowledge and perception of the training needs of Portuguese physicians in relation to GMF. The tested hypotheses were:

H 6 - Physicians do not have enough knowledge about TF.

H 7 - There is no unanimity of physicians' opinion.

H 8 - There is a need for university education.

H 9 - The socio-demographic characteristics influence opinion, knowledge and / or training.

H 10 - There are different profiles of physicians.

Chapter 5 describes the personal and professional experience of Portuguese physicians and nutritionists in relation to TF. It investigates the hypothesis:

H 11 - There are differences in personal and professional conduct between physicians and nutritionists regarding TF.

H 12 - The socio-demographic characteristics influence the personal and professional conduct.

H13 - There is a correlation between personal and professional conduct.

Chapter 6 presents a multidisciplinary training module for nutritionists and physicians about genetically modified foods from the Science, Technology and Society perspective. It tries to answer the hypotheses:

H 14 - It is possible to develop/establish multidisciplinary training on TF in the perspective of the methodology Science, Technology and Society for both physicians and nutritionists.

H 15 - The contents presented in the module are important.

H 16 - Do professionals agree with the contents presented in the module?

Chapter 7 includes the final considerations, limitations and future research.

Status of thesis articles

ACCEPTED

Vieira, I., Brandão, T.R.S., Pinto, E. and Silva, M. (2020). Genetically modified foods: construction and validation of a questionnaire to ascertain the knowledge, opinion and training of physicians and nutritionists / Alimentos geneticamente modificados: construção e validação de um questionário para averiguar o conhecimento, a opinião e a formação de médicos e nutricionistas. *Demetra*, 15:e42178. DOI:1012957/demetra.2020.42178

Vieira, I., Brandão, T.R.S., Pinto, E. and Silva, M. (2020). A survey study assessing opinions, knowledge and training needs of physicians concerning the field of transgenic foods / Um inquérito sobre a opinião, conhecimentos e necessidades de formação dos médicos relativamente aos alimentos transgénicos. *Acta Médica Portuguesa*, 33(4):252-260. DOI: 10.20344/amp.11946

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SUBMITTED

Transgenic foods: Personal experience and professional conduct of Portuguese physicians and nutritionists regarding
Brazilian Journal of Food Technology.

CHAPTER 1 - Literature Review

The present literature review focuses on transgenic foods. It begins by describing the basic concepts of genetics and the main techniques of genetic engineering, also presenting the purposes of the development of TF and their interface with health and the environment. Legislation and ethics, with their principles, are included to complement the process of understanding the food context where these foods are inserted. Concerns, controversies, scientific limits and uncertainties, stakeholder views and the precautionary principle are presented in order to set the discussion and understand the inherent complexity of the issue. The goals of the Science, Technology and Society approach and the relationship with the nutritionists and physicians' training are presented.

1.1 Genetics

Some terminologies related to TF are presented, as well as the reference to the most used processes, methods, and techniques of genetic modification, and the modified characteristics (in use, under study and future).

1.1.1. The terminology of transgenic foods

Previously, it is important to clarify some concepts that are often used and sometimes confusing: transgenic food, genetically modified organism, genetic engineering, transgene, DNA, RNA, gene, event, plant breeding by genetic engineering and traditional breeding. Transgenic foods are foods produced from or using a genetically modified organism (GMO) and are also called genetically modified food (GM food). Transgenic foods receive in their DNA a gene from another living being in a way that does not occur naturally, *i.e.*, by mating and / or by natural recombination, but by the use of genetic engineering techniques, used in biotechnology (recombinant DNA technology).

GMO is a genetically modified organism without receiving genetic material (RNA or DNA) from a different organism (EC, 2001). The terms transgenic organism and genetically modified organism are not synonymous: every transgenic organism is a genetically modified organism (GMO), but not all GMO are transgenic organisms. The exact same can be said for the food derived from these life forms

Genetic engineering techniques perform molecular analyzes of gene characterization, expression and modification, *i.e.* manipulation of genetic material (DNA and RNA) of

living organisms. DNA - deoxyribonucleic acid constitutes hereditary material in plants, animals or microorganisms - contains the genetic information that coordinates the development, functioning and transmission of the characteristics of each living being. One way of storing genetic information is in the form of a genetic code: composed of four chemical bases: adenine, guanine, cytosine and thiamine; the order, or sequence, of these bases determines the information available to build and maintain an organism. RNA-ribonucleic acid- functions in the regulation, coding and decoding of genes. One of the functions of RNA is to produce proteins from information acquired from DNA. And genes are small sections of DNA and are characterized as being the basic physical and functional unit of heredity (genetic factors transmitted to offspring) (Medicine, 2018; NIH, 2018).

It is emphasized that there is a difference between the method of breeding plants by genetic and traditional engineering, regarding the process and results. Genetic engineering allows the introduction of the specific gene(s) into the plant and it is responsible for the characteristic of interest; by restricting the introduction to one or a few genes identified, scientists can introduce the desired trait without introducing genes responsible for undesirable traits. In the traditional process of plant reproduction there is the introduction of a number of genes in the plant. These genes may include the gene responsible for the desired trait as well as genes responsible for undesirable traits (Manshardt, 2004).

1.1.2. Process, method and most used techniques in genetic modification

Transgenic foods have been developed in order to acquire certain desirable characteristics. The process of producing a transgenic involves a number of strategies, summarized in: identifying the genetic interest, isolating the gene(s) of interest, amplifying the gene to produce many copies, associating the gene with a promoter, transferring from the construction to the recipient, evaluating the integration and behavior of the chosen gene, and later, evaluating the behavior of the genetically modified organism in the extrinsic environment (NRC, 2004; Greenaway, 2008).

The methods employed for DNA transfer are divided into two groups: (i) those that do not involve vector to carry the gene, eg bombardment with metal particles, electroporation and / or chemistry, and those (Gaskell, Allum *et al.*, 2010) that involve the use of a vector organism such as bacteria or viruses (Schmidt, Lafayette *et al.*, 2008; Barampuram & Zhang, 2011).

The most commonly used techniques are Biobalistics (Gaskell, Allum *et al.*, 2010) and those involving a vector organism, such as bacteria - *Agrobacterium Tumefaciens* (Chart

1.1). The Biobalistics technique consists of using tiny particles of tungsten or gold, which are coated with the desired DNA, and then bombarded into the cells; the whole process is carried out in a vacuum chamber with the aid of a microparticle accelerator; and the inserted DNA dissociates from the particles and integrates with the new genome (Schmidt, Lafayette *et al.*, 2008). On the other hand, a method involving the use of a vector - soil bacterial organism called *Agrobacterium Tumefaciens* has a small amount of extrachromosomal DNA, called tumor - inducing plasmid with self-replicating capabilities. During the infection stage of the plant by this bacterium, the DNA-T (DNA-transferred) portion of the plasmid is incorporated into the genome of the plant cell. Thus, a resultant infection leads to tumors, to the placement of the gene of interest from the donor plant, and to the encoding of the new desired characteristics in the new plant (Barampuram & Zhang, 2011).

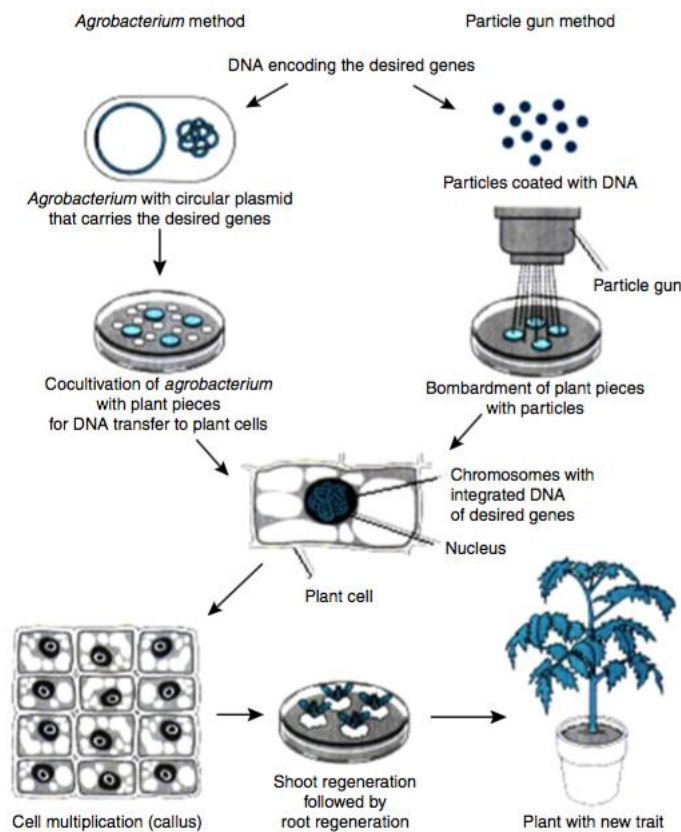


Figure 1.1. Transgenic plant production (Somers, 2014).

1.1.3. Modified characteristics

Transgenic foods currently in use come from the first generation of traded genetically engineered products. They are genetically modified crops (GM crops) with agronomic changes. Highlight for insect resistant (i) culture, which presents genes used in the development of insect resistance from the bacterium *Bacillus thuringiensis*, most in the form of delta endotoxin genes known as cry proteins; and the other crop is herbicide tolerant (Gaskell *et al.*, 2010): designed to withstand one or more of the following herbicides: 2,4-dichlorophenoxyacetic acid, dicamba, glufosinate, glyphosate, sulfonyleurea, oxynil, mesotrione and isoxaflutole. However, currently, most soybean and corn crops are tolerant to the glyphosate herbicide (Yonekura-Sakakibara & Saito, 2006). GM crops, under study and future, can be called second and third generation, respectively (Gomez-Magana & Barca, 2009). Under study (or second generation) are the cultures that present features with a focus on the consumer, such as: increased protein levels, modified or healthier fats, modified carbohydrates, increased taste or increased micronutrients; rice with higher content of beta-carotene, tomato with higher carotenoid content, corn with increased vitamin C, soy with better composition of amino acids and potato with higher calcium content. Third-generation (future) GM crops: (i) are plants that have characteristics to provide greater capacity to resist to abiotic stress, such as: dry, high temperature or saline soils; and / or (Gaskell, Stares *et al.*, 2010) characteristics that may provide health benefits, such as drug production (Newell-McGloughlin, 2008; Gomez-Magana & Barca, 2009; Pandey, Kamle *et al.*, 2010).

1.2. Food and nutrition

Topics related to production (global and European) and import (European) of GM food; types of foods that may contain the transgene, as well as examples that are currently on the European market, are presented.

1.2.1. Production

According to the report of the International Service for the Acquisition of Agri-Biotech Applications, the spread of GM crops has been increasing (ISAAA). The main crops that contributed in the 21 years (1996 to 2016) of commercialization of biotech crops include: soybean, corn, cotton and canola, corresponding to 2.15 billion hectares. The countries that contributed to this scenario were, in descending order of planting magnitude: United States, Brazil, Argentina, Canada, India, Paraguay, Pakistan, China, South Africa, Bolivia,

Uruguay, Australia, Philippines, Myanmar, Sudan, Spain, Mexico, Colombia, Vietnam, Honduras, Chile, Portugal, Bangladesh, Costa Rica, Slovakia, and Czech Republic. By 2017, the global acreage of genetically modified crops increased from 185.1 million hectares to 189.8 million hectares, an increase of 3% equivalent to 4.7 million hectares (ISAAA, 2017).

In the European Union (EU), in 2017, only two countries (Portugal and Spain) grew transgenic maize. These two countries corresponded to the planting of 131,535 hectares of the total of 2017, indicating a slight fall of 4% compared to 136,363 hectares in 2016. These two countries consistently grew the MON810 transgenic corn event - the only biotech event approved for EU planting. Spain planted 124,227 hectares and Portugal planted 7,308 hectares. In relation to Portugal, in 2017, only four regions grew transgenic maize (MON 810), in descending order of planting magnitude: Alentejo, Lisbon, Center and North (ISAAA, 2017).

1.2.2. European import

The EU has imported biotech crops for use in livestock and poultry industry. In 2017, according to the EU's Agricultural Biotechnology Yearbook, soybeans (33 million tons), maize (62 million) and rapeseed (more than 3,8 million tons) were imported. In relation to Portugal - there is an annual import of transgenic soy in the order of 875,000 tons of soy bran for livestock and animal industry, mainly biotechnology from Brazil, the United States and Argentina (ISAAA, 2017).

1.2.3. Types of foods that may contain the transgene

The World Health Organization classifies in four categories the foods that may contain the transgene. In category 1 we can find GMF, such as corn and soy. In category 2 there are foods that contain some components of GMF, such as: starch, oil, amino acids, vitamins, etc. In the third category there are foods containing GMF components, such as: dairy drinks that may contain modified starch from transgenic maize. In the fourth category are foods containing ingredients processed by enzymes produced by transgenic organisms, for example: fructose-rich corn syrup produced from corn starch and using the enzyme glucose isomerase (Uzogara 2000; WHO, 2005).

1.2.4. Examples of transgenic foods that are currently on the European market

In the European market, only five plant species are approved for human consumption. It is possible to find GMF in the by-products and derivatives: soy (beverages, tofu, oil, flour, lecithin), corn (oil, flour, syrups, sweetcorn, flakes), oilseed rape and beet. Two types of characteristics were introduced, with tolerance to herbicide - gene CP4EPSPS and PAT; and with insect resistance - cry gene (ISAAA, 2017; Santis, Stockhofe *et al.*, 2018).

1.3. Health

Health outcomes are presented: negative (allergenicity, gene transfer and resistance to antibiotics), positive, and possible unintended effects.

1.3.1. Negative outcomes

1.3.1.1. Allergenicity

Transgenic foods have the potential to cause allergic reactions in general. This risk is comparable to the risks associated with traditionally grown foods (Raybourne *et al.*, 2003). However, the proteins produced by any newly introduced genes have the potential to cause an additional allergic response. To avoid this allergenicity, gene transfer from commonly allergenic foods is discouraged unless it can be proved that the protein produced by the introduced gene will not be allergenic. Food allergy is characterized by a pathological deviation of the immune response. The most frequent and severe allergic reactions are mediated by a particular class of immunoglobulins called IgE antibodies. The problem of food allergens involves not only consumers, but also individuals who are exposed to these foods, for example farmers, packers and others. Allergens in transgenic foods potentially involve: changes in endogenous protein levels, expression of known allergens and / or expression of new proteins that may be allergenic (Bernstein, Bernstein *et al.*, 2002). During the risk assessment, the allergenicity of GM plants is assessed based on the structural characteristics and physical and biochemical properties of the newly expressed protein using *in silico*, *in vitro* and *in vivo* tests in accordance with appropriate Codex Alimentarius guidelines (Codex, 2009) and EFSA (2010). The evaluation of allergenicity of GM plants includes two elements: the evaluation of the entire GM plant and the evaluation of newly expressed proteins. The key question to assess the allergenic potential of the whole transgenic plant is whether the use of transgenic methods has an unintended effect on the levels of the plant's native allergenic proteins (EFSA, 2006; Codex, 2009).

1.3.1.2. Gene transfer

Another negative point is the possibility of transferring genetic material from transgenic foods to the cells of the human body or to the bacteria in the intestinal tract. This comes from the horizontal transfer of genes through the viability of absorption of DNA fragments by the intestinal microflora or somatic cells lining the intestinal cells. Although the likelihood of such an occurrence is extremely low, the Food and Agriculture Organization of the United Nations and the World Health Organization encourage the use of technology without antibiotic-resistant genes and discourage the use of unnecessary DNA sequences. However, even though the probability of gene transfer from GMOs to mammalian cells appears to be extremely low and statistically insignificant, it is important to consider hypothetical health risks on the long-term scale (Jonasa, Elmadfab *et al.*, 2001; Eedea, Aartsb *et al.* 2004) .

1.3.1.3. Resistance to antibiotics

Not all cells subjected to the genetic modification technique are successfully transformed, so it becomes necessary to identify the modified cells; identification is performed by antibiotic resistant genes. Antibiotic resistance may develop due to the transmission of such gene(s) in the animal and / or human intestine. If antibiotic-resistant genes are transmitted to pathogenic microorganisms, this will make it difficult to control any bacterial infection. The lateral transfer of antibiotic resistance to the bacteria in animal or human systems can cause many health risks. However, in spite of being a possibility, it has not yet been reported (Hug, 2008). On the other hand, something very similar has been reported by Netherwood, Martín-Orúe *et al.* (2004).

1.3.2. Positive outputs

Positive outputs are those that benefit the producer and / or benefit the consumer. Agronomic modifications that protect the crop from biotic / abiotic stress or increase the total yield of the crop, benefit the producer; most commercially modified crops fit into this group. Scientists have begun to explore the great potential of biotechnology to produce plant varieties that confer a broad spectrum of benefits to consumers, both in health and food.

1.3.2.1. Agricultural benefits

According to the industry, the goal is to improve the quality of certain crops and to produce safer food, higher yielding planting, reducing the use of pesticides, improving

plant adaptation to unfavorable environments (Uzogara, 2000; Hug, 2008; Newell-McGloughlin, 2008; Pandey, Kamle *et al.*, 2010).

1.3.2.2. *Benefits of food and health technology*

It includes some benefits (Uzogara, 2000; Newell-McGloughlin, 2008; Pandey, Kamle *et al.* 2010), such as:

- (i) Improvement of nutritional composition: producing nutraceutical foods - example: golden rice, whose genome has been modified by the introduction of copies of genes that condition the synthesis of pro-vitamin A - carotenoids, including β -carotene; it is known that vitamin A and its pro-vitamin represent a group of biologically active compounds responsible for normal vision and body resistance.
- (ii) Improvement in technological and utility trends: the greatest interest is attracted by varieties in which the introduced change manifests changes in the technological process and / or processing, e.g. potato bulbs - changes in quantitative composition and technological parameters. These changes include a decrease in the amount of reducing sugars, a change in polyphenoloxidase activity responsible for the phenomenon of potato browning, and a reduction in the content of alkaloids that negatively affect storage.
- (iii) Improvement in animal products - attempts to improve the utility characteristics of production animals and obtain the greatest economic gains; the main objects of studies on transgenic processes include cattle and pigs, while the main directions of transformation involve the optimization of their feeding potential and reproduction parameters; specific examples of transgenics in animals is transgenic salmon.

1.3.3. Unintentional and potential effects

It is possible that the transgene may also manifest unexpected gene interactions, different from the predicted effects of genetic manipulation. Genes introduced into foods can silence existing genes, alter gene expression, or activate genes that were not previously expressed. Thus, the results of genetic manipulation may be unpredictable and genetically engineered products may be unstable. For example, some feeding studies have shown effects on the weight of animals fed with transgenic foods (Zhu, Li *et al.*, 2007). These unexpected results are likely to be linked to the specific gene added to the GM crop or to the specific side effects of a genetic transformation event that may potentially disrupt the metabolism. Other effects are associated with cancer potential; they may appear because many transgenic crops have higher pesticide residues than non-transgenic ones and the main

ingredient in some pesticides – glyphosate- has been associated with increases in non-Hodgkin's lymphoma (Dreiherr & Kordysh 2006). They may also increase anti-nutrients - substances that interfere with the use of nutrients. For example, glyphosate-resistant Roundup Ready soybeans were shown to increase anti-nutrients. In sheep and cattle, thermostable anti-nutrients, such as phytoestrogens, glucinins and phytic acid, cause infertility, allergic reactions and decreased availability of phosphorus and zinc, respectively (Dona & Arvanitoyannis, 2009; Ladics, Bartholomaeus *et al.*, 2015).

1.4. Environment

The possible interactions of transgenic cultures with the environment can trigger an impact in target and non-target species, as well as changes related to gene flow. Evidence of substantial environmental influences on health and food safety comes from working with environmental health indicators that show that agri-environmental practices have direct and indirect effects on human health, concluding that the quality of the environment influences food quality and safety (Neff, Merrigan *et al.*, 2015). Therefore, the cultivation of transgenic plants, on a large scale, causes the dissemination of transgenes, whose environmental effects on health and / or food production are difficult to measure (Haslberger, 2006; Hug, 2008).

1.4.1. Impacts on target and non-target species

Risks to biodiversity are reported and include any adverse effects on target and non-target species. These species can be grouped into several categories, such as (i) beneficial species, including natural enemies of pests (*e.g.*, ladybugs, parasitic wasps) and pollinators (*e.g.*, bees); (ii) Non-target herbivores; (iii) soil organisms; (iv) species of conservation interest, including endangered species and charismatic species (*e.g.*, monarch butterfly); and (v) species that contribute to local biodiversity (Andow & Zwahlen, 2006; Carpenter, 2011).

1.4.2. Changes related to gene flow

Gene flow between crops and wild species has occurred in nature for thousands of years. The gene flow is characterized by gene migration between populations (Andow & Zwahlen, 2006). The effects of these gene transfers between populations depends on several factors, such as the difference in gene frequencies in the two populations and the proportion of migrants (Andow & Zwahlen, 2006). In relation to the transgenes of

transgenic crops, primitive gene replacement may occur, reducing the genetic diversity of wild populations. Transgenes can also flow into other crop varieties, causing genetic contamination, reducing seed quality, threatening food security and organic food production, and damaging other crops (Andow & Zwahlen, 2006).

1.5. Ethics

Ethical considerations relating to food genetic engineering have been progressively introduced into European Community legislation, especially regarding research, environment, patents, animal welfare and medicine. The application of ethical principles serves to solve ethical dilemmas that arise when more than one interest is at stake. Transgenic crops generate concerns and controversies at social, economic and political levels, both at the local, national and international levels. In view of this, they need to be assessed according to ethical criteria. Some ethical principles are particularly important, such as the principles of justice, non-maleficence, integrity and respect (Solomons, 2002). The principle of justice is related to irreversibility vis-à-vis the most disadvantaged, in relation to those that have not yet been born, that is equality among all citizens; this principle requires an equitable distribution of resources and should minimize the variation in social factors so that the less fortunate also have rights. The principle of non-maleficence refers to not causing harm; to the need to be cautious about the premature use of technology when risks are not fully understood; it mentions the distinction between safety assurance and safety possibility. The principle of integrity mentions the need for scientific and independent action, for integrity in the search and application of knowledge and benefits in the research of genetic technology, both in the research design and in the adequate scientific qualification to carry out the work; and compliance with the relevant codes of best scientific practice. The principle of respect mentions the right of the individual (citizen) to autonomy, the right to know what is sown and eaten (Ricroch, Guillaume-Hofnung *et al.*, 2018).

1.6. Legislation

In this topic, the procedures for safety assessment, approval legislation, responsible bodies and post-trade monitoring are dealt with in a general and summarized way.

1.6.1. Safety assessment procedures

A safety assessment is required for all transgenic food developers. Developers should

prepare a file in order to register these foods before introducing them to the market. In general, this file should contain: (i) molecular characterization, which provides information on the structure, expression and stability of the inserted characteristics (Gaskell, Stares *et al.*, 2010); (ii) toxicological evaluation, which addresses the impact of biologically relevant changes in the transgenic plant and / or food and derived rations resulting from the genetic modification; (iii) evaluation of the allergenicity potential of the new protein(s) as well as of any food derived from the transgenic plant; (iv) nutritional assessment to evaluate whether foods and feeds derived from a transgenic plant are not nutritionally disadvantageous to humans and / or animals; (v) environmental assessment of transgenic plants (EFSA, 2006; Codex, 2009).

It is necessary to apply the difference test and the equivalence test. The difference test evaluates expected and unexpected answers related to compositional, phenotypic and agronomic evaluation; on the other hand, the equivalence test uses several non-transgenic varieties with a safe history (EFSA, 2011; Garcia-Alonso, 2013). According to the equivalence principle, if a new food or feed derived from a transgenic crop is substantially equivalent (meaning something that has the same value, the same similarities) to its conventional counterpart, then it is considered as safe as the food or feed of the conventional crop, and the evaluation then focuses on the safety of the features introduced. This comparative assessment allows the identification of any differences between the transgenic crop and its conventional counterpart that may have arisen due to genetic modification. The process follows a weight-of-evidence approach where numerous sources of information are used to identify these potential differences and their implications for food security (Herman & Price, 2013). It is important to note that the differences between the transgenic plant and its conventional counterpart are sometimes detected. However, a difference does not necessarily indicate that an adverse effect will occur. Once differences are detected, the likelihood that they may lead to an adverse effect on human or animal health is assessed. If there are differences, then risk assessment needs to be focused on the risk associated with these differences (Cellinia, Chessonb *et al.*, 2004).

1.6.2. Approval legislation

In the European Union, the deliberate release of transgenic crops into the environment and the placing on the market are monitored and regulated by various directives and regulations. Only crops which meet the obligations laid down in the relevant directives are approved for release in the Member States. In terms of specific legislation guiding /

development / use / approval / release of TF, the European Union operates through a centralized procedure whereby an agreement between Member States results in binding legislation requiring Member States to comply with it. The legislation on TF involves a wide range of legal documents, the most important being:

- Directive 2009/41 / EC on the contained use of genetically modified micro-organisms (EC, 2009).
- Regulation (EC) 1829/2003 on genetically modified food and feed. It regulates risk assessment procedures, describes the role of the EFSA and allows a single endorsement of genetically modified plants for human and animal feeding purposes (EC, 2003).
- Directive 2001/18 / EC on the deliberate release into the environment of genetically modified organisms. It regulates risk assessment in relation to the environment, includes socioeconomic assessments and provides a platform for ethical considerations (EC, 2001).
- Regulation (EC) 1830/2003 on the traceability and labeling of genetically modified organisms and the traceability of food and feed produced from genetically modified organisms and amending.
- Directive 2001/18 / EC. It involves the labeling of products and the traceability of producers and companies involved through a post-marketing monitoring system (EC, 2003).
- Regulation (EC) 1946/2003 on transboundary movements of genetically modified organisms. It is based on and applies the Cartagena Protocol on Biosafety in relation to GMOs and allows penalties in cases of non-compliance (EC, 2003).
- Directive (EU) 2015/412 amending Directive 2001/18 / EC as regards the possibility for Member States to limit or prohibit the cultivation of GMOs in their territory (EC, 2015).

1.6.3. Responsible bodies

Applicants submit the file to the EFSA, which assesses safety for human, animal and environmental health. EFSA evaluations are carried out by the GMO panel, composed of scientific experts. The final risk assessment evaluated by EFSA is the basis on which the European Commission proposes a decision to the Member States for the placing on the market of a GMO. In Portugal, the competent authorities are the Portuguese Environment Agency, the Planning Office of the Ministry of Agriculture and Rural Development, and the General Directorate of Veterinary Food.

1.6.4. Post-market monitoring

Legislation also imposes post-market monitoring of the environment for each GMO authorized through Regulation 1830/2003 (EC, 2003) and Regulation 65/2004 (EC, 2004), concerning the rules for traceability and labeling of transgenic foods, including genetically modified variety seed, and of food and feed produced from GM foods. Traceability and labeling are imposed on any authorized GM foods. Post-trade surveillance aims to identify and monitor any unexpected and adverse effects in the short and / or long term. For the consumer, labeling is important because it provides information and some freedom of choice; traceability facilitates the withdrawal of a product from the market if there is an unexpected risk, as well as supporting the monitoring of potential human and environmental health effects.

1.7. Concerns about transgenic foods

Concerns include several stages, from the production of GM foods, to the consumer's plate. And they are relative: to the methods of genetic engineering, the interactions in the health of the consumption, the influences on the environment; the possibility of economic changes; ethical issues and legislation.

1.7.1. Concerns about genetic engineering methods

Gene transfer techniques may result in some errors, such as: new genetic material may not be successfully transferred to target cells, and / or may alter or suppress the function of a different gene, causing unexpected mutations, the resulting plant becoming toxic, infertile or inadequate. Thus, when a gene is introduced into the genome of an organism, the effects cannot be controlled or predicted, and may give rise to unexpected effects (Singer, Liu *et al.*, 2012). Another concern is the lack of consensus in the scientific community in terms of the methodology to be applied (duration of studies and replication) and the results found by the different studies (Hilbeck, Binimelis *et al.*, 2015).

1.7.2. Health concerns, in relation to GM food consumption

There is little / no information regarding (i) the effects of changes in nutrient composition of GM food, such as: nutrient interaction, gene-nutrient interaction and / or bioavailability of nutrients; and (Gaskell, Stares *et al.*, 2010) information regarding gene expression. Genetic modification could increase the plant's natural toxins; genes for some natural toxins, such as: protease inhibitors in legumes, cyanogenic cassava and beans, goitrogens

in canola species and pressor amines in bananas and plantains can be activated and lead to an increase in the levels of these toxins and pose a danger to the consumers of these crops. Genetic modification of food plants may transfer allergenic properties from the donor source to the recipient plant or animal, in addition to potential side effects. As for example: the case of the Brazilian chestnut with soybean (Nordlee, Taylor *et al.*, 1996; Papparini & Romano-Spica, 2004).

1.7.3. Concerns about the influence on the environment

It is estimated the possibility of negative influences on the environment concerning: (i) unintentional genetic transfer to wild plants (Andow & Zwahlen, 2006): example of oilseed rape (*Brassica napus* L.) and its wild relatives *B. rapa* L. (Brassicaceae) (Hall, Topinka *et al.*, 2000; Gaskell, Stares, *et al.*, 2010). Impact on target and non-target species: for example, cases reported in the Monarch butterfly (Oberhauser, Prysby *et al.*, 2001), as well as the example of (iii) corn in Mexico (Soleri, Cleveland *et al.*, 2006).

1.7.4. Concerns about economic changes

Two concerns are reported with possible impact on the economic scenario. First: limited access of the plant / transgenic animal, due to being patented, that is transgenic plants / animals, widely known as commodity products, are now considered property of the companies that produce them. Second: the use of transgenic technology obliges farmers to buy new seeds every year from the companies that have the patenting; In view of this, farmers become dependent on the companies holding the patent, as opposed to sowing the seeds of the previous years' harvest - it is argued that this would destroy traditional agricultural practices (Uzogara, 2000; Lemaux, 2009).

1.7.5. Ethical Concerns

In addition to the ethical considerations in the stages of development and production, it is necessary to look at the groups of transgenic crops consumption. The application of the principle of respect would be based on certain groups: for example, Jews and Muslims who do not eat grains that contain pig genes; vegetarians, in a similar way, would not like to eat vegetables and fruits that contain animal genes (Omobowale, Singer *et al.*, 2009). Therefore, the right to know what you eat should prevail in any production of GM foods. Other concerns are related to the need to take into account the principle of beneficence and autonomy: both policymakers and food producers must recognize local food environments

and the agricultural context of each community in order to effectively prepare communication strategies and equitably distribute any proposed transgenic food intervention (Glass & Fanzo, 2017).

1.7.6. Concerns about the imposition of legislation

Doubts remain as to safety assessment - most studies of transgenic animal feeding are short- or medium-term - too short to show effects such as organ failure, cancer, or long-term reproductive problems (chronic problems). Therefore, long-term studies and multigenerational studies on transgenics are required to eliminate whether the signs of toxicity commonly reported in shorter studies lead to severe disease - but such studies are not required / mandatory by legislation during the evaluation of a transgenic crop's safety (Snell, Bernheim *et al.*, 2012). Another concern is whether or not GM foods are labeled. Some studies on labeling of GM foods show different opinions. In view of this, other concerns arise, for example: mandatory labeling of GM foods could increase or decrease consumers' aversion to genetic engineering. However, it is known that labeling helps the consumer to identify the product and gives choices, as well as contributing to the traceability of possible unintended consequences of the food (Uzogara, 2000; Kolodinsky & Lusk, 2018).

1.8. Controversies

The controversy associated with transgenic foods is related to the risk-versus-benefit debate, in which advocates highlight the benefits of this food, while opponents seek to show the possible negative impacts. Thus, there is currently no scientific consensus regarding transgenic foods (Hilbeck, Binimelis *et al.*, 2015; Krimsky, 2015). Some controversies related to the effects of GM foods consumption on health, divergences in the use of genetic engineering, and GM foods approval procedures are presented.

1.8.1. Effects of transgenic food consumption on health.

Controversy 1 – Transgenic foods are safe to eat vs transgenic foods can be toxic, allergic, or have unintended nutritional changes.

A systematic review of 2015 did not find an association between adverse health effects and consumption of food produced through genetic engineering technologies. Although the number of available human studies is small, they maintain that there are no clear adverse

health effects with GM food consumption (Edge, Kunkel *et al.*, 2015). Another article in 2017 characterized scientific studies that mention evidence of the adverse effects of GM foods and concluded that there are methodological flaws that invalidate any findings of GM foods adverse effects on health (Sanchez & Parrott, 2017). On the other hand, a panel of experts from the Royal Society of Canada published a highly critical report on the regulatory system for transgenic food and crops; the report states that it is scientifically unjustifiable to presume that GM foods are safe without rigorous scientific testing and that the standard prediction for all GM foods should be that the introduction of a new gene will cause unforeseen changes in the expression of other genes in the pattern of proteins produced and / or metabolic activities; possible outcomes of these changes identified in the report included the presence of new or unexpected allergens (Royal Society, 2001). Another report from the British Medical Association concluded that regarding the long-term effects of transgenic foods on human health and the environment, many unanswered questions remain and that safety concerns cannot yet be completely ruled out; the report called for more research, especially on possible impacts on human health and the environment (BMA, 2004). A third report by the American Medical Association's Science and Public Health Council, which mentions beyond the potential benefits of transgenic technology, recognizes data gaps and potential risks for adverse events due to horizontal gene transfer, allergy and toxicity, and recommends that the current voluntary notification procedure should be practiced prior to the release of transgenic crops on the market (Delegates, 2012).

1.8.2. Divergences regarding the use of genetic engineering

Two controversies regarding the use of genetic engineering are presented.

Controversy 1 - Genetic engineering is accurate and results are predictable vs. genetic engineering is crude and imprecise, and the results are unpredictable.

Proponents of GM foods claim that genetic engineering is a precise technique that allows the genes encoding the desired trait to be inserted into the host plant without unexpected effects. But genetic engineering and associated tissue culture processes may be imprecise and highly mutagenic (Fagan, Antoniou *et al.*, 2012). This leads to unpredictable changes in the DNA, proteins and biochemical composition of the transgenic crop, resulting in unexpected toxic or allergenic effects and nutritional disorders, as well as unpredictable effects on the environment (Fagan, Antoniou *et al.*, 2012).

Controversy 2 - There is no great agricultural potential and it does not solve social, health and environmental problems vs. proponents of agricultural genetic engineering point to the potential of this technology to address social, health and environmental problems.

Proponents of genetic engineering advocate it as an essential means to meet growing food demands and relieve nutritional deficiencies around the world. By altering the nutritional components of food crops, advocates suggest that genetic engineering will improve yields and may also potentially mitigate nutritional deficiencies common in developing countries. For example, it is proposed that vitamin A and iron deficiency can be addressed by increasing the nutrient content and / or bioavailability of nutrients in certain foods. By genetically manipulating pest resistance in crops, the need for pesticides is expected to decrease, thus providing a considerable environmental benefit. On the other hand, critics of agricultural genetic engineering argue that the use of technology will actually threaten environmental quality and human health, amplifying recent negative trends and economic changes for farmers, exacerbating social inequality and leading to more concentrated corporate control (Antoniou, Robinson *et al.*, 2012). Some of the anticipated environmental threats include: increased use of certain herbicides, loss of biodiversity and increased resistance to pesticides among target organisms (Antoniou, Robinson *et al.*, 2012).

1.8.3. Procedures for the approval of transgenic foods

Controversy 1 - Transgenic foods are rigorously tested and regulated for safety vs. transgenic foods are not rigorously tested.

In many countries, transgenic foods are approved by regulators as being substantially equivalent to non-GM crops, but when this assumption is scientifically tested, transgenics are often found with unexpected and unintended differences (Antoniou, Robinson *et al.*, 2012). However, these differences are also challenged and refuted by pro-GMOs, who argue that there are no significant differences in the studies (Ricroch, 2013).

1.9. Science and scientific uncertainties

1.9.1. Science

Scientific innovations are deeply rooted in people's lives, in economics, in political choices about how people take care of themselves and use science's available resources. Regarding GM food, studies try to understand the attitudes and perceptions of consumers and society (Frewer, Van der Lans *et al.*, 2013). However, advances in the field of genetic engineering, in relation to GM food have brought numerous scientific debates to society. To mitigate these conflicts, the scientific community and bioethics have built substantial literature on the ethical and political implications of genetic engineering. However, there is still debate about the social responsibility of science. It is understood here on the social responsibility of science - strive to promote the good of society, produce reliable and impartial results, prohibitions of falsification, responsibilities when publishing or sharing research results. Therefore, it draws attention to the relationship between science and society and suggests duties - how science must protect and promote the common good (Sankar & Cho, 2015).

1.9.2 Scientific uncertainties

Intervening directly in the genome, inserting, creating or changing the function of the genetic material, is regarded as the basis of a revolution, but this scientific movement is very young. In relation to GM foods, there is currently a lack of research regarding the beneficial and / or harmful effects of the consumption of these foods on health and the environment. These knowledge gaps create a situation of uncertainty, promote conflicts and hinder a scientific consensus. This lack of research inhibits the ability to perform an accurate risk assessment of the extent of impacts and probability estimate (Barling, Vriend *et al.*, 1999; Kettler, Kennedy *et al.*, 2015). Given the lack of scientific understanding of the proposed beneficial effects and potential adverse effects of genetic engineering and transgenic release, it is possible to list quantitative and qualitative uncertainties described in Table 1.1 (Wickson, Gillund *et al.*, 2012, Nordgard, Bohn *et al.*, 2015). An important conclusion is that the emptiness in scientific understanding in the face of uncertainties and the complexity of cause-and-effect relationships warrant additional research. Initiatives to address the acceptance or rejection of a range of hazard-associated assumptions are necessary. In addition, because scientific boards play a key role in GMO regulations, scientists have a responsibility to address and communicate uncertainty to policymakers and the public. Thus, acceptance of uncertainty is not only a scientific issue, but it is also

related to public policy and involves an ethical dimension (Myhr & Traavik, 2002).

Table 1.1. Typology of uncertainty in Science (Wickson, Gillund *et al.* 2012)

| Type of uncertainty | Explanation |
|--|---|
| Quantitative | |
| Risk (estimated probability) | Imagines the possible impact and estimates the probability of occurrence of this impact, even if not knowing if it will occur or not. |
| Uncertainty (not estimated so far) | Imagines the possible impact, but does not know the probability of this impact occurrence. It is possible to estimate such a probability, but there is not enough knowledge to do so. |
| Qualitative | |
| Indetermination (impossible to be fully estimated) | For complex, open and interactive systems, it is possible to include all relevant factors and interactions in the estimate; therefore, knowledge is conditional and unstable. |
| Ambiguity (different ways of structuring an estimate) | It is possible, in a variety of ways, to refer to both the impacts on which there is interest and the way in which knowledge and estimates generated by these impacts are approached, interpreted and understood. |
| Lack of knowledge (not knowing what should be estimated) | Cannot imagine the possible impact. Cannot calculate the probability of the event, nor is aware of the purpose of the estimates. |

1.10. View of the various stakeholders

In this item, some relevant issues are presented regarding GM food of agrobiotechnological companies, scientists, nongovernmental organizations, farmers, consumers and politicians.

The agri-food system concerns both agriculture and food. The intersection between agriculture and biotechnology allowed for a transformation in the agrifood system, with emphasis on the production of transgenics (Raman, 2017). The commercialization of transgenic crops has raised a public debate from field to table involving a number of stakeholders. In view of this, considering the advances in the production of transgenic crops, it is possible to illustrate a series of conflicts in this agri-food system: On the one hand, there are (i) agro-biotechnology companies and affiliated scientists who present agricultural biotechnology as a solution to the scarcity of food, environmental resources

and combating infestation in the agricultural field; and on the other hand (Gaskell, Stares *et al.*, 2010) there are independent scientists, environmentalists, family farmers and consumers who warn about the fact that GM foods introduce new risks to food safety, the environment and human health, such as loss of biodiversity, increased resistance to antibiotics, allergies and other undesirable effects (Maghari & Ardekani, 2011).

1.10.1. Farmers

There is a complex variety of views on GM foods, among farmers. Despite this diversity, there are variations in such views, which occur within limited parameters, mainly concerned with expectations or concrete experiences about the advantages of transgenic crops, perceptions of associated risks and ethical issues (Almeida & Massarani, 2018).

While some advocate this technology for its ability to improve food production, others have expressed concerns about possible negative impacts. In favor are farmers who believe in reducing chemical fertilizers and pesticides; believe that transgenic crops require less investment in energy in agriculture, reducing carbon footprint; believe that higher harvests could offset greenhouse gas emissions on a scale similar to wind and solar; and believe they bring greater tolerance to abiotic stress (drought, heat, cold and salinity), and biotic stress (plants, animals, bacteria, fungi). On the other hand, there are farmers who point out some concerns: (i) with regard to the patenting of transgenic seeds; this leaves farmers with fewer options and varieties of seeds and fewer places to buy (Gaskell, Stares *et al.*, 2010); they condemn the presence of a corporate control - where most of the sales of transgenic seeds are controlled by some companies, that is, farmers who would buy transgenic seeds would need to sign contracts that dictate how the crop will be grown, including what chemicals to buy and forbidding them from saving seeds; (iii) they consider that the use of transgenic crops will promote an accelerated evolution of plant populations resistant to pests; (iv) they are concerned with the contamination of organic and conventional crops by transgenic genetics; and (v) as regards health, they claim that inserting genes that were not native into the original plant may cause new allergic reactions and other problems in the human body (Areal, Riesgo *et al.*, 2011; Wilhelm & Qaim, 2014).

1.10.2. Scientists

Currently, there is no consensus on safety regarding GM foods (Hilbeck, Binimelis *et al.*, 2015). There are divergent opinions among scientists on the relevance of hazards, adverse

effects, what kind of actions should be taken to avoid harm, as well as doubts as to the application of transgenic in agriculture and food production for better nutrition (Buiatti, Christou *et al.*, 2013). For example, in the scientific literature on the health effects of transgenic crops, three scientific positions can be found, as reported by Krimsky (2015) studies: (i) a group stating that there is no need to test GM foods, provided that the proteins encoded by the transferred genes and host organisms are known; GM foods are considered safe or safer than traditional hybrid cultures or other non-transgenic methods; a second group (ii) believes that each GM food must be tested for a variety of possible effects; they state that science cannot, a priori, confirm that a GM product is safe without conducting a testing program that includes multi-annual and multigenerational tests in animals fed with the transgenic culture; in the third group (iii), we find scientists who state in their published articles that some transgenic cultures, when administered to animals, exhibit detrimental effects compared to non-transgenic controls, and these results should draw attention to human health issues (Krimsky, 2015). It is well established in social science research that, in some fields, there is a financing effect in science, which comes from corporate sponsorship of research, in this case multinational corporations. This means that company-funded science tends to produce results consistent with the financial interests of companies (Diels, Cunha *et al.*, 2011).

1.10.3. Non-governmental organizations

Non-governmental organizations point out that genetic engineering allows for the patenting (privatization) of agricultural germplasm (which removes farmers' right to restate and multiply the profit of seed holders). They present scientific warnings about the consequences of the intrinsic difference between conventional breeding and genetic engineering. They criticize the lack of independence of studies on which national and European authorizations are based. They regret that the legal gaps are not filled (Paarlberg, 2014).

1.10.4. Agrobiotech companies

Agrobiotech companies do their marketing mainly with farmers, in addition to developing various social actions (Griesse, 2007). They promise that genetic engineering will contribute significantly to protect the environment and to feed humanity (Chauhan & Bhatnagar, 2014).

1.10.5. Consumers

In Europe, citizens' views on a variety of topics are regularly examined by Eurobarometer studies conducted by the European Commission to monitor the evolution of public opinion in the Member States. Important factors influencing consumer attitudes are the perception of risks and benefits, knowledge and trust, as well as personal values (Bawa & Anilakumar, 2013). In general, Europeans seem to have very positive attitudes towards technological developments. When asked, in the 2010 Eurobarometer, if certain technology could have a positive effect on the way of life, optimistic responses clearly outpaced pessimists. "Biotechnology and genetic engineering" were expected by 53% of respondents to have a positive effect, while 7% expected no effect, only 20% expected a negative effect and 20% don't know. This overall positive attitude is in contrast when asked about the specific application of biotechnology in transgenic foods. Most respondents were aware of this topic. Only 18% had not heard of it, while 55% had talked about it or actively sought information. In 2010, 23% of EU respondents stated that transgenic foods should be supported, while 61% disagreed with this view (Gaskell, Stares *et al.*, 2010).

1.10.6. Politicians and policies

The political representatives feel, on the one hand, the anti-GM food social pressure and, on the other, the pro-GM economic pressure of the agroindustry. The result of this equation varies from country to country and among political parties. Policymakers rely to a large extent on the scientific advice of experts to assess and make decisions on emerging technologies. Generally, this privileged role of science in decision making is based on the view that science offers objective knowledge, free from the influence of certain values, interests, or beliefs. The most important approach to incorporating science into policy-making, especially for new technologies, is now based on the concept of risk. The risk-based approach to decision making (or the process of risk analysis) is often described as being composed of three steps - risk analysis, risk management and risk communication. According to this approach, scientists first conduct risk assessments, where the identification and estimation of the likelihood of adverse impacts associated with the introduction of a particular technology occurs. Then the risks identified by scientists are evaluated by policy makers, who decide how they will be managed. Finally, after these decisions have been taken, the general public is informed about the risks and management initiatives chosen. A fundamental feature of this conventional approach is that it

presupposes a clear distinction between the phases of factual and objective risk assessment performed by a specialist and that of normative / value-based risk assessment (Wickson, Gillund *et al.*, 2012). In the case of GM food, the situation is somewhat different due to scientific uncertainties and limits, making it impossible to carry out a complete risk assessment, thus generating wide political divergences.

1.11. Precautionary principle

The Cartagena Protocol on Biosafety, established in 1992 under the United Nations Convention on Biological Diversity, arose from the need to establish procedures related to the proper use of biotechnology. It is a guiding document in GM food management and presents as a general principle the precautionary principle in the decision-making processes on GM food, given the scientific uncertainties about the possible environmental, economic and social impacts arising from its use. The protocol is based on the doubts that biotechnology poses new and serious problems, stating that the term biosafety itself refers to the need to protect human health and the environment from the possible adverse effects of modern biotechnology products (Rijssen, Eloff *et al.*, 2015). The precautionary principle is intended to assist in decision-making under uncertainty and it is a fundamental principle of EU environmental legislation. The recourse to the precautionary principle presupposes the identification of potentially dangerous effects arising from a phenomenon, product or process, and that scientific assessment does not allow the risk to be determined with sufficient certainty. The implementation of an approach based on the precautionary principle should begin with a scientific evaluation as complete as possible and, whenever possible, the identification, at each stage, of the level of scientific uncertainty (EC, 2016). The precautionary principle has been applied to a diverse range of fields, including health protection, environmental regulation, biodiversity management and emerging technologies. It may be difficult to agree on exactly how to implement the precautionary principle because risk insights may vary between decision-makers, stakeholders and citizens (EC, 2017).

1.12. Science, Technology and Society, and training

Science, Technology and Society (STS) is an interdisciplinary field of study that seeks, on the one hand, to explore and understand the ways in which modern science and technology shape society, values and institutions, and how values form science and technology, on the other hand (Mansour, 2009). It is also identified as a kind of curricular approach designed

to make traditional concepts and processes found in typical programs of science and social studies more appropriate and relevant at the academic level (Ziman, 1980). In this way, the STS approach seeks to offer a better understanding of science and technology in a social context, addressing social, ethical, economic, political and environmental implications.

Teaching through a STS approach can be carried out through themes of social relevance, accomplishment of activities to solve problems, confrontation of different points of view, critical analysis of arguments and / or discussion of the validity of scientific conclusions. Consequently, the studies promote a new way of understanding socio-scientific themes, since: (i) it encourages dialects of controversial issues, taking into account the positioning of interest groups (Yager & Tamir, 1993); (ii) it stimulates the understanding of conflicts and social responsibility (Bettencourt, Velho *et al.*, 2011); (iii) it prepares the student to face contemporary technological issues and scientific changes; in addition to (iv) contributing to the development of critical and reflective points of view (Hong & Park, 2012).

However, there are no studies in the literature, with nutritionists and physicians, which address the teaching of GM food through STS, studies that explore the STS approach in both health contexts (Webster, 2002; Knopes, 2019); as well as teaching biology, genetics and science (Sadler & Zeidler, 2004; Aikenhead, 2005; Lazarowitz & Bloch, 2005; Bettencourt, Velho *et al.*, 2011).

There are several social, ethical, economic and political dilemmas regarding the scientific and technological development of GM food, as described above. In this context, it is expected that teaching should take place through a meaningful and productive dialectic, of the real impacts and influences of GM food in society, in a comprehensive and integrated way (Key & Ma, 2008; Maghari & Ardekani, 2011). It is in this sense that the STS approach will contribute, that is to teach about GM food contextualizing all those involved in the food system.

1.13. Health providers

As transgenic plants are gradually being introduced into the European Union, public concern will probably grow about possible health problems (Paparini & Romano-Spica, 2004) and search for reliable information (Wunderlich & Gatto, 2015). Some studies with consumers demonstrated limited understanding, misunderstandings and even lack of knowledge of GM food products (Boccia & Sarnacchiaro, 2015). In view of this, it is considered that nutritionists and physicians are aware of the state of the art and, as they are

often the first professionals sought by a patient, they must be in a position to provide an informed opinion (Key & Ma, 2008).

There is some literature on the opinion, knowledge and perceptions of GM food among health professionals in the literature, but there is a lack of high-quality evidence. A study conducted with physicians generally concluded that while the physicians' perception of risk in relation to GM food is high, knowledge about these issues was low; and that in the face of increased consumption and prevalence of food in the supermarket, physicians should have more information about GM food to guide the community (Savas, Gultekin *et al.*, 2014). Another study carried out with dietitians showed that these professionals, in fact, lack knowledge about GM food, as well as a growing tendency of opposition when the knowledge is high; these findings suggest that it is essential for dietitians to be equipped with the latest evidence-based research to better educate and protect customers, consumers, and the general public's well-being (Vogliano, 2012).

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CHAPTER 2 - Construction and validation of a questionnaire to ascertain the knowledge, opinion and training of physicians and nutritionists regarding genetically modified foods.

Abstract

Genetically modified foods have recently entered the European market. This political decision generated social controversy due to debate over the actual health and environmental risks. Faced with this reality, health professionals, such as physicians and nutritionists, play a key role in decoding this new food technology. A diagnosis of the personal, professional reality and training needs of these specialists regarding genetically modified foods is therefore relevant. The questionnaire was implemented online in 2016, with 526 respondents. Validation strategies through semantic analysis, internal consistency analysis and exploratory factor analysis were applied. The questionnaire was validated, presenting a reliability based on Cronbach's alpha coefficient of 0.76. Seventeen factors were extracted, being organized in four themes: opinion, training, knowledge and personal / professional reality. This article highlights the importance of statistical procedures in the validation of questionnaires. The questionnaire could be implemented as a diagnostic tool to ascertain the reality of health professionals (namely physicians and nutritionists, in particular) dealing with challenges of introducing transgenic foods into human food diet.

Key words: reliability, exploratory factor analysis, Cronbach's alpha, internal consistency.

2.1. Introduction

GM foods have been taking on a permanent place on supermarket shelves, in the European Union in general and Portugal in particular. Their short-term and long-term effects on health and the environment are the subject of scientific discussion, which does not seem to end soon. Faced with such a reality, health professionals are important “actors” concerning this issue. They are sources of information regarded as independent and credible, to whom patients can rely for clarification of doubts about risks or benefits associated with GM foods. As such, a multidimensional survey on the personal and professional reality on the training needs of these professionals concerning the subject is justified. A tool that allows for the diagnosis of this reality is the application of questionnaires, with subsequent adequate analysis of the output data. Questionnaire-based studies allow evaluation of attitudes (Biasutti & Frate 2016; Tas *et al.*, 2015), perceptions (Oliveira *et al.*, 2016) knowledge (Cecchetto & Pellanda, 2013; Bradette *et al.*, 2016), satisfaction (Maurice-Szamburski *et al.*, 2017) and behaviors (Itani *et al.*, 2017) of individuals within different contexts. These questionnaires should include questions (items) that, in content and quantity, allow to evaluate the object of study in question (Boparai *et al.*, 2018). And of course all questionnaires should be reliable (give reproducible results) and valid (measure precisely what is intended to be measured) (Hill & Hill, 2000).

The construction and validation of questionnaires involve a semantic analysis of included items and analyses based on statistical methodology, such as exploratory factor analysis and internal consistency (Costello & Osborne, 2005; Fonseca *et al.*, 2013). Semantic analysis is the one that, at the level of linguistics, aims at the correction of errors and ambiguities and the clarity of question content. The exploratory factor analysis aims at simplifying the structure of the questionnaire, grouping the items into more representative factors and explaining the data variability, and eliminating those that do not have relevance in any of the factors (Isquierdo *et al.*, 2014; Watkins, 2018; Pestana & Gageiro, 2014). In this way, it is possible to separate the important information of the redundant and random ones, and the obtainment of groups that can explain subconceptions. Internal consistency is a form of measurement based on the correlation between different items, guaranteeing that all items tested are measuring the right concept. A validated questionnaire with appropriate methodology leads to greater confidence in the results of the research.

The present research aims at describing the steps in the process of creating a questionnaire examining the knowledge, opinion and training needs of physicians and nutritionists

regarding GM food. The validation of the questionnaire was achieved through semantic analysis, internal consistency analysis and exploratory factor analysis.

2.2. Methods

2.2.1. Identification of potential questions and initial questionnaire structure

The preliminary stage consisted of a bibliographical research on topics directly related to GM Food (*i.e.*, genetic engineering, biotechnology and food safety) and knowledge, opinion, perception and training regarding GM Food (Commission,1997; Gaskel *et al.*, 2000; Gardner & Jones, 2011; Kitto *et al.*, 2003; Amin *et al.*, 2014; Amina *et al.*, 2014; Burton & Pearse, 2002; Pootinga & Pidgeon, 2004; Pardo *et al.*, 2002; Bhavsar *et al.*, 2015; Traill *et al.*, 2004; Hallman *et al.*, 2003). This information was subsequently processed and adapted.

Based on the survey, a structured questionnaire was elaborated as follows: (i) introductory note with the research background and objectives, institution involved, clarification of the main concepts and declaration of confidentiality and anonymity; (ii) nine questions for socio-demographic characterization of the respondents and (iii) 60 questions on four thematic axes: knowledge (GM Food production, sale and labeling in Portugal), opinion (consumption, nutrition, health, risks / benefits), self-perception of training needs (type, content and form) and personal / professional reality as regards GM Food. Of these, 57 were closed in qualitative dichotomous scales (yes / no; true / false), Likert type, with 5 levels (totally disagree, disagree, neither agree nor disagree, agree, totally agree) or multiple choice with a single option. Only 3 were open-ended questions.

2.2.2. Construction and validation of the questionnaire

2.2.2.1. Semantic validation

The questionnaire above was sent to a sample of 13 physicians and 11 nutritionists, selected by convenience from several institutions, located in different geographic regions. These 24 individuals evaluated clarity, structure, presentation, relevance, efficacy and interactivity of the questionnaire (Costello & Osborne, 2005). Additionally, the questionnaire was evaluated by two specialists who have experience in the elaboration of measurement instruments (questionnaires) and relevant scientific production related to GM food and nutrition.

2.2.2.2. Implementation

The questionnaire was implemented in the LimeSurvey online platform (version 1.91+) and released from March to July 2016. To help garner visibility partnerships were sought with national associations of Physicians and Nutritionists, scientific meetings and social and professional networks. The questionnaire was disseminated within a universe of about 50 927 physicians and 2 300 nutritionists.

2.2.2.3. Statistical analysis

Respondent data was exported from LimeSurvey to Microsoft® Excel® (Microsoft Corporation, version 14.5.7) and later analyzed in the IBM SPSS Statistics 23 for Windows® program (SPSS Inc., Chicago, USA). Incomplete questionnaires that compromised the analysis were excluded (Pereira, 2004). Open and/or unanswered questions were also deleted. Subsequently, an internal consistency and factor exploratory analysis of the data was performed.

Reliability - The internal consistency of the questionnaire was evaluated based on Cronbach's alpha coefficient. Cronbach's alpha values range from 0 to 1, and the internal consistency of a questionnaire is greater as its value gets closer to 1. A coefficient value in the range of 0.6 to 0.8 was used as an indicator of acceptable moderate-to-moderate consistency (Pestana & Gageiro, 2014).

Exploratory factor analysis - The thematic axes of the questionnaire were validated by exploratory factor analysis, which allows for item grouping of items into factors and structure simplification thereby reducing the total number of questions. These factors adequately synthesize the information involved (Pestana & Gageiro, 2014).

The initial stage of exploratory factor analysis checked whether the data matrix was adequate for factorization, evaluating correlations between the items. The Kaiser-Meyer-Olkin (KMO) and Bartlett tests were used for this purpose. KMO values (or sample suitability index, calculated as the square of the total correlations divided by the square of the partial correlations of the items) can vary between 0 and 1: values under 0.5 are considered unacceptable, between 0.5 and 0.7 mediocre, between 0.7 and 0.8 good, between 0.8 and 0.9 optimum and above 0.9 excellent (Pestana & Gageiro, 2014). The Bartlett test evaluates whether the covariance matrix is similar to an identity matrix (i.e., unit diagonal elements and remaining ones equal to zero). If the null hypothesis of matrix equality is rejected (significance level of 0.05), the correlations between the items are adequate and if the data factor analysis can proceed (Pestana & Gageiro, 2014). Based on

these two tests, and if the data matrix can be factorized, the questionnaire can be subjected to an exploratory factor analysis using the principal components method. The method of factors extraction was based on the Guttman-Kaiser criterion, retaining factors with eigenvalues greater than 1 and percentage of variance explained by retained factors greater than 40% (Yeaomans & Golder, 2017; Hayton *et al.*, 2004).

The Varimax rotation criterion of the principal components matrix was used. The retention of the items in each factor was based on absolute values of factor loading equal to or greater than 0.3 (Pestana & Gageiro, 2014) and values of the calculated communalities (proportion of variance of each item explained jointly by retained factors, ranging from 0 to 1 greater than 0.5 (Watkins, 2018; Pestana & Gageiro, 2014).

The study was approved by the Scientific Council of the College of Biotechnology, Portuguese Catholic University, Porto, Portugal.

2.3. Results

2.3.1. Semantic analysis

Factual errors, question ambiguities, item distribution, questionnaire length and overall content adequacy were corrected during the semantic validation procedure.

Expert recommendations and suggestions were incorporated, some items were reformulated and others eliminated. The final questionnaire had 69 questions, of which 9 were on socio-demographic characterization and the remaining 60 on GM food.

2.3.2. Statistical analysis

The final sample was composed of 526 respondents: 278 physicians and 248 nutritionists. This sample size exceeds the ideal respondent value of 382 elements, with a sampling error of 5% and a confidence level of 95% (Pereira, 2004).

Of the 60 thematic questions (or items), 3 were excluded due to lack of answers (all were open-ended questions).

Reliability - The Cronbach's alpha coefficient obtained considering the 57 items was 0.76, revealing a substance-moderate consistency. This coefficient is a commonly used measure of reliability, that is, a measure to evaluate the internal consistency of questionnaires. The coefficient measures the coherence of the respondents' answers, its value indicating the extent to which the items and the scales that compose them measure the same concept.

Exploratory factor analysis - The questionnaire with the 57 items (Table 2.1) was submitted to an exploratory factor analysis using the principal components method. The obtained KMO index was 0.786 and the Bartlett sphericity test allowed to reject the null hypothesis to be rejected ($p < 0.05$), which shows a good correlation between the variables and corroborating the factor analysis.

The results of the method of factors extraction based on the Guttman-Kaiser criterion are shown in Table 2.2. A total of 17 factors were obtained, which had their eigenvalues values greater than 1 and explain 63% of the total variance of the items.

Table 2.1 presents the factor loading, communality and Cronbach alpha values of the items, grouped according to the results of the factor analysis after rotation of the principal components' matrix. The items included in the questionnaire were those that presented absolute loading values above 0.3 for all factors. This is considered the minimum value necessary for the factor loadings to be considered significant in exploratory analyses, being representative of the factors (Howard, 2016). The higher the factor loading the better the item and, in this sense, many have relevant factor loadings. Two items of the questionnaire were excluded because they presented a factor loading close to zero.

As regards communality values, four items were below 0.5 (shown in Table 2.1). However these values were higher than 0.43, which explains at least 43% of the total variance. We chose to keep these items within the factors. Regarding Cronbach's alpha values, the values revealed a substantial internal consistency, ranging from 0.69 to 0.73.

Altogether 17 factors were retained and described the correlation structure between 55 items. Based on their composition (presented in Table 2.1), the 17 factors were organized into 4 groups: opinion (factors 1, 2 and 3), training (factors 4 to 10), knowledge (factors 11 and 12) and personal/professional reality (factors 13 to 17) as pertains to GM food. These groups translate the objectives of the questionnaire.

Table 2.1. Factor loading, communalities and Cronbach's alpha of items grouped by factor

| Theme Area | Factor | Questionnaire Item | Factor Loading | Communalities | Cronbach's Alpha |
|------------|--------|--|----------------|---------------|------------------|
| Opinion | 1 | The consumption of genetically modified foods may induce an adverse clinical or nutritional picture. | -0.759 | 0.613 | 0.710 |
| | | The consumption of genetically modified food may lead to health problems. | -0.742 | 0.660 | 0.711 |
| | | There is scientific evidence that genetically modified organisms have negative health impacts. | -0.721 | 0.602 | 0.711 |
| | | It is likely that transgenic foods are associated with some kind of symptom or pathology, even if it is not yet scientifically established. | -0.691 | 0.602 | 0.713 |
| | | Consuming transgenic foods is, in practice, equivalent to the consumption of non-transgenic foods. | 0.680 | 0.653 | 0.695 |
| | | Current standards are sufficient to protect people from possible risks of genetically modified food. | 0.515 | 0.559 | 0.692 |
| | | If you chose a food product to buy and then notice that it was genetically modified, would you buy it (assuming there are other equivalents at the same price and without genetic modification)? | -0.496 | 0.563 | 0.696 |
| | 2 | Genetically modified seeds result in a healthier diet. | 0.743 | 0.666 | 0.691 |
| | | Genetically modified seeds allow for greener farming. | 0.716 | 0.649 | 0.697 |
| | | Transgenic foods currently on the Portuguese market are more nutritious than their conventional or biological counterparts. | 0.706 | 0.619 | 0.691 |
| | | Genetically modified organisms are an important tool in the fight against hunger in the world. | 0.606 | 0.609 | 0.696 |
| | | Genetic engineering can be used to produce food that brings benefits to mankind. | 0.548 | 0.578 | 0.695 |
| | 3 | The population is adequately informed about the consumption of transgenic foods. | 0.687 | 0.615 | 0.696 |
| | | | | | |
| Training | 4 | How do you keep up with the genetically modified food theme? News on the Internet. | 0.817 | 0.737 | 0.694 |
| | 5 | How do you keep up with the genetically modified food theme? Scientific magazines. | 0.737 | 0.670 | 0.690 |
| | | How do you keep up with the genetically modified food theme? Books and miscellaneous technical documentation. | 0.670 | 0.536 | 0.693 |
| | | How do you keep up with the genetically modified food theme? Conferences, lectures, seminars. | 0.667 | 0.601 | 0.693 |

| | | | | | | |
|-----------|----|--|---|--------------|-------|-------|
| | | How do you keep up with the genetically modified food theme? Contact with specialists. | 0.505 | 0.536 | 0.694 | |
| | 6 | Did you receive any kind of training on genetically modified organisms under the bachelor's degree? | 0.769 | 0.651 | 0.698 | |
| | 7 | What kind of topics would you like to see covered in that training? Genetically modified organisms and legislation. | 0.798 | 0.708 | 0.686 | |
| | | What kind of topics would you like to see covered in that training? Genetically modified organisms and ethics. | 0.796 | 0.664 | 0.685 | |
| | | What kind of topics would you like to see covered in that training? Genetically modified organisms and labeling. | 0.767 | 0.658 | 0.687 | |
| | | What kind of topics would you like to see covered in that training? Genetically modified organisms and environment. | 0.739 | 0.618 | 0.687 | |
| | | What kind of topics would you like to see covered in that training? Genetically modified organisms and genetics. | 0.653 | 0.563 | 0.688 | |
| | | What kind of topics would you like to see covered in that training? Genetically modified organisms and nutrition. | 0.555 | 0.649 | 0.691 | |
| | | What kind of topics would you like to see covered in that training? Genetically modified organisms and health. | 0.516 | 0.703 | 0.692 | |
| | | Do you consider it useful for your professional life to be continued training for updating on genetically modified foods? | 0.339 | 0.544 | 0.687 | |
| | | 8 | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? A theoretical work. | 0.842 | 0.797 | 0.691 |
| | | | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? A practical work. | 0.837 | 0.793 | 0.687 |
| | 9 | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? A short seminar. | 0.808 | 0.703 | 0.693 | |
| | | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? A class. | 0.759 | 0.655 | 0.694 | |
| | | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? An optional subject. | 0.446 | 0.43* | 0.692 | |
| | 10 | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? A required subject. | -0.631 | 0.624 | 0.696 | |
| | | What kind of training do you consider most appropriate to receive during the bachelor's degree in relation to genetically modified foods? A module within a subject. | 0.592 | 0.620 | 0.695 | |
| | | Do you consider it useful to have some kind of training on genetically modified foods during the bachelor's degree? | 0.327 | 0.47* | 0.696 | |
| | | | | | | |
| Knowledge | 11 | In Portugal the main transgenic crop is soybean. | 0.817 | 0.753 | 0.691 | |
| | | In Portugal the main transgenic in circulation is soybean. | 0.781 | 0.739 | 0.69 | |
| | | In Portugal organic food can also be transgenic. | 0.658 | 0.599 | 0.69 | |

| | | | | | | |
|--|-----------------------|---|--|--------------|-------|-------|
| | | In Portugal several horticultural transgenic food is sold. | 0.533 | 0.546 | 0.691 | |
| | 12 | In Portugal there is labeling of animal products produced using transgenic feeds. | 0.786 | 0.742 | 0.689 | |
| | | In Portugal there is labeling of transgenic foods. | 0.765 | 0.733 | 0.689 | |
| | | | | | | |
| Personal and professional reality | 13 | Do you feel it would be useful to take some kind of technical training on genetically modified organisms? | 0.447 | 0.623 | 0.692 | |
| | | Have you found difficulties or doubts (or do you feel you could find them) when talking about the subject of genetically modified foods with your patients / clients? | 0.405 | 0.45* | 0.689 | |
| | 14 | Have you performed any patient / client diagnoses involving the negative impact of genetically modified foods? | 0.833 | 0.729 | 0.695 | |
| | | In the last year, has any of the patients / clients raised any questions about genetically modified foods? | 0.826 | 0.717 | 0.691 | |
| | | On your own initiative (or would you indicate in any circumstance) do you tell your patient / client not to use genetically modified foods? | 0.730 | 0.659 | 0.690 | |
| | | If a patient / client asks if they can consume genetically modified food, what do you answer? | 0.638 | 0.602 | 0.695 | |
| | 15 | How many times have you talked about the subject of genetically modified foods with your colleagues? | -0.694 | 0.610 | 0.721 | |
| | | How many times have friends or family ever asked you for your opinion on genetically modified foods? | -0.664 | 0.561 | 0.721 | |
| | | How many times have you had the initiative to talk about genetically modified foods with your patients / clients? | -0.602 | 0.598 | 0.727 | |
| | | When you shop, do you want to know if you are carrying any genetically modified food? | 0.453 | 0.542 | 0.695 | |
| | | Have you ever looked for any kind of information about genetically modified foods? | 0.321 | 0.44* | 0.690 | |
| | 16 | Have you ever bought any transgenic food? | 0.886 | 0.887 | 0.690 | |
| | | Have you ever eaten any transgenic food? | 0.882 | 0.875 | 0.690 | |
| | 17 | Do you feel prepared to deal with transgenic issues that may arise, including some kind of symptom or pathology that may eventually be associated with them? | 0.781 | 0.695 | 0.696 | |
| | | | | | | |
| | Rejected Items | | With regard to your job colleagues, do you feel more or less prepared to deal with issues related to genetically modified foods? | 0.095 | 0.718 | 0.701 |
| | | | How do you keep up with the issue of genetically modified foods? Social communication (press, radio, TV). | 0.07 | 0.762 | 0.695 |

*Communalities value under 0.5

Table 2.2. Eigenvalues and total variance explained by factors extraction

| Factor | Eigenvalue | % of variance | % of the cumulative variance |
|---------------|-------------------|----------------------|-------------------------------------|
| 1 | 7.131 | 12.294 | 12.294 |
| 2 | 4.635 | 7.992 | 20.286 |
| 3 | 3.432 | 5.917 | 26.203 |
| 4 | 2.794 | 4.818 | 31.021 |
| 5 | 2.431 | 4.191 | 35.212 |
| 6 | 1.908 | 3.290 | 38.502 |
| 7 | 1.731 | 2.984 | 41.486 |
| 8 | 1.657 | 2.856 | 44.343 |
| 9 | 1.513 | 2.609 | 46.952 |
| 10 | 1.402 | 2.417 | 49.369 |
| 11 | 1.345 | 2.318 | 51.687 |
| 12 | 1.307 | 2.254 | 53.941 |
| 13 | 1.152 | 1.986 | 55.927 |
| 14 | 1.142 | 1.970 | 57.896 |
| 15 | 1.078 | 1.858 | 59.755 |
| 16 | 1.036 | 1.786 | 61.541 |
| 17 | 1.023 | 1.763 | 63.304 |

2.4. Discussion

The validation of the developed questionnaire, based on the factor analysis procedures and reliability tests, allowed for a better organization of the contents aimed at an understanding of the current needs of health professionals regarding the issues around GM food. Results herein validate the questionnaire according to appropriate statistical procedures and led to a reorganization of the items in 4 theme areas. These areas have been classified and include the following core issues: (i) opinion - consumption, nutrition, health, risks and benefits of GM Food; (ii) training - required contents, teaching-learning types and ways of updating; (iii) knowledge - issues related with the reality of GM food in Portugal, namely farming, circulation, sale and labeling; and (iv) personal / professional reality - issues, difficulties and doubts related to questions placed in a professional or personal context.

The methodology used to construct and validate the questionnaire aimed at physicians and nutritionists and regarding GM food was used by different authors, both in similar themes

and in different contexts. Ferreira *et al.* (2016), for example applied a factorial analysis and reliability tests to adapt and validate a questionnaire to nursing students about their perception of the type of supervision that is provided in clinical practice. Despite being a distinct thematic area of the present work, the methodology was similar and allowed these authors to find two factors that helped to clarify the behaviors.

In Turkey, Erdogan *et al.* (2009) developed a questionnaire to assess the attitude of university students towards biotechnology, with items on genetic engineering, GM food consumption, medical application, consumer perception, ethics and environmental impact perception. This questionnaire was validated by tests of reliability and exploratory factor analysis. The development of this instrument aimed to contribute to the scientific education in this area, which still presents great knowledge gaps. These authors obtained a KMO index of 0.860, which was slightly higher than the one obtained in our work (0.786). However, both values are indicative of the strength of the correlation between the items in the questionnaire, allowing to continue with the factor analysis.

In Malaysia, Amin *et al.* (2013) analyzed the attitude of distinct groups of individuals (agri-food producers, biotechnology industrialists, health professionals, members of governmental and religious organizations, students and the general public) for two types of GM food (soybean and palm oil) and a genetically modified drug (insulin). The dimensions incorporated in the questionnaires were familiarity, perception of benefits, perception of risks, acceptance of risks and, finally, incentives. The instrument was also validated with reliability tests and factor analysis. Understanding the public attitude towards genetically modified food was the main objective. The instrument of research of Amin *et al.*³³ was multidisciplinary, self-built, and also validated with reliability tests and factor analysis. These authors used a 7-point Likert scales from the lowest level of agreement to the highest one, larger than the one used in our work. In terms of internal consistency assessed by Cronbach's alpha values results were similar and above 0.70.

Fonseca *et al.* (2013) used an exploratory factor analysis to validate a questionnaire on the perception of Portuguese secondary school students on biotechnology. The main objective was to develop and validate statistical analysis procedures in questionnaires with multiple dimensions, using as pilot data the students' perceptions regarding the mentioned issues.

The questionnaire included questions on genetic engineering, applications of biotechnology, consumption of GM food, labeling and purchase intent similar to our research, using component analysis with varimax rotation. The analysis excluded items that reduced internal consistency and exhibited acceptable communality (above 0.40).

Oliveira *et al.* (2016) constructed and validated a questionnaire to evaluate the perception of Portuguese adults on functional foods, also using an exploratory factor analysis. These foods are characterized by their potential to promote health and well-being and reduce the risk of certain diseases, a feature highly leveraged by marketing. The capacity of this questionnaire was validated, being a useful tool to evaluate the perception of consumers with the aim of promoting more informed and conscious choices. Cronbach's alpha (=0.816) and KMO index (=0.855) were higher than the ones obtained in our work, revealing good internal consistency of the questionnaire and a good correlation between the items as well.

The results obtained with our work allowed us to construct a valid and reliable questionnaire that could be implemented as an instrument to diagnose the reality of health professionals (physicians and nutritionists, in particular) in the face of the challenges of introducing transgenics into human food diet.

2.5. Conclusion

The final questionnaire obtained and validated is an innovative instrument that will allow verifying the opinion, knowledge, training and personal / professional reality of Portuguese physicians and nutritionists regarding GM food, contributing to the characterization and identification of gaps related to this subject. It is worth mentioning that, although this instrument has been validated by physicians and nutritionists, it can be applied to other health professionals who are involved in this subject. The procedures used to validate the questionnaires, i.e., exploratory factor analysis and reliability, allow greater credibility to the research and consistency of the results attained from the research.

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CHAPTER 3 - Characterization of the opinion, knowledge and perception of the training needs of Portuguese nutritionists in relation to genetically modified foods

Abstract

Genetically modified (GM) food have been approved in the European Union. These foods have been questioned as to their actual benefits and risks. This is especially relevant in the case of the nutritional dimension, where consumers are confronted with daily decisions about how to best feed their families. Within this complex framework, health professionals are called upon to intervene and respond to the questions on opinion, attitude and science their clients bring in. The objective of this study was to evaluate the knowledge and opinion of nutritionists on the subject of transgenic foods and their perception of training needs. A questionnaire was applied between March and July 2016, and 248 individuals participated. The variables studied were opinion, knowledge and training. Descriptive calculations and multiple correspondence analysis were performed to obtain the respondents' profiles. With regard to opinion and knowledge results show that nutritionists are mostly unfavorable to genetically modified foods, even without knowing the technology in detail. They are aware of this illiteracy, which was confirmed by their answers to a number of objective questions about the national reality. Multiple correspondence analysis showed four different nutritionist profiles are sufficient to group all participants. These profile types differ in interest and confidence levels relatively to the GM technology. Portuguese nutritionists do not have an unanimous position on GM foods but mostly agree that specific training in this area should take place at the university level. This article highlights the different profiles of opinion, knowledge and formation of professionals, nutritionists, in relation to genetically modified foods.

Keywords: questionnaire; nutritionists' profiles; perspectives; types of training.

3.1. Introduction

Genetically modified foods are in circulation in the European Union (and therefore also in the Portuguese market): mainly maize, soybeans and their derivatives (ISAAA, 2017). The official position of the national government and the European Commission is that the authorized GM food is safe for human consumption (EU, 2017).

Genetically modified organism is an organism that has had its genome modified in the laboratory without necessarily receiving genetic material (RNA or DNA) from another organism. Transgenic is an organism that has been subjected to the specific technique of inserting genetic material from an organism belonging to a different species. Therefore it can be said that: every transgenic is a genetically modified organism, but not every genetically modified organism is a transgenic (ISAAA, 2017; EU, 2017).

These foods from new genetic technologies have been questioned as to the dimensions of their benefits and risks (Zhang *et al.*, 2016; Santis *et al.*, 2018; Sanchez & Parrott, 2017). The controversy also extends to the social dimension (Lucht, 2015) since innovations like this also have a direct impact on people's lives, often leading to conflicts with their own visions and values (Popek, 2017). This is especially relevant in the case of food and nutrition, where consumers are confronted with daily decisions about how best to feed their families. In this context, health professionals are called upon to intervene, sooner or later, and respond in the context of their clinical contact to questions of opinion, attitude and science (Edge *et al.*, 2015). Nutritionists, by the nature of their professional skills, are potentially at the center of this educational challenge in relation to GM food.

A number of studies have been published on the positioning of consumers (Boccia & Sarnacchiaro, 2015), farmers (Almeida & Massarani, 2018), adolescents (Lachowski *et al.*, 2018), experts (Aleksejeva, 2014), professors (Gardner, 2011) and even university students (Velickovic *et al.*, 2016) in assessments covering the most diverse countries and cross-country comparisons. However, there are few studies that analyze the opinion, knowledge of health professionals regarding GM food. Their perception of the specific training required for this new food category is also unknown.

In short, it remains unknown whether health professionals - nutritionists in particular - are following the challenge of introducing GM food in human nutrition. Taking this into consideration, it is justified to explore the reality of nutritionists in relation to GM food in Portugal, particularly evaluating the possibility of including this theme in their university education. This case study in Portugal could be extended to other countries because, as far as we are concerned, this professional group has been poorly studied in relation to this subject.

3.2. Methods

To obtain the nutritionists' profile in relation to GM foods, a questionnaire was elaborated with the following structure: (i) a brief introductory note - contextualization of the thematic, objectives, identification of the institution where the investigation takes place, clarification of the concepts (genetically modified organism, transgenic food and genetically modified food), a declaration of confidentiality and anonymity; (ii) seven questions of socio-demographic characteristics of the respondents (Table 3.1); (iii) twelve questions of opinion focusing on nutritional features, impacts on environment and on consumer's health (Figure 3.1); (iv) six knowledge issues related to cultivation sale, and labeling of transgenic foods in Portugal (Figure 3.2); and (v) seventeen questions related to self-perception of training needs on GM foods. These last questions are related to usefulness of training during university education, type of training (Figure 3.3), topics to be lectured (genetics, nutrition, health, labeling, legislation, ethics and environment), needs for deeper information on GM foods, and real applications (questions asked by patients on the topic). These 35 questions were closed in qualitative scales, Likert type, with 5 levels that later were grouped into 3 levels (disagree, neither disagree nor agree, agree) and multiple choice with a single possibility of response.

The questionnaire was developed by the authors, based on Hill & Hill (2008) guidelines. The questionnaire had been previously validated as described in Chapter 2.

The questionnaire was implemented in the online platform of LimeSurvey (version 1.91+) and released from March to July 2016 through the Portuguese Association of Nutritionists, in scientific meetings and in social and professional networks. The dissemination potentially covered a population of 2,347 nutritionists, the number of nutritionists enrolled in the Association at the time of this work. The study was approved by the Scientific Council of the College of Biotechnology, Portuguese Catholic University, Porto, Portugal. The professionals who participated in the survey had informed consent.

Survey respondent data was exported from LimeSurvey to Microsoft® Excel® (Microsoft Corporation, version 14.5.7) and subsequently analyzed in the IBM SPSS Statistics 23 for Windows® program (SPSS Inc., Chicago, USA).

In addition to the descriptive calculations, a multiple correspondence analysis (MCA) was also performed aiming at obtaining associations of the nominal and ordinal qualitative variables so that they could be represented in a few dimensions through the most discriminative variables. The number of dimensions was based on inertia, discrimination

measures and higher internal consistencies (Carvalho, 2017). The internal consistency was evaluated based on the Cronbach's Alpha value (Hill & Hill, 2008).

3.3. Results

3.3.1. Characterization of participants

The study included 248 nutritionists, 209 (84.6%) being women. The participants' age ranged between 22 and 59 years of age, with 64.2% of those living in the northern region of the country. It was found that a considerable proportion of the professionals had other training beyond the degree: 23.8% had a postgraduate degree, 17% had a master's degree and 6.8% a Ph.D. degree. Regarding the place where they completed their academic training, 51.4% referred to *Faculdade de Ciências da Nutrição e Alimentação* of University of Porto, with *Universidade Católica Portuguesa* emerging as the second most cited institution (16.5%) and *Instituto Superior de Ciências Médicas Egas Moniz* in third place (8.6%). Regarding the years of completion of the course, 56.0% concluded between 2011 and 2016. When asked how often they contacted patients, 53.8% of the professionals reported doing it daily (Table 3.1).

3.3.2. Identification of nutritionists' opinions regarding GM food

Results of nutritionist's opinions regarding GM foods are in Chart 3.1. Most participants (77.6%) agree that genetic engineering can be used in the production of foods that bring benefits to mankind (Question OP12). However, 59.8% agree that consumption of GM food may lead to health problems (Question OP11). In addition, 70.3% answer that consuming GM food is not equivalent to consuming non-transgenic foods (Question OP8). When asked whether the consumption of GM food can induce an adverse clinical or nutritional picture (Question OP7) and if there is scientific evidence that GM food has negative health impacts (Question OP4), most participants did not have a clear position: the majority reported not agreeing or disagreeing (46.6% and 48.2% for OP7 and OP4, respectively).

When asked whether GM food is likely to be associated with some kind of symptom or pathology, even if it is not yet scientifically established (Question OP2), 51.7% agree, opposing 35.6% who "neither agree nor disagree". Relatively to the sentence which states that current standards are sufficient to protect people from possible risks of GM food (Question OP10), it is found that a large proportion (61.4%) of respondents disagree with

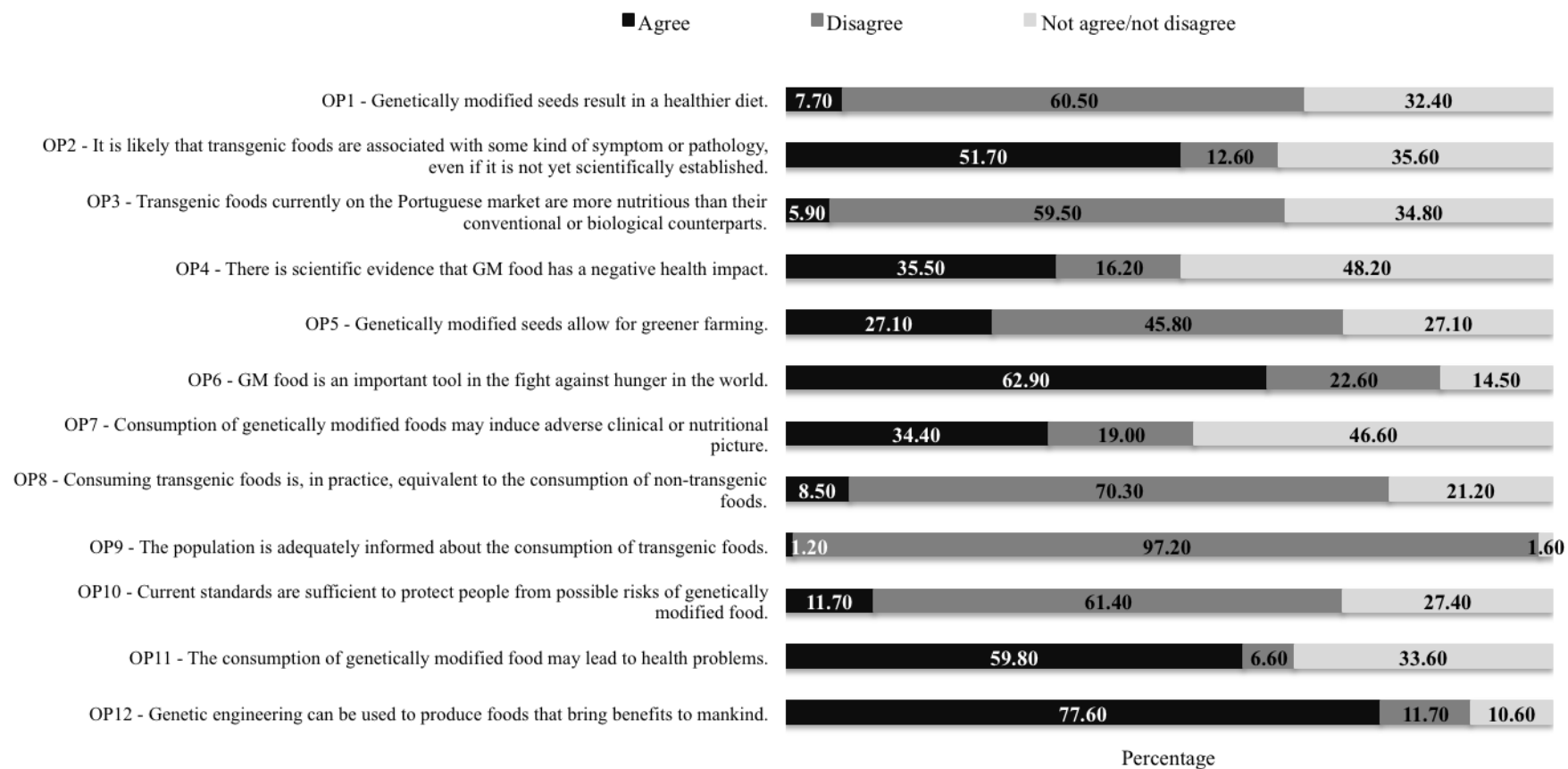
it. Almost unanimity appeared in Question OP9, where 97.2% of participants understood that the population was not adequately informed about GM food consumption. Concerning the usefulness of GM food in the fight against hunger in the world (Question OP6), 62.9% of the respondents agree with it although they also think (45,8%) that genetically modified seeds do not allow a greener agriculture (Question OP5).

Table 3.1. Characterization of study participants of nutritionist (n = 248)

| Variables | n* | % |
|---|-----------|----------|
| Genre | | |
| Male | 38 | 15.4 |
| Female | 209 | 84.6 |
| Age (years) | | |
| 22-25` | 83 | 35.3 |
| 26-30 | 66 | 28.1 |
| 31-35 | 34 | 14.5 |
| above of 35 | 52 | 22.1 |
| Level of training | | |
| Graduation | 129 | 52.2 |
| Masters | 42 | 17.0 |
| Ph.D. | 17 | 6.8 |
| Post-graduation | 59 | 23.8 |
| Region of residence (NUTS II**) | | |
| North | 156 | 64.2 |
| Center | 39 | 16.0 |
| Lisboa | 44 | 18.1 |
| Alentejo | 1 | 0.4 |
| Algarve | 1 | 0.4 |
| Madeira | 2 | 0.8 |
| Frequency of contact with patients | | |
| Diary | 133 | 53.8 |
| Weekly | 37 | 15.0 |
| Monthly | 21 | 8.5 |
| Irregularly | 20 | 8.1 |
| Never or almost never | 36 | 14.6 |
| Institution of university graduation (graduation) | | |
| School of Biotechnology of the Portuguese Catholic University | 40 | 16.5 |
| Faculty of Nutrition and Food Sciences of the University of Porto | 125 | 51.4 |
| Higher Institute of Health Sciences Egas Moniz | 21 | 8.6 |
| University Institute of Health Sciences-North (CESPU) | 18 | 7.4 |
| Others | 39 | 16.0 |
| Conclusion year | | |
| < 2004 | 52 | 21.4 |
| 2005 - 2010 | 55 | 22.6 |
| 2011 - 2016 | 136 | 56.0 |

* n do not always total sample size due to incomplete surveys.

** NUTS II - Nomenclature of Territorial Units for statistical purposes, level 2.



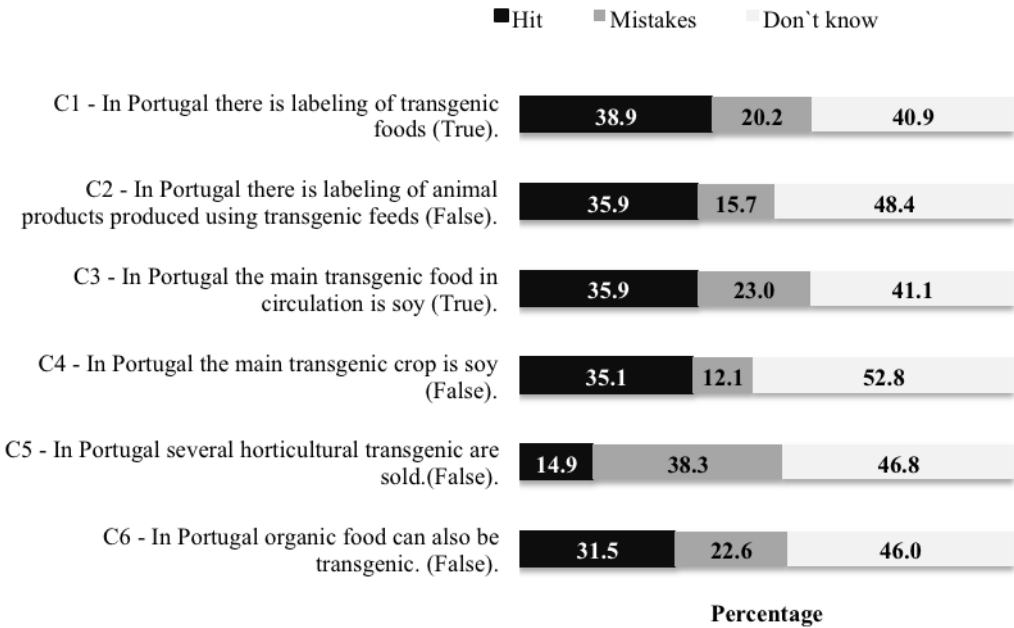
OP# refers to a question about opinion

Figure 3.1 Distribution of the responses related to the opinion on GM food.

Finally, the vast majority (59.5% and 60.5% respectively) disagree that GM food currently in the Portuguese market is more nutritious than their conventional or biological counterparts (Question OP3) and that GM seeds result in healthier food (Question OP1).

3.3.3. Identification of the nutritionists’ knowledge in relation to GM food

Chart 3.2 presents the results regarding the knowledge revealed by nutritionists about GM food. On average, only 32.0% of the respondents hit the six issues and 22.0% failed the answers. A considerable number of nutritionists assumed their illiteracy about the reality of GM foods in Portugal, averaging 46% of the respondents. Among the participants, 38.9% got a correct answer to the question of whether transgenic foods were being labeled in Portugal (Question C1, which is true). The highest mistake was related to Question C5; 38.3% failed the answer to the question of whether in Portugal several horticultural transgenic are sold, which is actually false.



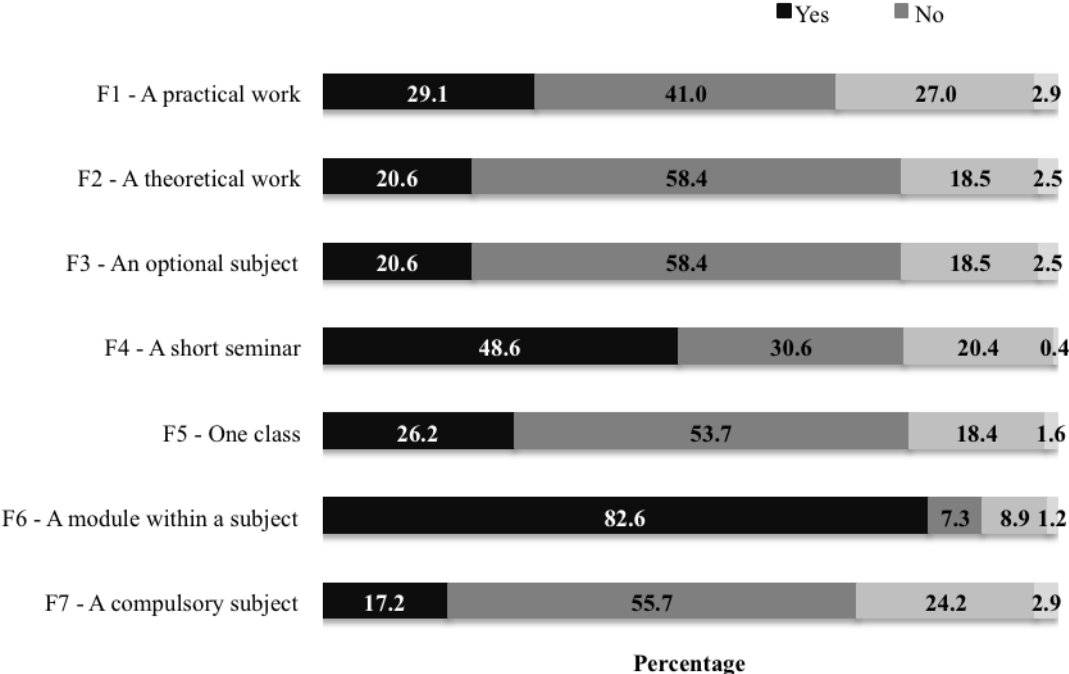
C# refers to a question about knowledge

Figure 3.2. Distribution of answers related to GM food knowledge.

3.3.4. Self-perception of training needs of nutritionists, in relation to GM food

Almost all of the respondents (95.6%) consider it useful to have some type of training on genetically modified foods during university education. When questioned about what type of training they considered more appropriate to receive, the vast majority (82.6%) preferred a

module within a subject during the degree, which is clearly more than one class but leaves open the exact number of hours devoted to the theme (Chart 3.3).



F# refers to a question about training

Figure 3.3. Distribution of responses related to the type of training on GM food.

Regarding the type of topics they would like to see covered in this training, all aspects suggested in the survey, genetics, nutrition, health, labeling, legislation, were considered very important (chosen by more than 80% of the participants) except for topics related to ethics and environment (chosen by 76.1 and 69.2% of nutritionists, respectively).

The need for more information is also evident in the 70.2% who stated that they had already researched some kind of information about GM food. In addition, 89.1% also affirmed to be useful throughout the professional life the existence of continuous training to update on GM food. The knowledge to be acquired will have real application: in the previous year, 21% of clients had asked nutritionists questions about GM food.

3.3.5. Identification of nutritionists' profiles

The MCA allowed the identification of two dimensions with high internal consistencies (Cronbach's Alpha of 0.83 and 0.77 for dimension 1 and 2, respectively). Dimension 1 included 17 questions and dimension 2 included 10 questions, which allowed each dimension to be characterized. The dimensions resulted as follows:

(i) The first dimension integrates in the 1A profile people with the opinion that consuming GM food is not equivalent to consuming non-transgenic foods and that these are no longer more nutritious nor healthier than their conventional or biological counterparts. They consider that genetic engineering does not allow a greener agriculture, that it is not an important tool in the fight against hunger in the world and it does not bring benefits to humanity. They also believe that the consumption of GM food may imply health problems and induce an adverse clinical or nutritional picture. They also admit that these foods are associated with some type of symptom or pathology with negative health impacts and that this is scientifically proven. They consider that the population is not adequately informed about the consumption of GM food and that the standards are not sufficient to protect people from possible risks. These nutritionists consider it important to receive health and nutrition training on GM food in the form of a module within a subject during the degree. In terms of knowledge, they agreed that in Portugal there is no labeling of products coming from animals fed with transgenic feeds.

By contrast, there is profile 1B, with nutritionists who consider that genetic engineering allows for a more ecological agriculture, being an important tool in the fight against hunger in the world and bringing benefits to humanity. These individuals consider that the current standards are sufficient to protect people from possible risks. They also reveal indifference about training during the degree and do not consider it important to include topics in GM food related to health and nutrition in training. This indifference is transversal to the other aspects of opinion, training and knowledge mentioned for the first profile (1A).

(ii) The second dimension includes, in profile 2A, the individuals who consider that the population is not properly informed about the consumption of GM food but agree that these foods allow a more ecological agriculture. These nutritionists are interested in training which addresses the topics of health, nutrition, genetics, environment, labeling, legislation and ethics.

Profile 2B includes a group of nutritionists who neither agree nor disagree on the level of information of the population and who disagree that these foods allow a greener agriculture. Their interest in GM food is minimal, not seeing any advantage in specialized training.

Although most nutritionists are suspicious of GM food, the method of multiple correspondence analysis has allowed the identification of other relevant profiles that represent subsets of the professionals studied. The two primary characteristics in the differentiation of the large nutritionists' profiles found are confidence / non-confidence versus usefulness / non-usefulness of GM food training. Table 3.2 presents these four sets and classifies them according to the respective variables meeting.

Table 3.2. Synthesis of the profiles obtained in the MCA based on the differentiating variables and matching with the nomenclature of Roberts et al. (2006) and Wilkins et al. (2008)

| | WANTS TRAINING | DOES NOT WANT TRAINING |
|-------------------------------|---|---|
| TRUSTS GM FOOD | Profile 2A FAVORABLE AND INTERESTED | Profile 1B FAVORABLE AND UNINTERESTED |
| | <i>(Discerning supporter)*</i> | <i>Promoting</i> |
| DOES NOT TRUST GM FOOD | Profile 1A SUSPICIOUS AND INTERESTED | Profile 2B SUSPICIOUS AND UNINTERESTED |
| | <i>Precautionary</i> | <i>Precautionary</i> |

* Wilkins et al. (2008) used the expression "*Cautiously supportive*" instead of "*Discerning supporter*"

Those who trust in the may have more interest (and in this case the specific formation is) or a more distant relationship (and there does not recognize usefulness to the study of the subject). The same is true of those who regard GM food with suspicion.

3.4. Discussion

As far as the authors are concerned, this study is the first to evaluate the opinion, knowledge and training of nutritionists in relation to GM food, particularly in the professional environment, in Portugal. The tested hypotheses that (i) nutritionists do not have sufficient knowledge about GM food, (ii) that there is no unanimity of opinions, and (iii) that there is a need for university education were largely supported by results.

3.4.1. Opinion and knowledge

Regarding opinion and knowledge, the figures obtained show that nutritionists are mostly unfavorable to transgenic foods, even without knowing the technology in detail. Lack of

knowledge is felt by themselves and it became evident in the answers to objective questions about national reality. These results paralleled those of Vogliano (Vogliano, 2012), who identified a lack of knowledge and varied perceptions in American dietitians. In this study, most respondents also revealed a cautious attitude towards genetically modified organisms. Schmidt *et al.* (2005) have reached similar conclusions about the knowledge and attitude of American health professionals, including dieticians, showing that in this survey knowledge about applications of food biotechnology and genetic engineering is equally inadequate.

3.4.2. Consumers rely on health professionals

Nutritionists agree that consumers are not properly informed about the consumption of transgenic foods. This is also due to the fact that 21% have already been questioned by their clients on this subject, which points at the same time to the search for information from credible sources by attentive consumers. It should be noted that in the most recent Eurobarometer (Commission, 2010) Portugal is the second most uninformed country in the European Union, with 44% of respondents seeking information about it at least once. The literature shows that, in fact, consumers trust and seek health professionals for health and food responses (Schmidt, 2005; Brown, 2003; Heffernan & Hillers, 2002), which effectively attributes to nutritionists the responsibility of interface between GM food and society. However, they do not feel and are not prepared to respond and to mediate the construction of this knowledge.

3.4.3. Content and type of training

The curricular inclusion of GM food requires not only a scientific-technological approach, but also a social and environmental one, as this is a complex theme. Some contributions to the pedagogical approach can be found in the literature, but there is scarce scientific material that includes pluridimensionality, with the dominant tendency being the refuge in the essentially technical description (Hilimire *et al.*, 2014; Rayner *et al.*, 2008). Perhaps as a result of this limitation, both consumers in general and health professionals in particular are ultimately dependent on the media, social networks and other informal channels whose rigor is far from being guaranteed (Quesada, 2014; Wunderlich & Gatto, 2015). The GM food theme is not the only one requiring such treatment, but it is one of the most recent. The space chosen by the respondents - a module within a subject - can create a model of an open methodology, of

reflection and production of knowledge about GM food, which serves interested nutritionists well beyond the validity period of the knowledge itself.

3.4.4. Professional profiles concerning GM food

Although most nutritionists are suspicious of GM food, the method of multiple correspondence analysis has allowed the identification of other relevant profiles that represent subsets of the professionals studied. The two primary characteristics in the differentiation of the four large profiles found are confidence / non-confidence versus usefulness / non-usefulness of GM food training. Table 3.2 presents these four sets and classifies them according to the respective variables meeting. Those who trust in the may have more interest (and in this case the specific formation is) or a more distant relationship (and there does not recognize usefulness to the study of the subject). The same is true of those who regard GM food with suspicion.

The result of nutritionists' profiles classification took the aggregations already published relative to dietitians (Roberts et al., 2006) and teachers (Wilkins et al., 2008) even farther. These two studies have identified three main groups: (i) the Discerning Supporter, (ii) the Promoting and Prompt, and (iii) the Precautionary. Table 3.2 includes these groups, attributed to the profiles identified for Portuguese nutritionists. The level of correspondence found is interesting, especially considering that the mentioned works did not use the MCA method. The set of cautious people is, in the present work, unfolded in two distinct profiles depending on the proximity and interest in the subject (and respective training).

The variances of perspective characterized in each sample can be attributed to differences in professional experiences / assignments as well as personal perceptions of a more ethical nature. Overall, these results demonstrate the need for a GM food approach that is inclusive, multidisciplinary and sensitive to changers that transcend mere biomaterial reading.

3.5. Conclusions

This exploratory and indicative study aimed to contribute to the understanding of the actual training needs of nutritionists in relation to transgenic foods. The identified lack of knowledge is a mirror of what is happening in society in general but, if reversed, can trigger a chain reaction that benefits all citizens thanks to the key role of nutritionists. It is concluded and recommended the insertion in the curriculum of the subject of GM food, in an inclusive and

multidimensional logic that takes into account both what is known and what is still to be discovered.

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CHAPTER 4 – A survey study assessing opinions, knowledge and training needs of Physicians concerning the field of Transgenic foods

Abstract

Transgenic (genetically modified) foods are being grown, sold and eaten in Portugal. As such it is important doctors keep up to date on any negative health consequences of such foods. An inquiry was run through 278 physicians. The objective was to identify their opinion, knowledge and training needs regarding transgenic foods. Opinionwise, 85.8% had an essentially neutral position, 12.5% had a negative view and a minority (1.7%) were positive. At the same time, 79.8% had a low knowledge level, 17.7% were average and only 2.5% showed top knowledge. It should be noted that 91.4% consider it useful to go through some kind of preparation during their university education and 65.1% said that it would be very useful during professional life to have continued education on the issue. Most doctors (83%) could be grouped together according to their interest in knowing more about genetically modified food. The others (17%) had disinterest in common. Medical doctors are considered reliable sources, to whom the general population can turn to in order to access valuable health information. This adds to the Medical doctor responsibility to stay up to date on genetically modified food. Under this vast subject the survey identified subtopics such as genetics, nutrition, health, environment, labeling, legislation and ethics as being of particular interest. This is a pioneering study on the position of physicians towards genetically modified food. The results point to a real need for Medical doctor education and training in this regard. Future course contents should fill basic gaps in genetically modified food knowledge as well as provide a holistic, farm to fork overview.

Keywords: Physicians' profiles; types of training; sources of information; correspondence analysis.

4.1. Introduction

With the advances in genetic engineering and the application of gene manipulation and recombination techniques to agriculture and food, new realities, new opportunities and potentially new dangers arise (Zhang *et al.*, 2016). The commercialization of GM food, which currently appear in Portugal in products with corn or soy, is one of the recent results of these technological advances and has generated discussion regarding the implications, health and the environment, associated with their consumption (Zhang *et al.*, 2016; Dunn *et al.*, 2017).

According to the European Directive 2001/18, transgenics are organisms "whose genetic material has been modified in a way that does not occur naturally through crossbreeding and / or natural recombination (CE, 2001). According to companies that develop them (Monsanto, Bayer, Pioneer), genetic modification of food is aimed at improving its quality, increasing production and increasing resistance to pests and other agri-environmental limitations (Lucht, 2015). There is, however, a lack of awareness and insecurity revealed by European consumers about the introduction of this food, fearing possible negative effects on health and the environment, both in the short term and in the long term (Lucht, 2015; Frewer *et al.*, 2013). Existing legislation itself (Directive 2001/18) provides for the existence of a post-marketing surveillance system since it recognizes that it is impossible to guarantee zero risks when GM food marketing authorization is granted.

In Portugal, and since 2005, there is little cultivation of a single variety of genetically modified maize (less than 10% of the total area dedicated to maize), with the GM food present in the national market being mostly imported from countries such as the United States and Brazil for use by the feed industry (ISAAA, 2017).

It should be noted that GM Food (dozens of varieties of corn and soy, which corresponds to millions of tons per year) are approved by the European Commission for both animal and human consumption and for the entire European Union (EU, 2017). In Portugal the direct consumption of GM food currently concentrates on oils (soy) and some low-expression imported products (corn) (WHO, 2005; Uzogara, 2000).

Health professionals, physicians in particular, are considered to be credible sources of information to which patients resort to clarify various topics, including the consumption of transgenic foods (Paparini & Romano, 2004; Key *et al.*, 2008), and to keep track of the impacts of such foods on the health of those who consume them. The guidance provided by health professionals will assist citizens in taking an individual position in relation to GM food

consumption. Therefore, these professionals should be aware of their determining role and able to respond to issues on this subject, with a thorough knowledge of the scientific principles and their social relevance (Sanchez & Parrott, 2017).

The objective of this study was to identify how physicians in Portugal perceive a set of questions related to GM food, aiming at a characterization of their opinion, knowledge and training needs in this area.

4.2. Methods

This study was based on a survey which included (ii) seven question of socio-demographic characteristics of the respondents (Table 4.1); (iii) twelve issues of opinion focusing on nutritional features, impacts on environment and on consumer's health (Table 4.2); (iv) six knowledge issues related to cultivation, sale, and labeling of transgenic foods in Portugal (Table 4.3); and (v) twenty-five questions related to self-perception of training needs on GM foods (Table 4.5 and 4.6: closed questions of typology, themes and sources of information; and three dichotomous closed questions and one open question described in item 4.3.4). Closed questions were used on qualitative scales, Likert type with 3 levels (disagree, neither disagree / nor agree, agree) or multiple choice with a single answer possibility.

The survey, created on the online platform of LimeSurvey (version 1.91+), was released from March to July 2016 with support from the Medical Association, in scientific meetings and in social and professional networks. The dissemination potentially covered a population of 50,927 physicians, corresponding to those enrolled in the Association, at the time of the study's development. The study was approved by the Scientific Council and by the Ethics Committee of the College of Biotechnology Portuguese Catholic University, Porto, Portugal. Data were exported from LimeSurvey to Microsoft® Excel® (Microsoft Corporation, version 14.5.7) and analyzed in the IBM SPSS Statistics 23 for Windows® program (SPSS Inc., Chicago, USA).

The respondents' opinion regarding GM food was classified as negative (disagree), neutral (neither disagree / neither agree) and positive (agree) - based on the number of opinions against or in favor. Knowledge about GM foods was classified as low, medium and high, according to the number of correct answers between 0-2, 3-4 and 5-6, respectively. Responses - "I don't know" were counted as wrong.

Chi-square independence tests were performed in a correspondence analysis (ANACOR) (Pestana & Gageiro, 2014) to investigate associations between questions and the sociodemographic characteristics of the responding physicians. Correlations based on the Spearman correlation coefficient (r_{Spearman}) were also investigated for ordinal variables.

A multiple correspondence analysis (MCA) (Carvalho, 2008) was carried out aiming at reducing the number of variables and subsequent analysis of clusters of all the questions, in order to obtain groups of variables related to each other. Quadratic Euclidean distance was used as a measure of similarity between the elements to be grouped, and Ward's method as agglomerative method (Carvalho, 2008). The Chi-square independence test was also used to obtain the relationships between the questions and the categories of answers obtained in each cluster, assuming a significance level of 5% (Carvalho, 2008).

4.3. Results

The final sample obtained was 278 doctors. This sample size exceeds the ideal value of respondents, which would be 248 elements, with a sampling error of 5% and a confidence level of 95% (Conchran, 1965).

4.3.1. Characterization of participants

Results on the sociodemographic characterization of study participants are shown in Table 4.1. The number of physicians responding was 278, 45.1% of which being women. Two-thirds of the sample were between 31 and 60 years of age and the majority lived in the North (36.3%) or in the Center (35.2%) of the country. It was found that a considerable proportion of the professionals had additional training beyond their degree: 17.6% had a Postgraduate degree, 29.9% had a Master's degree and 6.5% had a Ph.D. degree. Regarding the place where they studied, 33.5% referred to Coimbra's Medical School, 32.7% to Oporto's Medical School, 10.1% to Lisbon's Medical School and 8.6% to Lisbon's Faculty of Medical Sciences of "Nova" University. Regarding the year of completion of the degree, 38.4% completed it between 2005 and 2016. Professionals were also contacted about how often they contacted patients, and 87.4% reported doing so daily.

4.3.2. Characterization of physicians' opinions regarding GM foods

Physicians' opinions were aggregated according to three main concepts: (i) social, environmental and nutritional aspects; (ii) consumption and health; and (iii) information to consumers (Table 4.2). Regarding social, environmental and nutritional aspects of GM food, more than half of the physicians agree (71.2%) that genetic engineering can be used in the production of foods that benefit humanity and are an important tool in the fight against famine in the world (66.9%). On the other hand, 38.5% disagree that genetically modified seeds allow a more ecological agriculture and 49.6% disagree that genetically modified seeds result in a healthier diet. About half disagree that GM food currently in the Portuguese market are more nutritious than its conventional or biological counterparts (47.4%). Regarding the relationship between consumption and health, the majority of physicians (69.4%) disagree that consumption of GM food implies health problems, and 68.7% disagree that consuming GM foods is in practice equivalent to consuming non-GM food. In the questions about whether the consumption of GM food may induce an adverse clinical or nutritional picture and whether it is likely that GM foods are associated with some type of symptom or pathology, even if it is not yet scientifically established, 43.8% and 49.2%, respectively, say they agree. Regarding the existence of scientific evidence on negative health impacts, 39.9% neither agree nor disagree. Concerning the question of whether the population is adequately informed about the consumption of transgenic foods, the vast majority disagree (96%). A high percentage (60.1%) disagree that current standards are sufficient to protect people from potential dangers of GM food. Results of the correspondence analysis (ANACOR; Table 4.2) between each of the opinion questions and gender, age, level of education and place of residence allowed the identification of significant dependency relationships ($p < 0.05$), creating groups with the listed associations. Main results are: (i) Disagree that genetic engineering can be used in the production of foods that bring benefits to humanity (O1) is associated with being older (over 60 years old) and having a Master's degree; (ii) Disagree that the consumption of genetically modified foods can cause health problems (O6) is associated with being a woman and being in the age groups of 24 - 30 and 46 - 60 years old. Physicians' opinions were also classified as negative, neutral, and positive for GM food. The majority (85.8%) showed a neutral opinion, 12.5% had a negative opinion and a minority (1.7%) had a positive opinion.

There was a weak but significant correlation between these opinions and the level of physicians' training. The higher the level of training, the more negative was the physicians'

overall opinion on GM food ($r_{\text{Spearman}} = -0.1122$, $p < 0.07$). No significant correlations were found between the classification of opinion and the socio-demographic characteristics of gender, age and region of residence.

Table 4.1. Sociodemographic characterization of participants Physicians (n=278).

| Variable | n* | % |
|--|-----------|----------|
| Gender | | |
| Male | 153 | 54.9 |
| Female | 125 | 45.1 |
| Ade (years old) | | |
| 24-30 | 59 | 21.5 |
| 31-45 | 83 | 30.3 |
| 46-60 | 82 | 29.9 |
| acima de 60 | 50 | 18.2 |
| Higher level of academic | | |
| Graduation | 128 | 46.0 |
| Masters | 83 | 29.9 |
| Ph.D | 18 | 6.5 |
| Post-graduation | 49 | 17.6 |
| Region of Residence (NUTS II**) | | |
| North | 99 | 36.3 |
| Center | 96 | 35.2 |
| Lisbon | 60 | 22.0 |
| Alentejo and Algarve | 2 | 4.4 |
| Açores and Madeira | 6 | 2.2 |
| Frequency of contact with patients | | |
| Diary | 243 | 87.4 |
| Weekly | 10 | 3.6 |
| Monthly | 1 | 0.4 |
| Irregularly | 13 | 4.7 |
| Never or almost never | 11 | 4.0 |
| Institution of university graduation (graduation) | | |
| Coimbra's Medical School | 93 | 33.5 |
| Oporto's Medical School | 91 | 32.7 |
| Lisbon Medical School | 28 | 10.1 |
| Lisbon's Faculty of Medical Sciences of "Nova" | 24 | 8.6 |
| Outras | 39 | 14.2 |
| Conclusion year | | |
| < 1982 | 68 | 24.6 |
| 1983 - 1993 | 55 | 19.9 |
| 1994 - 2004 | 47 | 17.0 |
| 2005 - 2016 | 106 | 38.4 |

* n does not always total the sample size due to incomplete surveys.

** Nomenclature of Territorial Units for statistical purposes, level 2.

Table 4.2. Distribution of opinion responses and results of correspondence analysis between questions and sociodemographic characteristics

| Opinion Questions | Answer Category | | |
|--|-----------------------------|-------------------------------------|------------------------|
| | Disagree n (%) | Neither agree nor disagree n (%) | Agree n (%) |
| Social, environmental and nutritional aspects | | | |
| (O1) - Genetic engineering can be used in the production of foods that bring benefits to mankind. | 41 (14.7) ^{d,e} | 39 (14.0) ^{a,b,g} | 198 (71.2) |
| (O2) – Genetically modified organisms are an important tool in the fight against hunger in the world. | 38 (13.6) | 47 (16.9) ^a | 186 (66.9) |
| (O3) – Genetically modified seeds allow for greener farming. | 107 (38.5) | 98 (35.2) | 62 (22.3) ^a |
| (O4) – Transgenic foods currently in the Portuguese market are more nutritious than their conventional or biological counterparts. | 132 (47.4) | 114 (41.0) | 13 (4.6) ^a |
| (O5) -Genetically modified seeds result in a healthier diet. | 138 (49.6) ^a | 103 (37.0) | 19 (6.8) |
| Consumption and Health | | | |
| (O6) -The consumption of genetically modified food may lead to health problems. | 193 (69.4) ^{a,b,c} | 58 (20.8) | 27 (9.7) |
| (O7) - Consuming transgenic foods is, in practice, equivalent to the consumption of non-transgenic foods. | 191 (68.7) | 55 (19.7) | 32 (11.5) ^a |
| (O8) - The consumption of genetically modified foods may induce an adverse clinical or nutritional picture. | 47 (16.9) ^f | 109 (39.2) | 122 (43.8) |
| (O9) - There is scientific evidence that genetically modified organisms have a negative health impact. | 68 (24.5) ^a | 111 (39.9) | 75 (27.0) |
| (O10) - Transgenic foods are likely to be associated with some type of symptom or pathology, even if it is not yet scientifically established. | 40 (14.3) ^a | 83 (29.8) | 137 (49.2) |

Information to consumers

| | | | |
|---|------------|----------------------|-----------------------|
| (O11) - The population is adequately informed about the consumption of transgenic foods. | 267 (96.0) | 5 (1.8) ^f | 6 (2.2) |
| (O12) - Current standards are sufficient to protect people from possible risks of genetically modified food | 167 (60.0) | 93 (33.5) | 18 (6.5) ^a |

a-g Dependence with statistical significance (ANACOR; $p < 0.05$)

^a Female

^b 24 - 30 years old

^c 46 - 60 years old

^d over 60 years old

^e Master's Degree

^f Alentejo and Algarve

^g Azores and Madeira

4.3.3. Characterization of physicians' knowledge regarding transgenic foods

The evaluation of physicians' knowledge is systematized in Table 4.3. More than half of the respondents assume that they do not know how to answer most of the questions about transgenic foods in Portugal. The question more physicians got right (30.7%) was related to the existence of labeling of animal products produced using transgenic feeds, and the question more physicians failed (8.3%) was the one concerning the sale of transgenic horticultural products in Portugal.

Table 4.3. Distribution of knowledge answers regarding transgenics in Portugal

| Knowledge Questions | Correct Answer | Failed (%) | Do not know (%) | Correct answer given (%) |
|--|----------------|------------|-----------------|--------------------------|
| (C1) - In Portugal there is labeling of transgenic foods. | True | 19.9 | 54.5 | 25.6 |
| (C2) - In Portugal there is labeling of animal food produced with the use of transgenic feeds. | False | 9.4 | 59.9 | 30.7 |
| (C3) - n Portugal the main transgenic in circulation is soybean. | True | 13.0 | 58.8 | 28.2 |
| (C4) - In Portugal the main transgenic grown is soybean. | False | 12.3 | 66.4 | 21.3 |
| (C5) - In Portugal several transgenic horticultural products are sold. | False | 38.6 | 53.1 | 8.3 |
| (C6) -In Portugal organic food can also be transgenic. | Fals | 54.2 | 24.5 | 21.3 |

The level of knowledge, classified as low, medium and high according to the number of correct answers varied between 0-2, 3-4 and 5-6, respectively, is presented in Table 4.4. The results show that 79.8% of physicians have a low level of knowledge, 17.7% have an average level of knowledge and only 2.5% show a high level of knowledge.

There were no significant associations between each of the questions and the level of knowledge shown with the sociodemographic variables gender, age, level of education, and region of residence (ANACOR, $p > 0.05$ in all cases).

Table 4.4 Classification of the physicians' knowledge level

| Sociodemographic characteristic | Knowledge Level | | |
|--|-----------------|------------------|---------------|
| | Low n (%) | Average n (%) | High n (%) |
| Gender | | | |
| Male | 115 (75.6) | 32 (21.0) | 5 (3.2) |
| Female | 106 (84.8) | 17 (13.6) | 2 (1.6) |
| Age (years old) | | | |
| 24-30 | 45 (76.3) | 12 (20.3) | 2 (3.4) |
| 31-45 | 66 (79.5) | 16 (19.3) | 1 (1.2) |
| 46-60 | 67 (81.7) | 14 (17.0) | 1 (1.2) |
| over 60 | 40 (80.0) | 7 (14.0) | 3 (6.0) |
| Higher level of academic qualifications | | | |
| Bachelor's Degree | 105 (82.0) | 21 (16.4) | 2 (1.5) |
| Postgraduate Degree | 38 (77.5) | 10 (20.4) | 1 (49.0) |
| Master's Degree | 65 (78.3) | 16 (19.3) | 2 (2.4) |
| Ph.D. | 13 (76.5) | 2 (11.76) | 2 (11.7) |
| Region of residence | | | |
| North | 88 (88.8) | 10 (10.1) | 1 (1.0) |
| Center | 74 (77.0) | 18 (18.7) | 4 (16.6) |
| Lisbon | 44 (73.3) | 15 (25.0) | 1 (1.6) |
| Alentejo and Algarve | 7 (58.3) | 4 (33.3) | 1 (8.3) |
| Azores and Madeira | 5 (83.3) | 1 (16.6) | 0 (0) |

4.3.4. Perception of physicians' training needs regarding transgenic foods

Almost all of the physicians answering the survey (92.1%) stated that they had not received any type of GM food training in the context of their degree. However, 91.4% consider it useful to have some type of GM food preparation during academic education and 65.1% stated that it is very useful during professional life to have continuing training in order to keep up with this subject.

In relation to sources of information that physicians use to inquire about GM food (Table 4.5, scientific journals and news on the Internet are the most pointed (57.1 and 56.4%, respectively). Contacts with specialists and participation in congresses, lectures and seminars are the least recurrent (21.5 and 24.0%, respectively), however, 31.6% of the participants said that they "do not keep up with this issue". There were no significant associations between each of the sources of information and the sociodemographic variables gender, age, level of education and region of residence (ANACOR, $p > 0.05$ in all cases).

Table 4.5. Distribution of answers about sources of information physicians resort to

| Sources of information on GM foods | Answer Category | | |
|---|-----------------|----------------|--------------|
| | No n (%) | Maybe n (%) | Yes n (%) |
| Contact with experts | 173 (62.9) | 43 (15.6) | 59 (21.5) |
| Scientific journals | 74 (26.9) | 44 (16.0) | 157 (57.1) |
| Books and diverse technical documentation | 95 (34.9) | 49 (18.0) | 128 (47.1) |
| News on the internet | 66 (24.0) | 54 (19.6) | 155 (56.4) |
| Media (press, radio, TV) | 107 (39.1) | 56 (20.4) | 111 (40.5) |
| Congresses, lectures, seminars | 150 (54.5) | 59 (21.5) | 66 (24.0) |
| I do not keep up with this issue | 136 (49.5) | 52 (18.9) | 87 (31.6) |

The results of the answers' distribution regarding the typology and topics to be contemplated in the academic degree can be found in Table 4.6. When asked about the type of training they considered most appropriate, the majority (62.3%) preferred a module within a discipline during the degree and / or a short seminar (52.7%). In relation to subjects that they would like to see covered in this training, all the aspects suggested in the survey were considered important (always chosen by more than 65% of the participants), with health and nutrition aspects having the highest incidence (94.2% 89.2%, respectively). Results of the correspondence analysis (ANACOR, Table 4.6) allowed us to identify the following associations between training issues and some sociodemographic characteristics ($p < 0.05$): (i) being in the age group between 24 and 30 years old is associated with preferring an optional subject as a more adequate training typology; (ii) being a woman is associated with not choosing a module within a subject and not addressing GM food issues related to genetics and labeling. In addition to the questions presented in Table 4.6, a question of open answer was also included regarding other topics that they would like to see covered in this GM food training. Subjects related to scientific evidence, myths, immunogenicity, autoimmune diseases, cancer and relationship with several stages of life (especially in what concerns children and the elderly) were mentioned.

Table 4.6. Distribution of answers on typology and training topics and results of the correspondence analysis between answers and sociodemographic characteristics

| Questions on training | Answer Category | | |
|----------------------------------|------------------------|---------------------------------|------------------------|
| | No n (%) | Do not know / Maybe n (%) | Yes n (%) |
| Tipology | | | |
| One optional subject | 138 (51.0) | 63 (23.2) | 70 (25.9) ^b |
| One module within a subject | 57 (20.8) ^a | 46 (16.8) | 171 (62.3) |
| One compulsory subject | 190 (69.1) | 60 (21.8) | 25 (9.1) |
| One lesson | 114 (41.6) | 58 (21.2) | 102 (37.2) |
| One short seminar | 60 (21.8) | 70 (25.5) | 145 (52.7) |
| One theoretical work | 125 (45.6) | 86 (31.4) | 63 (23.0) |
| One practical work | 118 (43.2) | 80 (29.3) | 75 (27.5) |
| Topics | | | |
| Transgenic foods and genetics | 12 (4.4) ^a | 32 (11.6) | 231 (84.0) |
| Transgenic foods and labeling | 23 (8.3) ^a | 62 (22.5) | 191 (69.2) |
| Transgenic foods and nutrition | 5 (1.8) | 25 (9.0) | 248 (89.2) |
| Transgenic foods and health | 4 (1.4) | 12 (4.3) | 261 (94.2) |
| Transgenic foods and environment | 16 (5.8) | 64 (23.2) | 196 (71.0) |
| Transgenic foods and legislation | 26 (9.4) | 68 (24.6) | 182 (65.9) |
| Transgenic foods and ethics | 20 (7.2) | 59 (21.1) | 199 (71.6) |

^{a-b} **Dependence with statistical significance (ANACOR; $p < 0.05$)**

^a Female

^b 24 - 30 years old

4.3.5. Identification of physicians' profiles regarding GM foods.

The results of the multiple correspondence analysis and clusters analysis allowed to group all the questions into homogeneous groups that made it possible to identify two physicians' profiles in relation to GM food. The choice of two response profiles was based on a multiple correspondence analysis previously applied, considering two dimensions that explained 30% of the variability observed in the data. These two dimensions had a high internal consistency, evaluated by the value of the obtained reliability coefficients (Cronbach's Alpha), which were 0.877 and 0.835, revealing a high degree of homogeneity of the responses in each dimension (Pestana & Gageiro, 2014; Carvalho, 2008).

The first profile integrates 83% of physicians. These physicians understand that GM food are different and are neither more nutritious nor healthier when compared to their conventional or biological counterparts. They consider that genetic engineering does not

allow a greener agriculture, that it is not an important tool in the fight against hunger in the world, and that it does not bring benefits to humanity. They have no opinion as to whether consumption of GM food may lead to health problems, in particular the possible induction of adverse clinical or nutritional status. However, they admit that these foods are associated with some kind of symptom or pathology with negative health impacts, although they do not know if this is scientifically proven. They also consider that the legislation in force is not sufficient to protect health. They feel ignorant in what concerns GM foods national reality and support the possibility of receiving training during their degree. Their choice falls within the module format within a subject. Throughout their professional life, they consider GM food training very useful, keeping up to date through the internet and social communication.

The second profile covers only 17% of physicians. It consists of professionals for whom consuming GM food is equivalent to consuming non-transgenic foods. They consider that genetic engineering allows a greener agriculture, that it is an important tool in the fight against hunger in the world and that it brings benefits to humanity. They believe that the consumption of GM food does not cause any health problems and that there is no scientific evidence to the contrary. Regarding legal and nutritional aspects, they admit that they do not have an opinion. In terms of general knowledge about GM food, they feel ignorant and recognize the importance of training during the degree, choosing a class or a short seminar as preferable formats. They do not consider lifelong training relevant.

4.4. Discussion

This is the first study to detail the opinion, knowledge and training needs regarding GM foods. The hypotheses that (i) doctors do not have sufficient knowledge about transgenic foods, that (ii) there are different points of view and (iii) there is a need for training, have been confirmed by themselves.

4.4.1. Opinion

In relation to the opinion of the Portuguese physicians, it was possible to perceive that the majority has a neutral position on GM food. Positive opinions were found in the study by Schmidt *et al.* (2005) with 241 health professionals (43 physicians) in the United States of America, based on a survey of attitudes, beliefs and concerns about biotechnology and GM

food. Overall, the results indicated that a majority of respondents agreed that food biotechnology has the potential to positively affect human health in the next 20 years (55%) and that genetically modified functional foods can contribute to reducing disease risks (51%). About 28% of respondents said they had no opinion on these issues.

Different and related opinions of health professionals were found in Turkey. Burcu (2017), based on a survey answered by 307 obstetrics practitioners, concluded that most individuals revealed negative opinions about GM food. Savas *et al.* (2013), based on a study on GM food involving 200 Turkish physicians, found that 80.5% of physicians surveyed defined GM food as harmful. Similar results were published by Koçak *et al.* (2010), where 56.9% of the 427 participating medical students considered that GM food production is risky for all living organisms in nature. In the study by Ergin *et al.* (2015), also involving medical students, about 76% of the respondents considered that GM food could harm human health and 79% felt that they could not be safely consumed.

Different opinions found within physicians may arise from the lack of knowledge of the scientific evidence about GM food or what it actually demonstrates, as well as the inexperience of positioning themselves. Currently, GM food in circulation in the Portuguese market are authorized for human consumption (Uzogara, 2000). There are already studies that point to negative impacts on health (Tsatsakis et al, 2017, 2008; Ozkok, 2015). Other concerns are related to environmental (Kramkowska *et al.*, 2013; Dizon *et al.*, 2010) and ethical issues (Glass & Fanzo, 2017) which may lead to specific groups to doubt the current scientific results where it is concluded that GM food are safe (Tsatsakis et al, 2017, 2008; Ozkok, 2015). In what concerns the environment, the use of pest-resistant seeds can possibly lead weeds and herbivores to resistance. This resistance can lead to increased use of pesticides and, consequently, increases the residues of these products in food and in the environment itself, triggering ecological imbalances. Considering the ethical issues, there are some principles in debate, such as, for example, the principle of justice (irreversibility towards the most disadvantaged and those who were not born yet), principle of nonmaleficence (guarantee of safety versus possibility of safety) and principle of respect (right to know what one sows and eats) (Dizon *et al*, 2016; Glass & Fanzo, 2017).

4.4.2. Knowledge

Knowledge of Portuguese physicians in relation to GM food, according to the classification used in this study, can be classified as low. Similar results were reported by

Savas *et al.* (2014), where 40% of the respondent physicians considered their level of knowledge about GM food to be bad or very bad.

Ergin *et al.* (2015), relatively to 377 medical students, verified that 81.4% of the subjects surveyed assessed their knowledge about GM food as insufficient. Keskin *et al.* (2010) concluded that medical students have a low level of knowledge about the effects of GM food on humans and that they should be trained. Burcu (2017), with regard to health professionals in training, concluded that their knowledge of GM food was satisfactory.

Health professionals in general, and physicians in particular, are considered sources of reliable information (Wunderlich & Gatto, 2015) whom the population chooses to resort for obtaining solid information about food and health, which adds to the responsibility to ensure sufficient knowledge about GM food.

4.4.3. Training

The results of this study seem to justify the inclusion of a module on GM food within a curricular unit in the medical degree. Subtopics related to genetics, nutrition, health, environment, labeling, legislation and ethics were pointed out as of interest by the great majority of physicians surveyed. These contents will fill basic gaps in GM food, providing a holistic view, from their production to the consumer table. A multidisciplinary approach will also allow a connection between technical concepts of genetic engineering and the dimensions that transcend science in the strict sense, such as acceptance of risk, the right to information and the options inherited from future generations, among others. Studies by Schmidt *et al.* (2005), Ergin *et al.* (2015) and Koçak *et al.* (2010) corroborate the training needs of physicians identified in this study.

The means mentioned as sources of information that Portuguese physicians use to keep up-to-date on GM food are noteworthy for better management of communication and training strategies. Scientific journals and the Internet were the most pointed, as in Savas *et al.* (2013), where the internet is referred to preferred source of information by 23% of physicians surveyed. Scientific journals and continuing education programs are indicated by 71% of respondents in the study by Schmidt *et al.* (2005). Social networks are mentioned by 72.5% of those surveyed by Burcu (2017), while Koçak *et al.* (2010) found that 67.8% obtain information through television and radio.

4.4.4. Physicians' profiles concerning transgenic foods

This study showed that physicians are divided into two groups concerning GM food, differing in opinion, confidence and interest in this topic. One group, which covers the vast majority of physicians (83%), has a profile interested in learning more about GM food, assuming in the first instance an unfavorable position and distrust. Another minority group (17%) has a disinterested, confident and pro-GM food profile. The characterization of these profiles helps to understand the position of physicians in this area and can guide future training strategies.

4.5. Conclusion

This study is groundbreaking in relation to the position of Portuguese physicians regarding GM foods. The results showed neutral opinions on the subject, most of the respondents belonging to a profile that characterizes them as interested but skeptical. The results presented also revealed a low level of knowledge of physicians in relation to GM foods, which points to a real need for training in this subject, eventually to be addressed in the form of the inclusion of a specialized module within the scope of a pre-existing course in the degree.

The present study employed a convenience sample, so caution is required in any generalization. However, this work fills a gap in the current literature on the relationship between doctors and GM food. As the implications of the results presented for any future revision of the academic curriculum in medical schools are clear, the ultimate consequences of such a process will be felt by patients, as a result of an improvement in competence and clinical practice in this area. It is hoped that future research will clarify the best strategy to ensure that health professionals in general and doctors in particular learn to deal with the speed of evolution, intrinsic uncertainty and above all ignorance of the consequences - impossible to anticipate - that such a technology recent and as potent as genetic engineering actually entails.

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CHAPTER 5 - Personal experience and professional conduct of Portuguese physicians and nutritionists in relation to genetically modified foods

Abstract

Health professionals are currently faced with media and controversial scientific issues, such as transgenic food. Although professional conduct should be guided by the best evidence and conduct recommendations and is, therefore, somewhat standardized, decision-making in the professional environment is individualized and depends on personal knowledge, path and type of professional framework. It also depends on how to deal with the unknown and the uncertainty underlying a recent technology based on a molecular transformation whose implications may not be known and have not been studied for many decades. It is therefore important to note and characterize the experiences of health professionals (in particular Portuguese doctors and nutritionists) in relation to transgenic foods, in both personal and professional spheres. Information was analyzed about 526 health professionals, 248 nutritionists and 278 physicians, by means of a questionnaire. A positive correlation was identified between the relevant classifications attributed to the personal and behavioral issues attributed to the professional questions related to the GM food and the more relevant the thematic of the GM food on a personal level, the more alert it is to communicate, advise, monitor and have difficulty. For nutritionists this relationship was defined by $r_{\text{Spearman}} = 0.39$, $p < 0.001$ and for physicians by $r_{\text{Spearman}} = 0.55$, $p < 0.001$. A weaker but statistically significant correlation was obtained between the ages and the classifications attributed to the professional issues, and it was possible to verify that older health professionals are more alert to the subject of GM food. This was observed in both nutritionists ($r_{\text{Spearman}} = 0.13$; $p = 0.042$) and physicians ($r_{\text{Spearman}} = 0.17$, $p = 0.004$). There were no significant correlations between the classifications of personal and professional issues and gender, education and region of residence. Two groups were identified regarding the behavior of nutritionists in relation to GM food. A less interested and involved group consists of 59.7% ($n = 148$) of nutritionists. Another group was characterized as more attentive and involved and consisted of 40.3% ($n = 100$) of nutritionists. For physicians, although two groups have also been identified, both may be classified as having low involvement in relation to transgenic foods. One of the groups which consists of 94.6% ($n = 263$) of these professionals, presents however a more attentive behavior. In general, both professionals have limitations in relation to transgenic

foods. Therefore, in the face of uncertainties in the professional-patient relationship and in relation to transgenic foods, the research suggests that a frank dialysis or the precautionary principle should be used when necessary.

Key words: Professionals' conduct; personal-professional issues; uncertainties; professional-patient relationships

5.1. Introduction

Health professionals are currently faced with media and controversial scientific issues, such as transgenic food (Buiatti *et al.*, 2013; Batista *et al.*, 2009). These new genetically modified foods have led to scientific, political and economic debates, involving nutritionists and physicians alike (Schoettler *et al.*, 2015). It is therefore imperative that these professionals take responsibility for being adequately informed about the dietary guidelines they provide or recommend to patients and clients (Aspry *et al.*, 2018). On the one hand, the use of these foods seems to be innocuous, based on approvals they have received from the committees that evaluate them, but on the other hand, much of the population and many health professionals are skeptical about the use of these foods. Keeping this in mind, these professionals must learn to deal with the uncertainties and recognize the possibility of damages, in addition to potential benefits (Beresford, 1991; Kim & Lee, 2018; Han *et al.*, 2011).

Although professional conduct should be guided by the best evidence and conduct recommendations and is, therefore, somewhat standardized, decision-making in the professional environment is individualized and depends on personal knowledge, path and type of professional framework (Limentani, 1999; Iavicoli *et al.*, 2018; Livne, 2018). It also depends on how to deal with the unknown and the uncertainty underlying a recent technology based on a molecular transformation whose implications may not be known and have not been studied for many decades.

The lack of sound scientific evidence in terms of real food and ecological security should lead us to take refuge in some ethical principles (Klingler *et al.*, 2017), with emphasis on the precautionary principle (Grandjean, 2004; Martuzzi, 2007). In the area of health specifically, its importance has been growing for the last 20 years (Martuzzi & Tickner, 2004). Its purpose is to set guidance measures in situations where scientific knowledge still

does not speak with one voice, but instead presents contradictory information and provides some important but often inconclusive alerts (Gonzales *et al.*, 2014; Martuzzi, 2005).

The future of GM food involves many aspects, such as public acceptance (Luch, 2015), legislation (Davisona & Ammann, 2017) and scientific evolution. This may result in biofortification of food for humanitarian purposes, new applications in health and opportunities in the food industry, among others (Egolf *et al.*, 2019). Health professionals will not want or be able to escape the role for which they have been trained: to help the population cope with the challenges and uncertainties of health and well-being, which can include GM food. It is therefore important to note and characterize the experiences of health professionals (in particular Portuguese doctors and nutritionists) in relation to transgenic foods, in both personal and professional spheres.

5.2. Methodology

5.2.1. Sample

Information was analyzed about 526 health professionals, 248 nutritionists and 278 physicians, who met the following criteria: be registered in their professional Association. The dissemination potentially covered a population of 2347 nutritionists and 50,927 physicians, the number of registered professionals at the work's date (2016).

5.2.2. Survey

This study was based on the previously developed and validated survey (Vieira *et al.*, 2020). that assessed knowledge, opinion and training of health professionals, namely physicians and nutritionists, in relation to transgenic foods.

The survey includes questions on the respondents' sociodemographic characterization (7 questions), personal experience (6 questions) and professional reality (8 questions). These questions were multiple choice and had a single correct response.

The questionnaire was implemented in the online platform of LimeSurvey (version 1.91+) and released from March to July 2016 through the Portuguese Association of Nutritionists and Physicians, in scientific meetings and in social and professional networks. The Scientific Council of the College of Biotechnology Portuguese Catholic University, Porto, Portugal, approved this study.

5.2.3. Statistical analysis

Data provided by the survey's respondents were exported from LimeSurvey to Microsoft® Excel® (Microsoft Corporation, version 14.5.7) and later analyzed in the IBM SPSS Statistics 23 for Windows® program (SPSS Inc., Chicago, USA).

Independence tests of Chi-square associated with a correspondence analysis (ANACOR) were performed to detect associations between the questions (personal and professional) and the characteristics concerning gender, age, place of residence and level of education.

The responses of the personal questions to the GM food were classified as less significant (-) and more relevant (+), as they indicated that the respondent attributed more or less importance to the topic of GM food. Responses to professional questions were classified as less alert (-) and more alert (+) regarding behaviors in the context of communication, advising, monitoring and having difficulties. It generated a new variable through the scores, and later, correlations were investigated between personal and professional classifications based on Spearman's correlation coefficient (r_{Spearman}) and Qui-square independence tests. The level of significance assumed was 5%.

Multiple correspondence analysis and cluster analysis were used in order to classify the questions into homogeneous groups. Euclidean Quadratic Distance was used as a measure of similarity between the elements to be grouped and the Ward method as agglomerative method (Hill & Hill, 2000; Carvalho, 2008).

5.3. Results

5.3.1. Sociodemographic characterization of participants

Table 5.1 shows the results of the participants' sociodemographic characterization. The total number of respondents was 526, 47% being nutritionists and 53% physicians. The distribution by gender revealed that 63.5% were women and 36.1% were men, mostly aged between 20 and 35 (54.4%). Geographically, the majority came from North of Portugal (48.0%) and Center (25.7%). It was also found that a considerable proportion of professionals had training beyond their bachelor's degree (20.5% with a postgraduate degree, 23.8% with a master's degree and 6.7% with a Ph.D.) was found.

5.3.2. Descriptive analysis of the personal and professional experience of health professionals in relation to transgenic foods.

5.3.2.1. Personal experience

The distribution of answers regarding physicians and nutritionists' personal questions about transgenic foods is shown in Table 5.2. The vast majority of health professionals, 92.3% of nutritionists and 74.8% of physicians, declare that it would be useful to attend

Table 5.1. Sociodemographic characterization of the participants

| Variables | Nutritionist n= 248* (%) | Physician n=278* (%) | Total n= 526* (%) |
|--|-------------------------------------|---------------------------------|------------------------------|
| Gender | | | |
| Male | 38 (15.4) | 152 (54.9) | 190 (36.1) |
| Female | 209 (84.6) | 125 (45.1) | 334 (63.5) |
| Age (years) | | | |
| 20 - 35 | 187 (78.2) | 99 (35.9) | 286 (54.4) |
| 36 - 50 | 45 (18.8) | 62 (22.5) | 107 (20.3) |
| acima de 50 | 7 (2.9) | 115 (41.7) | 122 (23.2) |
| Level of training | | | |
| Graduation | 129 (52.0) | 128 (46) | 257 (48.9) |
| Masters | 42 (16.9) | 83 (29.9) | 125 (23.8) |
| Ph.D. | 17 (6.9) | 18 (6.5) | 35 (6.7) |
| Post-graduation | 59 (23.8) | 49 (17.6) | 108 (20.5) |
| Region of residence (NUTS II**) | | | |
| North | 156 (64.2) | 99 (36.3) | 255 (48.5) |
| Center | 39 (16.0) | 96 (35.2) | 135 (25.7) |
| Lisboa | 44 (18.1) | 60 (22.0) | 140 (26.6) |
| Alentejo e Algarve | 2 (0.4) | 12 (2.3) | 14 (2.7) |
| Açores e Madeira | 2 (0.4) | 6 (1.2) | 8 (1.6) |

* n do not always total sample size due to incomplete surveys.

** Nomenclature of Territorial Units for statistical purposes, level 2.

some kind of training on genetically modified foods (Personal - PE1). Both nutritionists (70.2%) and physicians (56.8%) have already sought some kind of information (PE2). However, when they shop (33.6% nutritionists, 32.1% physicians), they do not ask if they are taking any GM food, versus only 29.6% and 22.7% of nutritionists and physicians respectively who seek to know whether or not they are purchasing any GM food (PE4).

Most also believe that at some point they have already consumed GM food (57.9% nutritionists, 41.0% physicians) (PE5) and have already bought (49.8% nutritionists, 33.8% physicians) this kind of food (PE3). They also point out (41.9% nutritionists, 37.5% physicians) that friends / family have already asked them for their opinion on genetically modified foods, although not more than ten times (PE6). This results are shown in table 5.3.

5.3.2.2. Professional experience

The answers' distribution regarding professional questions about transgenic foods is also shown in Table 5.3. Only 21.0% of the nutritionists and 15.1% of the physicians were questioned by patients about GM food, in the transitional year (Professional - PR1). Both nutritionists (21.9%) and physicians (15.8%) took the initiative to talk about GM foods with patients / clients (PR2) as well as talking with their job colleagues (53.4% nutritionists and 41.8% physicians), but not more than ten times that same year (PR3).

On the other hand, if patients asked if they could consume GM food, the answers would be (PR4): "it is better not to consume / important not to consume this kind of food" (46.0% nutritionists, 39.5% physicians), followed by "I would not respond "(31.9% nutritionists, 36.4% physicians). On their own initiative, 35.1% of nutritionists and 46.9% of physicians would not suggest the consumption of GM food under any circumstance (PR5). Of those who talked to patients about GM food, 57.6% of nutritionists reported some difficulties and 50.5% of the physicians mentioned many limitations (PR8). The vast majority (84.2% nutritionists, 89.2% physicians) stated that they had never made any diagnosis that involved the negative impact of GM food (PR6). Both nutritionists (77.4%) and physicians (79.1%) claimed not to feel prepared to deal with questions about GM food, including some type of symptom or pathology that may be associated with them (PR7).

5.3.3. Associations between personal and professional's experience and sociodemographic data

The results of the correspondence analysis between each of the personal and professional questions and the demographic characteristics (gender, age, level of education and place of residence) allowed for identification of a significant dependency relationships ($p < 0.05$) indicated in Table 5.2 (personal questions) and Table 5.3 (professional issues). It emphasizes a significant association between being a doctor and whether or

Table 5.2. Distribution of answers regarding nutritionists and physicians' personal questions in relation to GM foods

| Personal Questions | Answer Category | Nutritionists n (%) | Physicians n (%) |
|--|---|---------------------------|---------------------------|
| (PE1) - Do you feel that it would be useful to attend some kind of technical training on genetically modified foods? | • Yes. | 228 (92.3) | 208 (74.8) |
| | • No. | 6 (2.4) ^a | 24 (8.6) |
| | • I do not know. | 13 (5.3) | 46 (16.5) |
| (PE2) – Have you ever searched for any kind of information about genetically modified foods? | • Yes. | 174 (70.2) | 158 (56.8) |
| | • No. | 51 (20.6) | 88 (31.7) |
| | • I do not remember. | 23 (9.3) | 32 (11.5) |
| (PE3) – Have you ever bought any transgenic foods? | • Yes. | 123 (49.8) ^{f,g} | 94 (33.8) ^{b,d} |
| | • No. | 39 (15.8) ^a | 33 (11.9) |
| | • I do not know. | 85 (34.4) | 151 (54.3) |
| (PE4) – When you go shopping, do you seek to know if you are buying any genetically modified foods? | • Yes. | 73 (29.6) | 63 (22.7) |
| | • No. | 83 (33.6) ^d | 89 (32.1) |
| | • Sometimes. | 69 (27.9) | 50 (18.1) |
| | • I would like to know it but I do not know how to do it. | 22 (8.9) | 75 (27.1) |
| (PE5) – Have you ever consumed any transgenic foods? | • Yes. | 143 (57.9) | 114 (41.0) |
| | • No. | 18 (7.3) | 13 (4.7) |
| | • I do not know. | 86 (34.8) ^a | 151 (54.3) ^{b,d} |
| (PE6) – How many times have friends or family asked for your opinion on genetically modified foods? | • None. | 111 (45.1) | 129 (46.6) |
| | • Once. /Not more than ten times. | 103 (41.9) | 104 (37.5) |
| | • More than 10 times. | 21 (8.5) ^c | 22 (7.9) ^{c,g,h} |
| | • I do not remember. | 11 (4.5) | 22 (7.9) |

^{a-h} Dependency with statistical significance (ANACOR; $p < 0.05$)

^a Male

^b 20 - 35 years old

^c over 50 years old

^d Postgraduate Degree / Master's Degree

^e Postgraduate Degree / PHD

^f Lisbon

^g Alentejo and Algarve

^h Azores and Madeira

not, she consume if a patient asks her - not to consume genetically modified foods; and being a nutritionist (independent of sex and 36-50 years old) in having the initiative of telling the patient not to consume GM food (both, $p < 0.01$). A positive correlation was identified between the relevance classifications attributed to the personal and behavioral issues attributed to the professional questions

related to the GM food and the more relevant the thematic of the GM food on a personal level, the more alert it is to communicate, advise, monitor and have difficulty. For nutritionists this relationship was defined by $r_{\text{Spearman}} = 0.39$, $p < 0.001$ and for physicians by $r_{\text{Spearman}} = 0.55$, $p < 0.001$. A weaker but statistically significant correlation was obtained between the ages and the classifications attributed to the professional issues, and it was possible to verify that older health professionals are more alert to the subject of GM food. This was observed in both nutritionists ($r_{\text{Spearman}} = 0.13$; $p = 0.042$) and physicians ($r_{\text{Spearman}} = 0.17$, $p = 0.004$). There were no significant correlations between the classifications of personal and professional issues and gender, education and region of residence.

Table 5.3. Distribution of answers concerning nutritionists and physicians' professional questions on GM foods and classification given to responses in terms of behavior

| Context | Professional questions | Answer category | Nutritionists | Physicians | Classification of behavior* |
|--|---|--|------------------------------|-----------------------------|-----------------------------|
| Communicate | (PR1) – Last year, did any of your patients/ clients asked any question about genetically modified foods? | • Yes. | 52 (21.0) ^h | 42 (15.1) | + |
| | | • No. | 137 (55.2) | 198 (71.2) | - |
| | | • I do not remember. / I do not contact with patients. | 59 (23.8) | 38 (13.7) | - |
| | (PR2) – How many times have you taken the initiative to talk about transgenic foods with your patients/ clients? | • None. | 108 (43.7) | 182 (65.5) | - |
| | | • Once/ Not more than ten times. | 54 (21.9) | 44 (15.8) | + |
| | | • More than ten times. | 33 (13.4) ^c | 28 (10.1) | + |
| | | • I do not remember. / I do not contact with patients. | 52 (21.0) | 24 (8.6) | - |
| | (PR3) - How many times have you talked about genetically modified foods with your colleagues? | • Not even once. | 35 (14.2) | 109 (39.2) | - |
| | | • Once/ Not more than ten times. | 132 (53.4) | 116 (41.8) | + |
| | | • More than ten times. | 44 (17.8) ^{b,c,e,f} | 33 (11.9) | + |
| • I do not remember. | | 36 (14.6) | 20 (7.2) | - | |
| Advise | (PR4) - If a patient/ client asks you if he can consume genetically modified foods, what will you answer? | • They can consume them. | 42 (16.9) | 49 (17.6) | + |
| | | • It does not matter whether or not to consume them. | 13 (5.2) | 18 (6.5) ^{a,e,f,i} | + |
| | | • It is better not to consume them. / It is important not to consume them. | 114 (46.0) | 110 (39.5) | + |
| | • I do not know / I would not answer. | 79 (31.9) | 101 (36.4) | - | |
| | (PR5) - On your own initiative, do you tell (or would you tell under any circumstance) your patient/client not to consume genetically modified foods? | • Yes. | 64 (25.8) ^{c,g,h} | 69 (24.9) ^{d,e,j} | + |
| • No. | 87 (35.1) | 130 (46.9) | + | | |
| • I do not know. / I do not contact with patients. | 97 (39.1) | 78 (28.1) | - | | |
| Monitor | (PR6) - Have you performed any patient / client diagnosis involving the negative impact of genetically modified foods? | • Yes. | 5 (2.0) ^{d,e} | 8 (2.9) | + |
| | | • No. | 208 (84.2) | 248 (89.2) | + |
| | | • I do not remember. | 34 (13.8) | 22 (7.9) | - |

| | | | | | |
|------------------------|--|---------------------------------------|-------------|---------------------------|---|
| Have difficulty | (PR7) - Do you feel prepared to deal with transgenic issues that may arise, including some kind of symptom or pathology that may eventually be associated with them?ou patologia que eventualmente lhes possa estar associado? | • Yes. | 23 (9.3) | 29 (10.50) | + |
| | | • No. | 192 (77.40) | 219 (79.10) | + |
| | | • I do not know. | 33 (13.3) | 29 (10.50) | - |
| | (PR8) - Have you ever found any difficulties or doubts (or do you feel you could find them) when talking about genetically modified foods with your patients/clients? | • No limitation at all. | 5 (2.4) | 19 (8.8) ^{a,f,i} | - |
| | | • Some limitations. | 118 (57.6) | 79 (36.6) | + |
| | | • Many limitations. | 72 (35.1) | 109 (50.5) | + |
| | | • I do not know. / I do not remember. | 10 (4.9) | 9 (4.2) | - |

^{a-j} **Dependency with statistical significance (ANACOR; p < 0.05)**

- ^a Female ^f Ph.D.
- ^b Male ^g Center
- ^c 36 - 50 years old ^h Lisbon
- ^d Postgraduate Degree ⁱ Alentejo and Algarve
- ^e Master's Degree ^j Azores and Madeira

* - less alert / + more alert

5.3.4. Identification of health professionals' conduct regarding transgenic foods

The results of the multiple correspondence analysis and the cluster analysis allowed to group all the questions into homogeneous groups that enabled identification of personal and professional behaviors in relation to transgenic foods. This analysis was performed separately for nutritionists and physicians.

5.3.4.1. Nutritionists

Two groups were identified regarding the behavior of nutritionists in relation to GM food. A less interested and involved group consists of 59.7% (n = 148) of nutritionists. These nutritionists, at a personal level, have already sought some kind of information about GM food; however, when shopping, they do not seek to know if they are buying GM food, and also do not know if they have already bought or consumed any. Neither friends nor family asked for their opinion on GM food. In the professional field, they have spoken with job colleagues about GM food, but never took the initiative to speak with their patients about this topic. In the previous year, no patient asked any questions on this topic. If a patient asked about it, they would respond that was/is better not to consume GM food, but would not take the initiative to heed their own advice. This group also shows that if they are not prepared to deal with the issues that GM food may raise, including identifying any symptoms or pathology that may be associated with consuming these foods. To date, they have never performed diagnoses on patients that suffered a negative impact on health due to GM food consumption, and pointed out that they could find many limitations when discussing this issue with them.

Another group was characterized as more attentive and involved and consisted of 40.3% (n = 100) of nutritionists. These nutritionists are interested in knowing more about GM food. When shopping, they make sure they are aware if they are taking any of these foods and admit that they have already bought and consumed them. They also sought additional information and responded to friends' and family's questions about GM food. In the professional context, they answered questions from customers about GM food and, if the question arises or even on their own initiative, they advise them not to consume GM food. In the same way, they would, on their own initiative, tell the patient not to consume GM food. They have talked about the subject with their colleagues and with patients more than 10 times. They have demonstrated that they are not prepared to deal with issues that may arise about GM food, including some kind of symptom or pathology that may eventually

be associated with them. They have never performed diagnoses to patients that involved the negative impact of these foods and pointed out that they might encounter some limitations when discussing this issue with them. Likewise, two groups of physicians were identified in relation to GM food.

5.3.4.2. Physicians

Although two groups have been identified, both can be classified as having low involvement in relation to transgenic foods.

The first group, which consists of 94.6% (n = 263) of these professionals, presents more attentive behavior, and includes participants who have never taken the initiative to advise non-consumption. However, if a patient asked about this, the answer would be "it is better not to consume these foods / it is important not to consume these foods". It should be noted that in the previous 12 months no patient asked any questions nor was any diagnosis made involving the negative impact of GM food.

The remaining physicians constitute a group consisting of only 5.4% of the total (n = 15), who, in their majority, do not regularly have contact with patients. They do not remember if they have already made a diagnosis to patients involving the negative impact of GM foods and never took the initiative to talk to them about this topic.

Both profiles had a similar behavior in relation to having already sought some kind of information about GM food. When they shop, they try to find out if they are carrying any of these foods, but on the other hand, many of them did not know if they have already bought or consumed them. Friends or family have never asked for their opinion about GM food consumption. However, in a professional environment, they have talked to their colleagues about it more than 10 times. They have encountered many difficulties and doubts when discussing this issue with their patients and do not feel prepared to deal with this topic, including some kind of symptom or pathology that may be associated with GM food. Both profiles overlap in that members of both groups feel that it would be useful to attend some type of technical training on GM food.

5.4. Discussion

The goal of this work is to first evaluate the relevance, behavior and involvement in personal and professional issues of nutritionists and physicians in relation to GM food in Portugal. The findings indicate that the topic of GM food is relevant and show that they are

alert at the professional level, despite feeling unprepared to deal with GM food in practice, possibly because of poor involvement. It highlights the scarcity of high-quality evidence regarding the contents of this research.

5.4.1. Relevance

It was clear in this study that both nutritionists and physicians, whenever they shop, make sure they know if they are buying any type of GM food, and inclusively have already bought and consumed them. Regarding consumption, it is possible to state that more than 57.9% of nutritionists and 41,0% of physicians have already consumed GM food. Similar results were found in a study by Burcu (2017), carried out with 307 obstetricians, through a survey on TF knowledge, which concludes that the vast majority have consumed these foods (92.7%). Different results regarding consumption were found: (i) the study by Koçak *et al.* (2010), covering 427 medical students, revealed that only 12.2% would consume transgenic foods, 33.4% would be hesitant and 54.4% would not consume them; and (ii) the studies of Turker *et al.* (2013), focusing on a sample of 287 nursing students, concluded that only 14% would consume GM food.

In relation to purchasing, more than 30% of nutritionists and doctors claim to have bought some GM food. In relation to purchasing, more than 30% of nutritionists and doctors claim to have bought some GM food. Turker *et al.* (2013) reported that 85.5% of nursing school students who participated in a study on knowledge, attitude, behavior about genetically modified organisms admitted buying them. Different results were found by Keskin *et al.* (2010) with 175 Turkish medical students, concluding that among the 28.6% of individuals who read food labels, 50.9% say they would not buy a product if they perceived it to be a GM food.

Studies that have been carried out report that there are factors that influence consumption / purchasing relative to GM food, such as: confidence (Yue *et al.*, 2015), information (Boccaletti & Moro, 2000), choosing a more ethical consumption (Chern *et al.*, 2002) and / or health awareness (Singinal, 2018). It is believed that differences in consumer / purchasing behavior regarding nutritionists and physicians can also be influenced by these factors.

It is also interesting to highlight in this study that both nutritionists and physicians (over 20%), when shopping, make sure they know if they are buying any GM food. Different results were found in the study by Schmidt *et al.* (2005); despite being a study conducted during 14 years in the United States on the attitudes and concerns of health professionals (a

total of 241 individuals, 43 physicians) regarding biotechnology applications in the production of transgenic foods. The study showed that in relation to habits of reading labels with information on GM food, most respondents (71%) reported "never" or "rarely" doing so. Only 8% pay attention to labels.

The results of this research demonstrated that most physicians and nutritionists are interested in transgenic foods on a personal level, and make some effort to be informed about this subject, recognizing the usefulness of technical training on GM food. Results of Schmidt *et al.* (2005) corroborate findings from this research, concluding that 89% of professionals admitted they were willing to know more about this topic.

5.4.2. Behavior

Regarding issues raised in a workplace, health professionals recognize difficulty to talk and to monitor, and emphasize that they do not feel prepared to deal with questions about transgenics.

Different results were found in the studies of Schmidt *et al.* (2005), which pointed out that the majority of professionals (54%) were comfortable with their ability to discuss the biotechnology applied to GM food production with their patients, presenting greater certainties and fewer doubts in patient-doctor communication. This environment of uncertainties in the health area has been considered and widely discussed (Kim & Lee, 2018). It is known that limitations during care (professional / patient) may arise, however there is a way to overcome them (Beresford, 1991; Kim & Lee, 2018; Han *et al.*, 2011). Understanding these limitations in a professional environment will contribute to the development of adequate strategies in patient care, besides collaborating in decision making (Beresford, 1991). Therefore, it recommends that these health professionals (doctors and nutritionists) develop strategies to minimize such uncertainties.

In the literature, it is possible to find guidelines for situations of difficulty and / or doubt (Salgado, 2008; Hardavella *et al.*, 2017) in the professional-patient relationship. Most authors propose that the approach and management of difficult situations should focus on communication, that is, involve the patient in the decision-making process, with explanations of the results and risks that are known, admitting the possibility of biases (Hardavella *et al.*, 2017). In addition, it is recommended, on a case-by-case basis and if there are persistent doubts (in relation to GM food), that the precautionary principle should be applied. The precautionary principle is a useful strategy for decision making when

physicians and patients have no evidence related to the potential outcomes associated with various choices (Resnik, 2004).

5.4.3. Relevance and behavior

The experiences with the GM food in the personal context were associated positively, it was determined that the professionals who gave more relevance to this subject in the personal scope, had consonant behavior in the professional scope. In other words, professionals who communicate, advise and monitor more consistently are more likely to feel relevant in attending some type of technical training, and have even sought some kind of information regarding GM food. On the other hand, professionals can avoid activities in which they do not have as much instruction, since there is risk in intervening beyond the limits of their competence. Corroborated that as the instructions increase, they may be much more alert in clinical activity to communicate, advise and monitor. In view of this, it is corroborated by some studies (Whelan, 2008; Collins *et al.*, 2013; Lapham *et al.*, 2000) carried out in the area of genomics and nutritional genomics in which they measured the involvement and trust of health professionals that concluded that many professionals avoid involvement in activities in which they have no confidence; otherwise, as confidence grows through education, the performance of clinical genetics activity to inform, counsel and monitor grow. Regarding the involvement, the authors identified that there are differences between professionals. Nutritionists had a greater say in this subject, most likely because they are experts in the food field and therefore are the most active and reliable providers of nutritional advice.

5.5. Conclusion

In short, this research highlights greater involvement of nutritionists than physicians regarding personal and professional issues surrounding GM food. A positive correlation was identified between the relevant classifications; attributed to the personal and behavioral questions - attributed to the professional questions regarding the GM food, and that: as personal interests increase, the performance in workplace increases. In general, both professionals have limitations in relation to transgenic foods. Therefore, in the face of uncertainties in the professional-patient relationship and in relation to transgenic foods, the

research suggests that a frank dialysis or the precautionary principle should be used when necessary.

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CHAPTER 6 – The training of health professionals about genetically modified foods from the perspective of the Science, Technology and Society

Abstract

The topic of transgenic foods presents several challenges related to thought fragmentation and to the proliferation of knowledge that continuously changes, and is thus divided into several isolated areas. In order to understand transgenic food, more integrated analyses are needed that include diverse perspectives and combine both scientific and professional experiences. A new model concerning awareness and training about transgenic food for health professionals is needed in order to update and broaden these professionals' knowledge and understanding of the subject. The objective of this work was to establish and assess a training module for Nutrition Sciences and Medical Sciences in relation to transgenic food, and additionally to contribute to the construction of a comprehensive learning concept involving scientific, technological and social knowledge. This teaching module is an integrative and multidisciplinary proposal that studies the transgenic foods currently on the market through an integrated scientific, technological and societal approach. The topics offered in the module were: genetics, health, the environment, legislation, ethics, controversies, concerns, visions of the various stakeholders, the scientific method, uncertainty and the precautionary principle. The module structure was evaluated from September to December 2018 through a questionnaire and interview. The results of the questionnaire were analyzed in the program SPSS, and the interviews in the program Nvivo using content analysis techniques. Participants in this study include: 14 health professionals, 7 of whom were nutritionists and the other 7, physicians. The structure of the training module presented is innovative and has its genesis in the current GM foods state of art. It has been found that both physicians and nutritionists agree or strongly agree with most of the topics that will be included in transgenic food training. For both nutritionists and physicians, topics with a greater level of agreement were related to "Health" and the lowest level of agreement regarded "Stakeholders' insight". In terms of the topics' relevance, physicians considered all of them important. For the interviewees, the module's contents are well structured, comprehensive, well explained and organized by topic. There are, however, differences in the approach between the Nutrition Sciences

degree and the Medical degree. Studies with a multidisciplinary approach and / or science, technology and society can be found in the current literature, especially in the health and food areas, and so they report positive results. With unanimity, the individuals involved in this study agree and consider the themes presented in the module structure to be important, although there is a difference between the courses of nutrition science and medicine regarding the way in which training is offered as well as differences in some content.

Key words: Training module; general contents; transversal contents; controversies

6.1. Introduction

While biotechnology has been a tool that has accompanied humanity for more than four thousand years, since the discovery of how to control the fermentation of fruit and cereals, genetic engineering was first used in food just over twenty years ago. In these two decades, social controversy has kept alive national and international public discussion. In addition to the advances that have been achieved, new discoveries and applications raise concerns not only in the scientific community, but also in areas classically recognized as social. In the last two decades, the social controversy over the benefits and harms in health and the environment (Assest & Bal, 2000; Buiatti *et al.*, 2013; Pellegrino *et al.*, 2018), as well as concerns about the monopoly of world trade, the reliability of public institutions, the integrity of regulatory agencies, the loss of both individual and ethical choice, and the future of food supply, have kept the national and international public discussion alive (Verma, 2013; Maghari & Ardekani, 2011).

Although genetic engineering is no more than a sub-area of biotechnology, delimited by the use of direct gene alteration techniques in target organisms, with the concomitant alteration of functionalities, the level of expansion that it has reached all over the planet (for example, 189.8 million hectares of genetically modified plants worldwide, in 2017) guarantees its own status in the agri-food sector. GM foods have been discussed extensively across continents and both sides of the debate are clearly set (Brookes & Barfoot, 2017; Commission, 2010; Dunwell, 2014).

It is in this context of technological complexity that the role of health professionals gains an unexpected significance. In spite of officially guaranteeing legal criteria and, until now, despite the fact that negative impacts on health or the environment are controversial (Domingo & Bordonaba, 2011; Santis *et al.*, 2017), the process of authorization and commercialization of GM foods cannot prevent the possibility of unforeseen (by definition) surprises, which puts health professionals at a critical point in providing information and reliably advising patients, answering questions and maximizing safety and wise behaviors.

The implications of this reality are both comprehensive and profound. They are comprehensive because they potentially involve various medical and nutrition specialties. They are profound because the minimum level of preparation necessary to deal with such a dimension of abstraction and lack of knowledge has yet to be defined.

The need to integrate specialized training content should become more and more indispensable with the expected evolution of GM foods in both lateral (increasingly authorized varieties) and vertical (increasingly typologies of GM foods, from biovaccines to pharmaceuticals) directions, and also following the growth of the forces that involve, interact and modify this new agri-food system.

The GM foods topic presents several challenges, related to thought fragmentation and to the proliferation of knowledge that quickly changes, dividing itself in isolated areas. In order to understand GM foods, more integrated analyses are needed, including diverse perspectives and scientific and professional experiences. A new model of attention and training concerning GM foods for health professionals is needed in order to update and broaden these professionals' thought.

The objective of this work was to set and assess a training module for Nutrition Sciences and Medical Sciences in relation to GM foods, in addition to contributing to the construction of a comprehensive learning concept connected to scientific, technological and social knowledge.

6.2. Methodology

6.2.1 Creating the module structure

This teaching module (topics included in Table 6.1) is an integrative and multidisciplinary proposal (Hilimire *et al.*, 2014; Pedersen, 2016) that focuses on the GM food on the market nowadays, through a scientific, technological and societal approach (STS) (Maghari & Ardekani, 2011; Mansor, 2009). Transgenic foods were discussed in order to include the perspective of objective information (general topics) and the perspective of uncertain information (transversal themes).

Genetic engineering's basic concepts and main techniques are described at the beginning (Barampuram & Zhang, 2011; NRC, 2004) and the purposes of transgenic foods' development and their relation with health (Uzogara, 2000; Kramkowska *et al.*, 2013) and the environment are presented (Uzogara, 2000; Kramkowska *et al.*, 2013; Brookes & Barfoot, 2017). Legislation (Varzakas, 2017) and ethics (Thompson & Hannah, 2008; Dizon *et al.*, 2016), with their principles, are included to aid and complement decision-making at points where science does not (yet) offer self-sufficient answers.

Transversal dimensions of transgenic foods, often poorly explored in academic circles, were recognized and included in the discussion, although there is not what can be

considered a unique answer: stakeholders' points of view (Bawa & Anilakumar, 2013; Menozzi, *et al.*, 2017; Lack, 2002; Zhamg, 2016), concerns (Abubakari, 2018; Kris-Etherton, 2014), social controversies (Uzogara, 2000; Myhr & Traavik, 2001), limits of the scientific method, incorporation of uncertainty and lack of knowledge (Spelt *et al.*, 2009; Ball *et al.*, 2014) and the precautionary principle (Sandin, 2006; Myhr & Traavik *et al.*, 2002) in decision-making and, finally, the possible integration of the health professional in this narrative, all contribute to the discussion surrounding GM foods.

6.2.2 Evaluation of the module's structure

6.2.2.1. Instruments

Three instruments were designed to evaluate the module's structure. Instrument 1 consisted of a survey (i) that was created using closed questions with a 5-level Likert scale to assess agreement (1-strongly disagree, 2-disagree, 3-neither disagree nor agree, 4-agree, 5-strongly agree) and importance (1-unimportant, 2-little important, 3-neither little important nor unimportant, 4-important, 5-very important) with the contents presented in the module. Instrument 2 (ii) consisted of a survey with open questions that were placed in a semi-structured interview to evaluate content, structure, emerging topics, inclusion of the module in the degree's plan, difficulties, and qualifications to be developed within training. The third and final instrument (iii) was a module evaluation survey that, besides being made up of closed questions of agreement and importance (concerning instrument 1), included open questions about the opinions regarding qualifications developed with this kind of training.

6.2.2.2. Participants

Participants in this study were 14 health professionals, of whom 7 were nutritionists and the other 7 physicians, including academic and professional representatives working as nutritionists or physicians.

The inclusion criterion for instruments 1 and 2 was to be a professor affiliated with a university. The sample consisted of 5 representatives from Medical schools and 5 from faculties with degrees in Nutrition Sciences.

For instrument 3, sampling was carried out in the private sector. Physicians and nutritionists who practiced the profession were contacted. Four professionals (2 doctors and 2 nutritionists) participated.

6.2.2.3. Data collection

Data collection took place from September to December of 2018 through three activities. The objective of each action was previously highlighted, and the confidentiality of the information collected was guaranteed.

The first activity consisted in disseminating instrument 1 online. Subsequently, semi-structured interviews were carried out in person at the participants' universities (instrument 2). Training was carried out at the College of Biotechnology, Catholic University of Portugal, Porto, Portugal (Asprela Campus) with a duration of 4 hours, focusing on the contents of Table 6.1. Subsequently, presented as a lecture, the module was evaluated with regard to the agreement and importance of contents and opinions about the knowledge acquired (instrument 3).

6.2.2.4. Data analysis

The results of the interviews (instrument 2) were analyzed in the program Nvivo® version 11.4.2 (QSR International, Pty Ltd.) using the techniques of content analysis according to Bardin (1977), through three chronological segments: a pre-analysis (organization of research material), material exploration (procedures for coding, classifying and categorizing collected material), results processing, inference and interpretation. In the content analysis process, categories were set *a priori*, assuming the topics included in the open questions put to the university participants.

Data from surveys (instruments 1 and 3) were exported from Microsoft® Excel® (Microsoft Corporation, version 14.5.7) and later analyzed in the IBM SPSS Statistics 23 for Windows® program (SPSS Inc., Chicago, USA). Measurements of central tendency (mean) and dispersion (standard deviation) were used to characterize the sample data concerning agreement and importance of the module's contents. Qui-square independence tests were carried out in association with a correspondence analysis to investigate associations between the questions and the sociodemographic characteristics of the respondents. The level of significance assumed was 5%. The surveys' internal consistency was evaluated based on Cronbach's alpha value. These values range from 0 to 1, the internal consistency of a survey being greater when the value is closer to 1 (Hill & Hill, 2000).

6.3. Results

6.3.1 Participants' description

Of the 14 participants, 78% were women and 22% were men, all aged between 26 and 69, and living in cities in North and Central Portugal. They work in areas related to clinical nutrition, oncology, anatomy, research methodology, nutrition and life cycle, gastrotechnics, food, food toxicology, family medicine and cardiology.

Universities collaborating in this research were: University of Porto, Piaget Institute of Viseu, Cooperativa de Ensino Superior Politécnico e Universitário CESPU, University of Lisbon, University of Trás-os-Montes and Alto do Douro, University of Coimbra, “Nova” University of Lisbon and University of Beira Interior. The duties performed by the 10 participants are: supervisor, headmaster or executive supervisor. The participants are associate or assistant professors. The four participants from the private sector work in the family medicine, nutrition and oncology areas.

6.3.2 Surveys

The degree of agreement was evaluated in relation to the twelve topics related to GM foods (Table 6.1). It has been found that both physicians and nutritionists agree or strongly agree with most of the topics to be included in GM foods training (mean score for response score greater than 4). Only in item 10, and for both professionals, the average was slightly below a score of 4. For both nutritionists and physicians, topics with a greater level agreement were related to "Health" and the lowest level of agreement lies in the "Stakeholders' insight".

In terms of the topics' relevance, physicians considered all of them important or very important. Only the "Controversies" topic had a lower average rating, with a score of 3.8. Nutritionists also classified most of the topics as important or very important, but the topics "Genetics", "Concerns", "Controversies" and "Stakeholders' insight" obtained a lower average score, classified as neither important nor important by this group of health professionals.

For both nutritionists and physicians, "Health" was the topic that had the least variation (assessed by the standard deviation) of answers concerning agreement and importance. The "Precautionary Principle" was the topic that presented less variation in responses of importance for nutritionists.

In order to measure the reliability of the surveys' items, the Cronbach Alpha test was

applied. The numbers obtained were 0.94 for agreement and 0.97 for significance, revealing high internal consistency. Physicians' and nutritionists' agreement and importance responses were independent ($p > 0.05$) of all characterization data (gender, age, place of work and / or profession).

6.3.3 Interviews

In the interviews, there were questions that sought to achieve a variety of impressions and perceptions that the various individuals have in relation to the training module on GM food. These perceptions were reorganized into secondary groups (Table 6.2), with transcription of some of the respondents' comments (in the sections below). In general, health professionals have made an important contribution in all aspects.

6.3.3.1. Group I - Contents

With regard to content, what would you change, add or remove?

For the interviewees, the module's contents are well structured, comprehensive ^(a), well explained and arranged by topics ^(b). On the other hand, based on the destination degree of the training offer, they consider some more important topics and other less important ones ^(c). They raise concerns about the relevance of each content because, being health professionals, they already consider having some knowledge foundations in specific areas ^(d). They also express concerns about the training's duration, which may be short ^(e) and, finally, about the module's operationalization, since moments of discussion during the learning process ^(f) would be necessary.

^(a) "... first this proposal is very comprehensive and being comprehensive means that few things will be left out" ... "it gives me the impression that nothing is left out ..."

^(b) "... it is well explained by area what one intends and what one would like to include in each topic, and therefore it appears to be very extensive for what would be only a module integrating a subject..."

^(c) "... I would consider some more important or less important, or more important for certain professionals. Focusing on health "

^(d) "... my doubt about the relevance of each of the components, therefore, if most technical issues, from the point of view of genetics, the molecular part, biochemistry, probably for a professional, this being a goal for the professionals, probably will not have as much interest or relevance, or at least

Table 6.1. Classification of agreement and importance attributed by nutritionists and physicians to the contents of the training module

| Contents of the training module | Agreement | | | | Importance | | | |
|--|---------------|------------|------------|------------|---------------|------------|------------|------------|
| | Nutritionists | | Physicians | | Nutritionists | | Physicians | |
| General Topics | \bar{X} | s | \bar{X} | s | \bar{X} | s | \bar{X} | s |
| 1. Genetics | 4.4 | 0.5 | 4.3 | 0.9 | 3.9 | 0.7 | 4.0 | 1.2 |
| 1.1 GM food definition. | 4.6 | 0.5 | 4.6 | 0.5 | 4.1 | 0.9 | 4.1 | 1.2 |
| 1.2 Current and new techniques of genetic modification (method, process and results). | 4.1 | 0.4 | 4.1 | 1.2 | 3.6 | 0.8 | 4.0 | 1.2 |
| 1.3.1.3 Modified characteristics (in use, under study and future ones). | 4.4 | 0.5 | 4.1 | 1.1 | 3.9 | 0.4 | 3.9 | 1.3 |
| 2. Nutrition | 4.7 | 0.5 | 4.4 | 0.8 | 4.6 | 0.8 | 4.3 | 1.5 |
| 2.1 Purpose and challenges of the production of transgenic foods sold in Portugal and the EU. | 4.7 | 0.5 | 4.4 | 0.8 | 4.6 | 0.8 | 4.3 | 1.5 |
| 3. Health | 5.0 | 0.0 | 4.7 | 0.5 | 4.7 | 0.5 | 4.9 | 0.4 |
| 3.1 Health consequences. | 5.0 | 0.0 | 4.7 | 0.5 | 4.7 | 0.5 | 4.9 | 0.4 |
| 4. Environment | 4.6 | 0.5 | 4.6 | 0.8 | 4.0 | 1.0 | 4.3 | 1.0 |
| 4.1 Interaction of genetically modified crops with the environment. | 4.6 | 0.5 | 4.6 | 0.8 | 4.0 | 1.0 | 4.3 | 1.0 |
| 5. Ethics | 4.4 | 0.5 | 4.4 | 1.1 | 4.0 | 1.0 | 4.3 | 1.1 |
| 5.1 Ethical principles implied by transgenic food technology. | 4.4 | 0.5 | 4.4 | 1.1 | 4.0 | 1.0 | 4.3 | 1.1 |
| 6. Legislation | 4.7 | 0.5 | 4.3 | 1.0 | 4.3 | 1.3 | 4.1 | 0.9 |
| 6.1 Safety assessment of transgenic foods. | 4.7 | 0.5 | 4.3 | 1.0 | 4.3 | 1.3 | 4.1 | 0.9 |
| Transversal Topics | | | | | | | | |
| 7. Concerns | 4.2 | 0.5 | 4.1 | 1.2 | 3.7 | 0.9 | 4.0 | 1.0 |
| 7.1 Concerns about genetic engineering methodologies. | 4.0 | 0.6 | 3.9 | 1.2 | 3.6 | 0.5 | 4.0 | 1.0 |
| 7.2 Concerns about interactions with health. | 5.0 | 0.0 | 4.4 | 1.1 | 4.6 | 0.5 | 4.3 | 1.0 |
| 7.3 Concerns about influences on the environment. | 4.7 | 0.5 | 4.4 | 1.1 | 4.3 | 1.0 | 4.1 | 0.9 |
| 7.4 Concerns about economic changes. | 4.0 | 0.6 | 4.0 | 1.3 | 3.3 | 1.1 | 4.0 | 1.0 |
| 7.5 Concerns about political connections. | 3.4 | 0.5 | 4.1 | 1.2 | 3.0 | 1.0 | 3.7 | 1.0 |
| 7.6 Concerns about linkage and ethical constraints. | 4.0 | 0.6 | 4.3 | 1.3 | 3.6 | 1.0 | 3.9 | 0.9 |
| 7.7 Concerns about the imposition of legislation. | 4.0 | 0.8 | 3.9 | 1.2 | 3.6 | 1.0 | 3.9 | 1.1 |
| 8. Controversies | 4.1 | 0.5 | 4.0 | 1.2 | 3.9 | 0.8 | 3.8 | 1.2 |
| 8.1 Controversy regarding the effects of the consumption of transgenic foods on health. | 4.7 | 0.5 | 4.1 | 1.2 | 4.6 | 0.8 | 4.0 | 1.3 |
| 8.2 Controversy regarding the findings of the use of genetic engineering. | 3.7 | 0.5 | 3.7 | 1.3 | 3.6 | 0.5 | 3.6 | 1.1 |
| 8.3 Controversy regarding GM food approval procedures. | 4.0 | 0.6 | 4.1 | 1.2 | 3.6 | 1.0 | 3.7 | 1.1 |
| 9. Scientific Method | 4.2 | 0.6 | 4.1 | 1.2 | 3.9 | 0.8 | 4.0 | 1.0 |
| 9.1 Science and values. | 4.0 | 0.8 | 4.3 | 1.0 | 3.4 | 0.8 | 4.1 | 1.1 |
| 9.2 Limits: on knowledge concerning genetics, consumption, approval laws, effects on the environment, and unintended effects - unknown to science. | 4.6 | 0.5 | 4.3 | 1.0 | 4.3 | 0.8 | 4.0 | 1.0 |
| 9.3 Types of uncertainties - quantitative and qualitative. | 4.1 | 0.4 | 3.9 | 1.6 | 3.9 | 0.9 | 3.9 | 0.9 |
| 10. Stakeholders's insights | 3.9 | 0.7 | 3.8 | 1.6 | 3.4 | 0.9 | 4.0 | 1.2 |
| 10.1 Concept and structure of the food system. | 4.1 | 0.7 | 3.7 | 1.6 | 3.4 | 0.5 | 4.1 | 1.2 |
| 10.2 Perspective of agrobiotechnological companies. | 3.9 | 0.7 | 3.7 | 1.6 | 3.0 | 0.8 | 3.9 | 1.2 |
| 10.3 Scientists' point of view | 3.6 | 1.0 | 3.9 | 1.7 | 3.3 | 1.0 | 4.0 | 1.2 |
| 10.4 Aspects of interpretation of non-governmental organizations. | 3.7 | 0.5 | 3.7 | 1.6 | 3.1 | 0.9 | 3.9 | 1.2 |
| 10.5 Overview of family farmers. | 4.1 | 0.7 | 3.9 | 1.7 | 3.7 | 1.1 | 4.0 | 1.2 |
| 10.6 Consumers' perceptions. | 4.6 | 0.5 | 3.9 | 1.7 | 3.7 | 1.1 | 4.1 | 1.2 |
| 10.7 Scenario through the politicians' perspective. | 3.4 | 0.5 | 3.7 | 1.6 | 3.1 | 0.7 | 3.9 | 1.2 |
| 11. Precautionary principle | 4.9 | 0.4 | 4.6 | 0.8 | 4.4 | 0.5 | 4.3 | 1.0 |
| 11.1 Principle of precaution as an adjunct in the decision-making process. | 4.9 | 0.4 | 4.6 | 0.8 | 4.4 | 0.5 | 4.3 | 1.0 |
| 12. Role of health professionals | 4.5 | 0.7 | 4.3 | 1.3 | 4.4 | 1.0 | 4.0 | 1.6 |
| 12.1 Information. | 4.7 | 0.5 | 4.6 | 1.1 | 4.7 | 0.8 | 4.1 | 1.6 |
| 12.2 Counseling. | 4.6 | 0.5 | 4.4 | 1.1 | 4.4 | 1.0 | 4.0 | 1.5 |
| 12.3 Monitoring. | 4.3 | 1.1 | 3.9 | 1.7 | 4.1 | 1.2 | 3.9 | 1.6 |

values in bold correspond to averages and standard deviations of each theme.

\bar{X} = average

s= standard deviation

agreement (1-strongly disagree, 2-disagree, 3- neither disagree nor disagree, 4-agree, 5-strongly agree)

importance (1-unimportant, 2-little important, 3-neither little important nor unimportant, 4-important, 5-very important)

coverage and interest, as it could ... maybe more related to ethics, legislation, therefore ...”

(e) "... my only concern is that for the number of hours it is scheduled, it is too long ..."

(f) "... I found it a very complete module but it is not described how it is operationalized. So, we can see the contents, but eventually it would be interesting in the operationalization, to include discussion ... "

6.3.3.2. Group 2 - Structure

Do you think it is feasible to manage the module with multiple topics?

In relation to the module structure, which is multidisciplinary and focused on the STS approach, health professionals agree that it is feasible and expected ^(a), fundamental ^(b), desirable ^(c) and essential ^(d), as the new challenges in the food field require more sustainable production ^(d). On the other hand, GM foods is on the market and tend to increase ^(e). A structure that depends on trainers and targets students is pointed out ^(f), so as to pass on the information and increase receptivity to the topic, the attendance of this kind of training ^(g) at the academic level being important.

(a) "... I think it is feasible. I think it is expectable."

(b) "...honestly, it is essential."

(c) "...I think so. Possible and desirable."

(d) "... I think this is essential and it should happen. Perhaps at this moment it is one of the main challenges of nutrition and food universities to give this comprehensive vision on the agri-food system and all the issues and expressions related to the whole, from sustainability ... Sustainability in terms of resources, soil, water, energy, etc., but also of practices, that is, I include the introduction of genetically modified organisms, like this practice, although it does seem to bring benefits."

(e) "... I think it is more and more important for people to have this knowledge, because this kind of food will exist more and more."

(f) "... I think it is possible. ... It depends on who and with whom you will work, ... "

(g) "... it is always possible. Under these circumstances there are two important factors. One is information that can be given, and the other is receptivity. Information passes on through the insistence of this type of training."

6.3.3.3. Group 3 – Emerging topics

Does the degree structure follow the emerging topics?

The answers related to this group demonstrated the interest of curricular units' coordinators in keeping updated contents ^(a), depending on each professor and curricular unit that is taught ^(b), and fulfilling requirements stipulated by accrediting entities ^(c).

^(a) "...in medicine, yes. Some subjects clearly enter nuclear units. The elective units are sometimes the deepening or an extension of the nuclear units for students who wish to go further in areas of their liking, but obviously for a few years the degree has undergone a very extensive update and there have been new areas that have entered and other more classic areas which have lost some weight."

^(b) "... we are in constant evolution, even those who are not, so nothing closed. For example, in physiology, anatomy, there should be many changes. For 30 years they have kept practically the same thing, all very similar. Other courses each year will be updated and that requires work by the teachers and the organization of the degrees themselves in keeping the topic updated."

^(c) "... exactly, it respects these new topics. But according to our proposal. We must always introduce a theme, a topic or another, it would not affect anything. But the whole structure goes in view of the curricular unit, and what is sent to the ministry; the record is sent, everything is sent and we always have to keep this in mind."

6.3.3.4. Group 4 – Inclusion in the degree plan

If it were to include the module of GM foods training in the curricular plans of the degrees in Medicine and Nutrition Sciences, in which curricular unit (s) would it be feasible?

They consider it important to include the module in the health portion ^(a). There are, however, differences in the approach between the Nutrition Sciences degree and the Medical degree. In Nutrition Sciences, it is stated that it can be taught as a nuclear or optional subject ^(b). In Medicine, since there is no nutrition subject ^(c), they refer to it as continuing training^(d).

^(a) "... optional I do not believe, because the module is so important to be addressed in the health part."

^(b) "... but essentially it would be in these subjects, the second half of the third year seems to be a good time to include transgenic food, genetics, food safety,

community nutrition, concepts of public health and to achieve a deeper thought on these matters."

^(c) "... I think that in elective subjects there are no nutrition issues. But they can do some internship related to this area. But in fact, nutrition is not part of the syllabus. There may be related things, but inside other subjects. I believe that in diabetes they also talk about nutrition. But I told you, it is very directed to the disease. It's not so much to health. "

^(d) "... this could happen by means of a workshop, or a course, summer school, or even a postgraduate course, for example."

6.3.3.5. Group 5 – Difficulties

Which difficulties do you foresee with the module introduction?

The interviewees report lack of materials / information on GM foods ^(a), lack of skills ^(b) and difficulties in the multidisciplinary approach involving the module ^(c). There are doubts about the curricular units where the module can be integrated ^(d). There are also concerns about the receptivity of students ^(e) and of health professionals and teachers ^(f), who are accustomed to a traditional teaching format and are resistant to changes in the structure of existing curricular units ^(g). They also anticipate difficulties in attracting interest ^(h).

^(a) "... the difficulties I see are mainly a lack of a wake-up call on the subject. I think this is the main difficulty to collect information."

^(b) "... I think we would have difficulties in several things, one of them is in fact that people should have the skills to train others on this area."

^(c) "... I do not think it's impossible. But it is something that we still are not yet very familiar with. I'm saying this, although I work on other courses where we do more of this."

^(d) "... Finding in which curricular unit you can integrate the module can be another problem. We could put it in nutrition or in the technology area, or in the health area. So, we have to see where we are going to integrate this module."

^(e) "... for this and for the format of all teaching in general, I have some difficulty in accepting for this module."

^(f) "... even among professionals and professionals , there is some difficulty in talking, discussing...we are a little traditional."

^(g) "... this sometimes requires changes in curricular structures, resistance to change, on the part of teachers who may be in charge of those subjects."

(h) "... difficulty of a topic in arousing interest. The biggest difficulty would be to know whether there were people interested. "

6.3.3.6. Group 6 – GM foods *framework*

Is there any topic related to GM foods in the curricular plans of Medicine and Nutrition Sciences degrees?

Professionals report that there is not a single curricular unit that addresses GM foods; however, this topic may have been mentioned in genetics, either in the food context or in the human context ^(a). They consider that topics related to GM foods may also have been addressed in ethics ^(b), toxicology ^(c), food technology ^(d), community nutrition and public health ^(e). In the Medical degree, there is no curricular unit concerning nutrition and only contents related to risk factors of diseases are approached. There is a general absence of issues related to food quality and / or production ^(f).

^(a) "...no. I think there are some issues, in the case of genetics, about genetic construction, methods and processes. They have a curriculum unit on genetics and speak about biocells; whether in the context of food or in the context of human, living cells, these mechanisms can be repeated."

^(b) "... and then will be addressed later, probably in the curricular unit of ethics; therefore, this topic may find some ethical dilemmas here and can be addressed again, ..."

^(c) "... in toxicology I speak of them as a subject which has an interest in this point of view, but let us say that it is a very short culture."

^(d) "... there is not a single curricular unit that focuses on transgenic foods. This topic is addressed in genetics and in food technology."

^(e) "On the other hand, whoever integrates community nutrition or food policy will have more time to deal with information; the ones in charge of food policies will have to make some decisions but it will not be, I think, a clinical nutritionist; there will be more of a pressure on having to give responses and therefore challenges are great."

^(f) "... there is no specific subject of nutrition in the Medical degree in Portugal; they only speak of food very much in relation to cardiovascular disease, as a risk factor, for example in the field of diabetes, dyslipidemia, obesity... So, not as much as the quality of the food and the way it is produced, the industrial part, the commercial part... Nothing. This part is completely nonexistent in the curriculum."

6.3.3.7. Group 7 – Skills Acquired

What are the skills and competencies to be acquired / developed with training?

Those interested, after training in GM foods, should have the competence to impartially inform and advise users on GM foods ^(a, b, c). If patients consume GM foods, monitoring is important for studies on the impact of GM foods on health ^(d). They also point out that individuals who have been trained should be able to filter and synthesize information and be able to give a reasoned opinion, this critical analysis being a major challenge ^(e, f). However, only those interested can acquire more knowledge ^(g).

^(a) "... I think informing is important, without a doubt. Above all I think a nutrition professional should inform the person, his patient about the maximum of evidence-based information and should not try to influence with his personal opinion on the subject ..."

^(b) "... so, I think if they had competencies and managed to inform the population and the patients and finally managed to do some follow-up, this would be part of the monitoring of preventive medicine in general. So, I think these skills are correct ..."

^(c) "... I'm very concerned with what it means to advise the patient. I study nutrition ..."

^(d) "... if the person / client chooses to consume [GM foods] the professional should provide guidance. There is nothing in science that says it is totally harmful."

^(e) "... it is clear that a critical evaluation of all the evidence that exists about TF risk assessments is capable of, in the midst of so much information, synthesizing something and provide some kind of reasonable opinion. Competence is the most important, and being able to communicate this in an effective way as it needs to be – that is in the clinical context or in other contexts - seems to me to be the most important and it may be the main challenge: to be able to understand the context that leads to the production of these products and food - why they arise and why they are the basis of these initiatives."

^(f) "... no doubt about it. Nowadays the nutritionist is faced with many issues, emerging issues, with great speed. It is a tremendous challenge for the nutritionist to be up to date on all topics. If we talk about the clinical nutritionist - it's very challenging, every day new diets arrive, new evidence and he often has to study."

(g) "... yes. Only those who are interested. When we have interest in a thing, we go after it ourselves, we search it. If things get to me, great. But if they don't, I go after them. Now those who are not interested because their scientific interests lie in another area would not care about it."

6.3.4. Lecture and module assessment

In this session, the module was presented orally and, in the end, it was assessed through closed (Table 6.1) and open questions, both by means of a survey. The closed answers are counted in item 6.3.2. They present, in this session, the answers to the open questions. In a unanimous manner, health professionals who participated in the class pointed out that the training helped to better understand the subject, promoting the interest and development of an opinion on the subject.

Training has helped to understand the multidisciplinary dynamics of GM foods in what concerns science, technology and society. They pointed out that it is feasible to provide training with all these topics, with emphasis on the consumer and advice from the professional to the client / patient ^(a, b).

(a) "... greater emphasis on the consumer and advice from the health professional to the client / patient."

(b) "... it would further develop the role of health professionals in consumer advising, but also in the potential influence / commercialization of the food system, including TF."

Table 6.2. Groups of answers given by nutritionists and physicians who were interviewed

| Main Group | Secondary Groups | Nutritionists | Physicians |
|--|--|----------------------|-------------------|
| 1. Contents | The module is very comprehensive. | X | X |
| | Some contents are more important than others. | X | X |
| | Being careful about the relevance of each content. | X | X |
| | Being careful about the duration of each module. | X | X |
| | Being careful about the module operationalization. | X | * |
| | Need to set differences concerning the focus on the topics for each area - nutrition and medicine. | X | X |
| 2. Structure | It is feasible to teach the module with several subtopics. | X | X |
| | It depends on who and whom you work with to conceive the module. | X | * |
| | It depends on the type of information that is passed on. | * | X |
| | Receptivity that may exist. | * | X |
| | Insistence on this type of training. | * | X |
| 3. Emerging Topics | Although the program is strict, they agree that there must be changes. | X | X |
| | Although the curriculum is rigid, there are gradual changes. | X | X |
| | It is not included. | * | X |
| | It is included in the degree whenever there is demand for it. | * | X |
| 4. Inclusion in the degree plan | In nuclear subjects: public health, nutrition, food technology and innovation, human nutrition. | X | * |
| | In optional subjects. | X | X |
| | In other training activities during the degree (lecture, workshop). | * | X |
| | At the end of the degree. | X | * |
| 5. Difficulties | Lack of contents and materials for the module. | X | * |
| | Lack of knowledge of the methodology (multidisciplinary and STS). | X | * |
| | Doubts about in which part of the curriculum it can be integrated. | X | * |
| | The current teaching format may impair it. | X | * |
| | Lack of professors with the necessary competence. | X | X |
| | Little time for many contents. | X | X |
| | Having interested students. | X | X |

| | | | |
|-----------------------------------|--|---|---|
| 6. GM food framework areas | Genetics: genetic construction, methods and processes. | X | X |
| | Ethics and deontology. | X | X |
| | Food toxicology. | X | * |
| | Food technology. | X | * |
| | Human nutrition. | X | * |
| 7. Skills acquired | Advising. | X | X |
| | Informing. | X | X |
| | Monitoring. | X | X |
| | Developing critical analysis. | X | * |
| | Achieving a better understanding of the subject. | X | X |
| | Arousing the interest. | X | X |
| | Forming an opinion. | X | X |

x corresponds to the response attributed by health professionals
 * corresponds to the absence of response by health professionals

6.4. Discussion

The structure of the training module presented is innovative and has its genesis in the current GM food state of art. Beyond the risk/benefit factors, concerns, controversies, ethical, environmental and social dilemmas, were included and conceived in a multidisciplinary format based on the Science, Technology and Society (STS) approach. The diversity of the GM foods topic has been documented over a long period of time in various scientific studies and opinions held by groups of interest (Omobowale, *et al.*, 2009; González *et al.*, 2009; Almeida & Massarani, 2018; Paarlberg, 2014). GM foods fit into a theme that evolved in an environment of many uncertainties and lack of knowledge (Myhr & Traavik, 2002). Thus, the complexity related to GM food forces education to transcend the disciplinary boundaries and move to a more holistic view. This new perspective reflects the recognition that facing complex food issues requires a new paradigm of associations (thematic connections).

Studies with a multidisciplinary approach and / or STS are in the literature, especially in the health and food areas, and so they report positive results (described below). However, there is no similar work in the literature as proposed in this investigation, allowing only comparisons by analogy.

6.4.1. Feasibility of teaching a module with multiple subtopics

The results of this work are similar with the findings of Alonge *et al.* (2016), where feasibility in teaching a module with several subtopics is stated, that is, with transfer of knowledge from several perspectives. The work of Alonge *et al.* (2016) was conducted in the USA in the format of a module for postgraduate students, using multiple approaches concerning "implementing research and practice in public health". The potential of this method is the ability to demonstrate the diffusion and transfer of knowledge from various perspectives. This teaching approach can potentially influence the method of teaching at the postgraduate level in health professions, where various subjects intersect.

6.4.2. Difficulties in applying the module / activity within this approach

In relation to the difficulties of applying the module, it was possible to detect fears in the receptivity of teachers who are possibly used to the traditional format. Similar opinions were presented in the studies of: (i) Gehlert *et al.* (2010), where the challenges of multidisciplinary approaches in education issues were reported. These approaches are regarded as potential conflicts among teachers due to the diversity of mindsets,

divergences of perspectives and opinions; Reme *et al.* (2015) described and discussed the development and delivery of a transdisciplinary teaching module at the Harvard School of Public Health, related to Occupational Safety and Health, reporting that working with a multi-pronged approach required the identification of key-people from/in each relevant area, who could play a very important role in the development and implementation process; (iii) Stokols (2006), a pioneer in transdisciplinary research considered that few researchers would be prepared to provide time, effort, and preparation in such collaborations. It is corroborated by Stokols (2006) that overcoming these challenges would require strategic training and experience, along with encouraging the development of interpersonal skills. Therefore, in general managing a module for multiple themes depends on who and whom one works with.

Other difficulties reported in this research come from getting interested students. Studies by Abubakari (2018), Kartens *et al.* (2002) and Gero (2017) corroborate these findings. Abubakari (2018) mentioned that the challenges also appear on the part of the students in accepting and interacting with these new methodologies. Kartens *et al.* (2002) developed an interdisciplinary degree in science and policy of sustainable agriculture for students of political sciences and agricultural sciences.

The main barriers to learning were the differences in the origins of technical concepts and the levels of motivation of students to study a subject outside their specialty. Gero (2017) has developed an interdisciplinary study in Israel focusing on education in science and engineering. The vast majority of students at the beginning of the course had negative attitudes towards interdisciplinary learning and teaching, while at the end of the course the vast majority expressed a positive attitude. In this study the teachers pointed out that one of the difficulties was to find interested students.

6.4.3. Skills to be developed

Both Nutritionists and Physicians point out advising, informing, monitoring, achieving a better understanding, arousing interest and forming opinions, as skills to be developed and acquired with this training. Studies by Lambert & Monnier-Barbarino (2005) corroborate these findings. Through the formatting of a teaching module on reproductive health issues applied to undergraduate and graduate students, in which a pedagogical approach divided into three-stages (unidisciplinary, multidisciplinary and multi/transdisciplinary) was utilized. The results achieved by each student were based on their ability to translate disciplinary knowledge, establish open dialogue, cross disciplinary barriers, separate

themselves from their initial opinion, and develop curiosity about the perspectives and concerns of others (Ball *et al.*, 2014).

6.4.4. Health professionals and the module's insertion in the degree plan

There is a real need to prepare health professionals for the advance of scientific knowledge related to the topic of GM food. To meet this challenge, it is necessary to have a holistic view of the production chain.

The inclusion of the GM food module in the Nutrition Sciences degree plan was more indicated in nuclear and / or elective subjects, such as: genetics, ethics, food toxicology, food technology and human nutrition. For the degree in Medicine, the prevalence was in optional subjects and / or activities at the end of the course. Possibly this difference comes due to the nature of the courses, as nutrition science is more related to food issues and medicine congruent with health. On the other hand, some studies point out and, therefore, corroborate, the importance of physicians knowing more about nutrition, given the constant need for them to approach this topic in patient care (Ball *et al.*, 2014). In view of this, there appears to be a growing demand for inclusion of emerging issues in the curricula (Irby & Wilkerson, 2003), and the need to improve the nutritional education of health professionals (Kris-Etherton *et al.*, 2014) .

These demands come from changing views on health and disease. There are an increasing number of studies about food production, nutrition, health and interrelations in the context of climate change, increasing populations and urbanization (Harris & Lyon, 2014; Garnett, 2013; Sengooba *et al.*, 2009; Neff *et al.*, 2015; McDermott *et al.*, 2013), such as: studies in the field of public health, since there are countries that face food shortages, water, as well as socio-demographic and diet-related changes (Horton *et al.*, 2017; Foran *et al.*, 2014); as well as studies on transgenic foods, which involve food supply issues (Verma, 2013). In response, higher education is increasingly being asked to train students who are able to deal with emerging and complex issues (Choi & Pak, 2008; Lavin *et al.*, 2001), such as the GM food topic. Complex issues are often shrouded in scientific uncertainties and concerns and therefore generate divergences and require a well-rounded approach that is simultaneously ethical and social, economic and even political (Asselt & Bal, 2000; Hilimire *et al.*, 2014; Rosenfield, 1992). Therefore, I conjecture that the discussion of emerging issues should be managed in a formation that incorporates all these conflicting and ambiguous aspects, in which the GM food are undoubtedly inserted. We hope that the

training through this module can support the understanding of GM food and significantly improve patient care.

6.5. Conclusion

With unanimity, the individuals involved in this study agree and consider the themes presented in the module structure to be important, although there is a difference between the courses of nutrition science and medicine regarding the way in which training is offered and in some content. They point out that difficulties in implementing a module in this format however, will not be impossible. They positively believe that the module will contribute to students' proactive skill development. In view of this, this research corroborated the findings that the training proposed for a medical and nutritionist audience will provide a comprehensive understanding of the complexity of the GM food topic.

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CHAPTER 7 - Final considerations, limitations and future research

This chapter briefly presents the most relevant findings of the research undertaken. Limitations are referred and future research lines are pointed out.

7.1. Final considerations

Considering the data collected, both in the theoretical and practical components, the initial perspective on the importance of GM food as regards doctors and nutritionists is reaffirmed. These foods represent a growing scientific body of knowledge, where traits of disciplinary, academic and professional identity are still being shaped. They converge to define an important work area, with direct impact on health and the environment (whether positive or negative).

The current thesis contributes to the current literature on the positioning of health professionals regarding the topic of GM food. Here, data of qualitative and quantitative nature were combined in order to enlarge the understanding of the phenomena involved. Through the multivariate analysis, profiles that aggregate the varying interests and current demands of nutritionists and physicians regarding GM food issues were mapped out. This was made possible by the survey undertaken to ascertain the opinion, knowledge and training needs of health professionals, and resulted in the construction of an educational module that contextualizes the complexity of the GM food topic.

The work is innovative as it was the first approach to both personal and professional physicians and nutritionists's views regarding this subject (Chapters 3, 4 and 5). Chapter 2 focused on validating the questionnaire, which maximized confidence in research results. The questionnaire is capable of measuring the desired characteristics of opinion, knowledge, training and personal and professional conduct regarding GM food. Two characteristics are ensured in this instrument: validity (it proves statistically that the questionnaire actually measured what it was proposed to) and reliability (it proves reproducibility).

Regarding the opinions presented in Chapters 3 and 4, differences between nutritionists and physicians were identified. Nutritionists reveal more unfavorable opinions and physicians a more neutral opinion. This characterization details how these professionals perceive GM food. The influence of age, gender, and level of education in both opinions and knowledge could be detected. Overall nutritionists and physicians have poor

knowledge of GM food. The fact is that, in Portugal, this topic is almost universally absent from university syllabi.

Some typical information sources were pointed out by professionals. However, it is known that the process of knowledge acquisition involves various steps. In order to truly understand GM and what it entails, interest, reliable information and critical thinking must come together. As such, health professionals generally considered it useful to have some kind of training on the subject, both during university and in continuing education (Chapters 3 and 4). However, nutritionists differed somewhat from physicians regarding the ideal training format (Chapter 6).

GM being a new technology applied to a heretofore untouched realm (the direct manipulation of DNA), and given the limited overall knowledge of genetics so far available, health professionals are called upon to advise and decide despite scientific ignorance and uncertainty, on top of their limited training (Chapter 5). Only a very particular kind of skill set training can aim at success within such a framework (Chapter 6). Front and center must be the ability to think critically, evaluate and weigh the unexpected: precisely what scientists seem most wary of doing. It is obviously not easy to teach what is yet to be discovered.

7.2. Limitations

The small number of participants involved in the pilot study included in Chapter 6 may limit the inference of conclusions. We can note this, in particular, in the option for the "lesson", in which only four professionals participated. There may have been low participation precisely due to the lack of knowledge of the subject by health professionals, and the corresponding lack of investment. Therefore, the need for larger samples is evident. As regards the survey, the minimum number of participants required to ensure a reasonable level of representativeness was exceeded.

7.3. Future research

From what has been previously stated it would be interesting to develop other research studies in the field of teaching-learning in transgenic foods for health professionals, since this type of research is scarce. Some lines of reflection include:

- Apply the module in college classes of nutrition and medicine.

Since the sample of health professionals was small (in class) and did not allow for data generalization, it would be timely to extend and validate the results. Much can be done to improve and fine-tune the training package.

- Describe and characterize the type of knowledge acquired after exposure to the module.

The module here developed must be tested to ascertain the actual outcomes. Thus, it would be interesting to extend the work in order to obtain additional data.

- Study the opinion, knowledge and training needs of other health professionals.

Nothing is known about the opinion, knowledge and training needs of other health professionals, such as nurses, psychologists and pharmacists, among others.

- The questionnaire should evolve for use in other regions.

Finally, although in practice it is difficult to achieve - given the number of professionals that would need to be mobilized - it would be advantageous to extend this study to other professionals of other nationalities, cultures, religions and social strata.

Ideally information and experiences gathered will result in better public service, better health, a better environment and a more just and peaceful society.

