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Novel foods and novel processing techniques as threats and challenges to a hypersensitive world

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Abstract

Novel foods and novel processing techniques are a real challenge for science, industry and administrative bodies but are not a threat to consumers, so although the question why consumers are very wary of 'novel food' is undoubtedly interesting, this paper does not deal with consumer attitudes but with definitions of 'foods', 'functional foods' and 'novel foods' and with particular issues regarding functional foods and novel foods. New challenges in food safety arise through the introduction of novel processing techniques into the food chain. Advantages and disadvantages of novel processing techniques such as supercritical carbon dioxide, high-pressure treatment, and high-intensity electric-field pulses are described. Special attention is paid to the influence of genetic-modification technology and other novel processing techniques on food allergy potency.
Keywords: functional foods; novel foods; safety aspects; novel processing techniques; supercritical carbon dioxide; high-pressure treatment; high-intensity electric-field pulses; food allergy

Definition of foods, functional foods and novel foods

Definition of foods

It took a very long time for the EU to define the term 'food'. According to the EC definition (European Commission 2002), foods are all substances that are destined for consumption by human beings or substances in a processed, partially processed or unprocessed condition that can be expected to be taken by human beings. Beverages, chewing gum, as well as all substances that are intentionally added to foods during their production – including water – are also foods. Examples of non-foods according to this definition are: feedstuffs, cosmetics, tobacco and tobacco products, plants before harvest, living animals and several other things.

Function of foods

It is, however, instructive to consider the functions of foods. They have either two or three functions: The first function is connected to nutrition, namely to provide man with the necessary nutrients in such a way that these nutrients are available to the body. The second function is that of pleasure – foods have to be offered in such a way that the consumers can enjoy them, which means that they should provide a good

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flavour and that they should reveal socio-cultural properties. A third possible, but not essential, function is an added value to give foods one or more positive health effects. Foods that fulfil this latter function are said to be ‘functional foods’.

Functional foods

The definition of ‘functional foods’, proposed by ILSI (International Life Science Institute), seems to meet the goals of functional foods very well. A food is a ‘functional food’ if it has clearly been documented that it has one or more properties beneficial to human health by improving the state of health or reducing health risks in addition to its nutritional value. ‘Functional foods’ can be produced by either adding, removing, concentrating or modifying one or more components of a food or by modifying its/their bioavailability (Figure 1). Interaction of different food ingredients

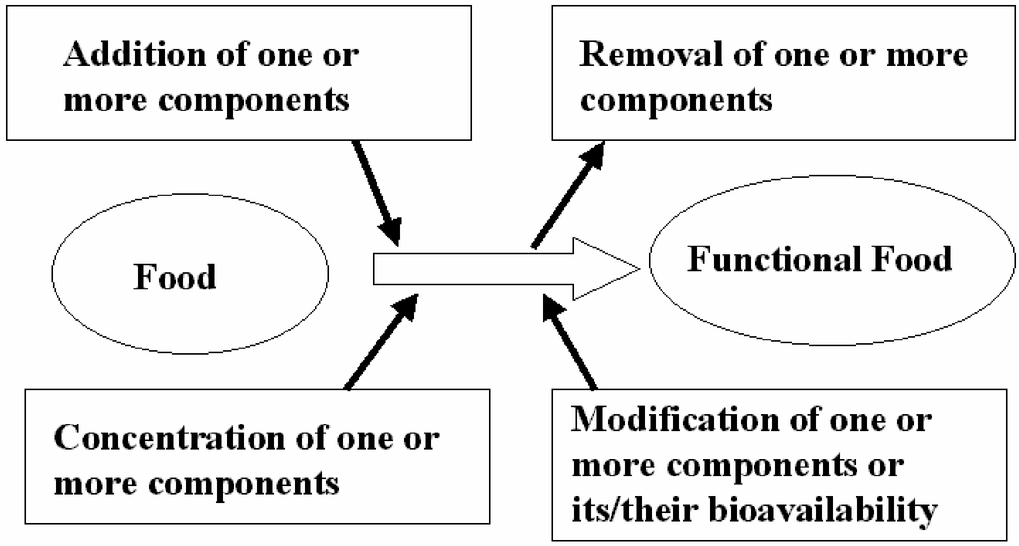

Figure 1. Producing functional foods

(synergisms, antagonisms), concentrations of the active ingredient, individual disposition, changes through storage and /or changes by treatment in the kitchen influence the functions. The following functions are often discussed: retardation of the aging process, prevention of certain diseases, enhancement of the immune system, control of the physical and emotional condition, and convalescence from diseases (Figure 2). The functional effect of ‘functional food’ has to be proven. For this purpose there are methods available utilizing indicators and factors (Figure 3).

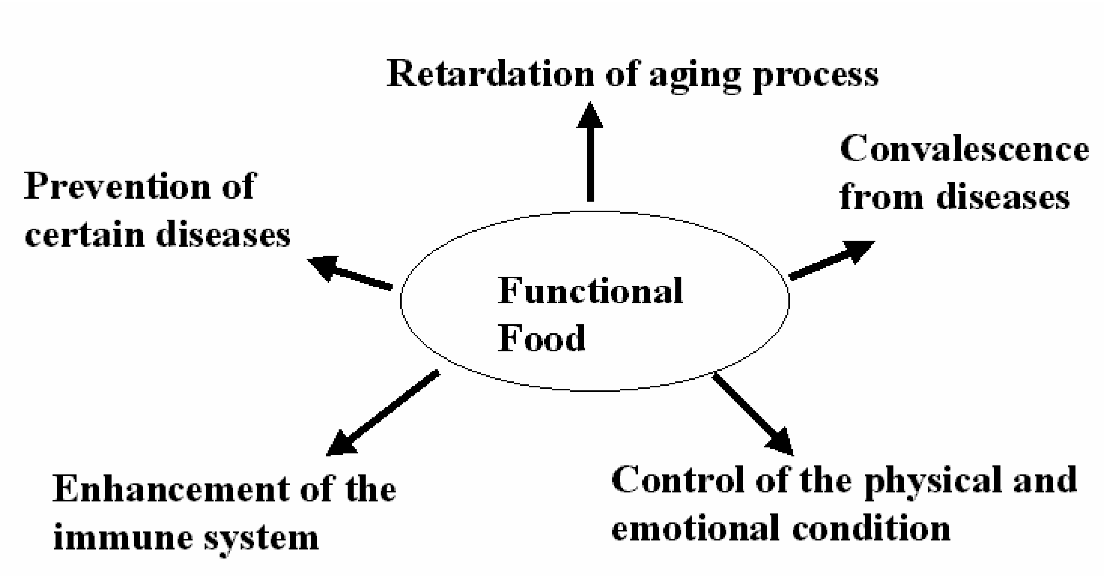

Figure 2. Effects of functional foods

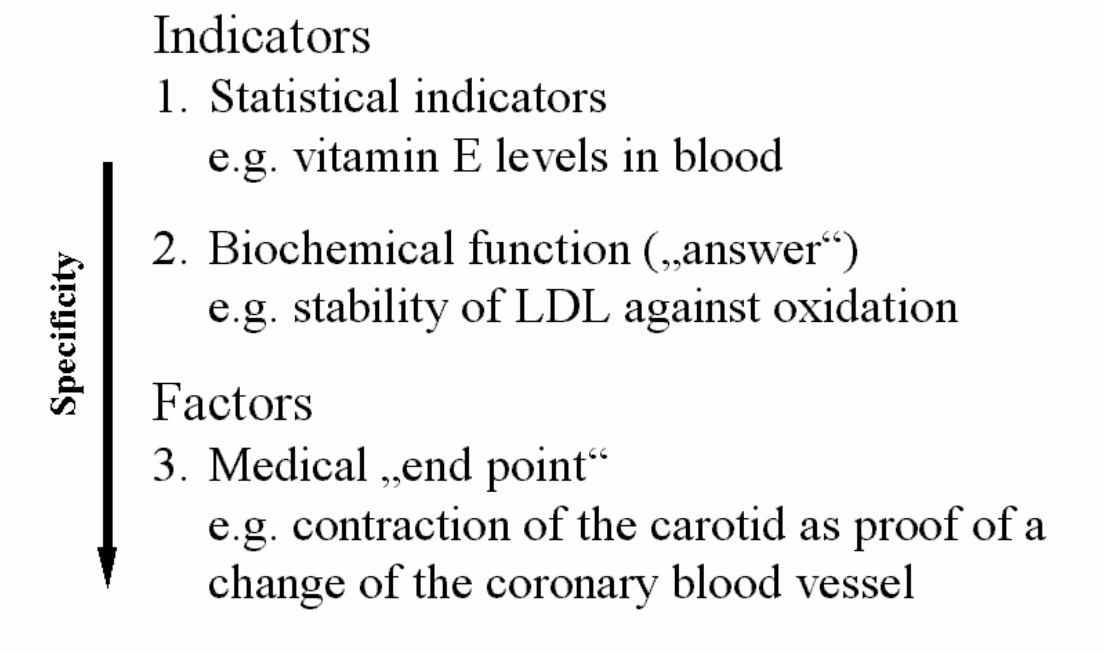

Figure 3. Proof of the effect of functional foods

Novel foods

Most of the ‘functional foods’ belong to the group of ‘novel foods’. In order to protect the consumer from undesirable effects of foods which have been hitherto not widely known in the EU or which have been produced with novel processing techniques, the Novel Food Regulation was introduced in 1997. According to this regulation, the circulation and labelling of ‘novel foods’ and of novel food ingredients that result from using chemical, biochemical, biotechnological and especially genetic procedures is regulated by EU authorities. The Novel Food Regulation subjects ‘novel foods’ to a prohibition with the option of approval. This means that foods have to be checked for safety before their circulation is notified or allowed. The very new aspect here is that the circulation of certain foods is only allowed after approval has been granted. 'Novel foods' may only be distributed in the EU if they fulfil three requirements: the products may not be dangerous to consumers, the consumers may not be misled, and the products may not be so different from conventional products as to cause deficiencies in certain nutrients. Substantial equivalence to conventional foods is therefore important.

There are six categories of 'novel foods' covered by the EC Novel Food Regulation (European Commission 1997):

- Foods and food ingredients containing or consisting of genetically modified organisms within the meaning of Directive 90/220/EEC.
- Foods and food ingredients produced from, but not containing, genetically modified organisms.
- Foods and food ingredients with a new or intentionally modified primary molecular structure.
- Foods and food ingredients consisting of or isolated from micro-organisms, fungi or algae.
- Foods and food ingredients consisting of or isolated from plants and food ingredients isolated from animals, except for foods and food ingredients obtained by traditional propagating or breeding practices and which have a history of safe use.
- Foods and food ingredients to which has been applied a production process not currently in use, where that process gives rise to significant changes in the composition or structure of the foods or food ingredients that affect their nutritional value, metabolism or level of undesirable substances.

Safety aspects

Figure 4 shows some proposals for defining the safety of 'functional foods'. There are three concentrations of ingredients in 'functional foods', which are defined as 'risk of deficiency' if, for example, a nutrient does not meet the requirement level, as 'safe concentration' and as 'risk of toxicity'. The recommended intake (RI) is comprised of the nutrient function and the added value and moves within the 'safe concentration' level. Risk of toxicity begins at concentrations of an ingredient at the lowest observed adverse-effect level (LOAEL). The safety assessment includes the following aspects:

- Risk identification, for example the identification of toxic effects.
- Safety assessment: determination of the LOAEL in studies with animals and humans; the definition of the 'safety index' (SI) is given as SI = LOAEL/ RI.
- Determination of the amount of ingestion; the probability that the ingestion exceeds the LOAEL.
- Determination of interactions with other food ingredients.
- Risk management – reduction of the risk of food ingredients with a low SI.

A risk-assessment programme that proves that 'novel foods' are safe should therefore include the following aspects (International Life Sciences Institute 2003):

- The compositional and nutritional characteristics of the 'novel food' determined with analytical tools, including their fate in biological systems.
- The previous history of human exposure.
- The expected applications as a 'novel food' and the predicted exposure.
- The necessity, appropriateness and outcome of animal studies and studies with humans.
- The necessity and outcome of post-launch studies.

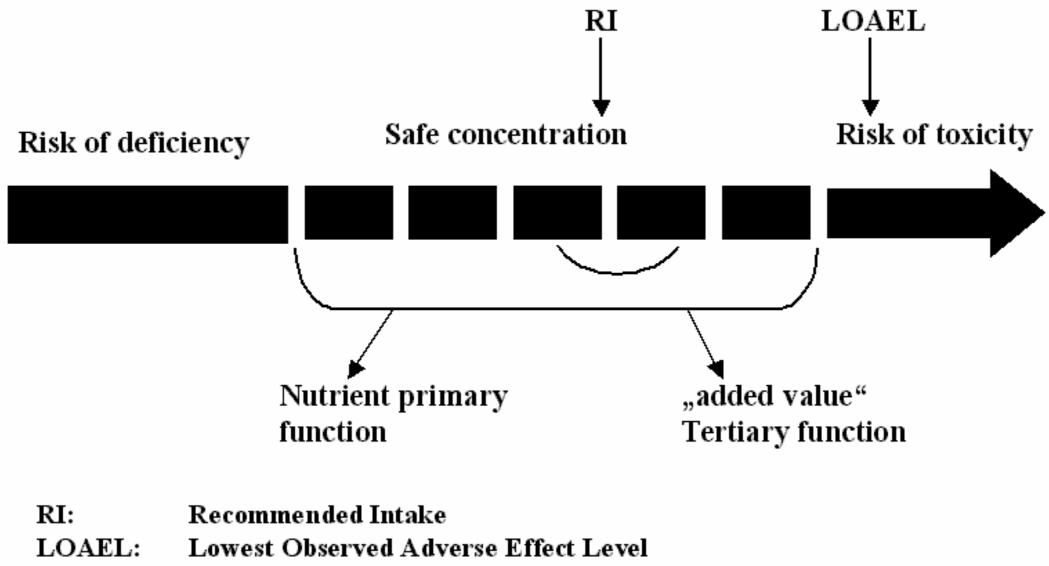

Figure 4. Safety aspects of functional foods

The ILSI Task Force of Europe on Novel Food recently proposed a safety assessment of ‘novel foods’ by equivalence and similarity targeting (SAFEST). Here ‘novel foods’ are divided into three classes (Jonas et al. 1996):

- Class 1: Foods or food ingredients which are substantially equivalent to a traditional reference food or food ingredient.
- Class 2: Foods or food ingredients which are sufficiently similar to a traditional reference food.
- Class 3: Foods or food ingredients which are neither substantially equivalent nor sufficiently similar to a traditional reference food.

Some examples are given of how various ‘novel foods’ fit into the SAFEST approach. Genetically modified bakers’ yeast is substantially equivalent to conventional yeast and belongs to class 1 and EC category a, genetically modified brewers yeast is sufficiently similar to conventional yeast and belongs to class 2 and EC category a, carbohydrate polyesters are not sufficiently similar to a traditional counterpart and they belong to class 3 and EC category c; strawberry jam processed by ultrahigh-pressure treatment is not sufficiently similar to strawberry jam produced by traditional processing and it belongs to class 3 and EC category f; chili con carne sterilized using Ohmic heating is sufficiently similar to chili con carne sterilized by other heating processes and it belongs to class 2 and EC category f.

Novel processing techniques

During the last few years some novel processing techniques have emerged which are, however, not widely used in Europe. Figure 5 shows the so called ‘technology hill’, in which the food-processing techniques are ranked according to past and future developments (Knorr 1998).

This figure shows that there are many approaches to introducing new techniques into food production. Some of these techniques are already widely used outside the EU, like, e.g., high-pressure pasteurization; other techniques, however, have the status of emerging techniques. The aims of developing novel processing techniques are to improve microbial safety and nutritional quality, to improve physical-chemical properties of foods by minimizing process intensities (for example the sensory or technological function), to reduce energy requirements, to reduce waste load, and to increase production and process efficiency. Most of the novel processing techniques are low-temperature applications (Mertens and Knorr 1992; Barbosa-Canovas, Pothakamury and Palou 1998; Busta 2000). Three processing techniques will be discussed here in more detail.

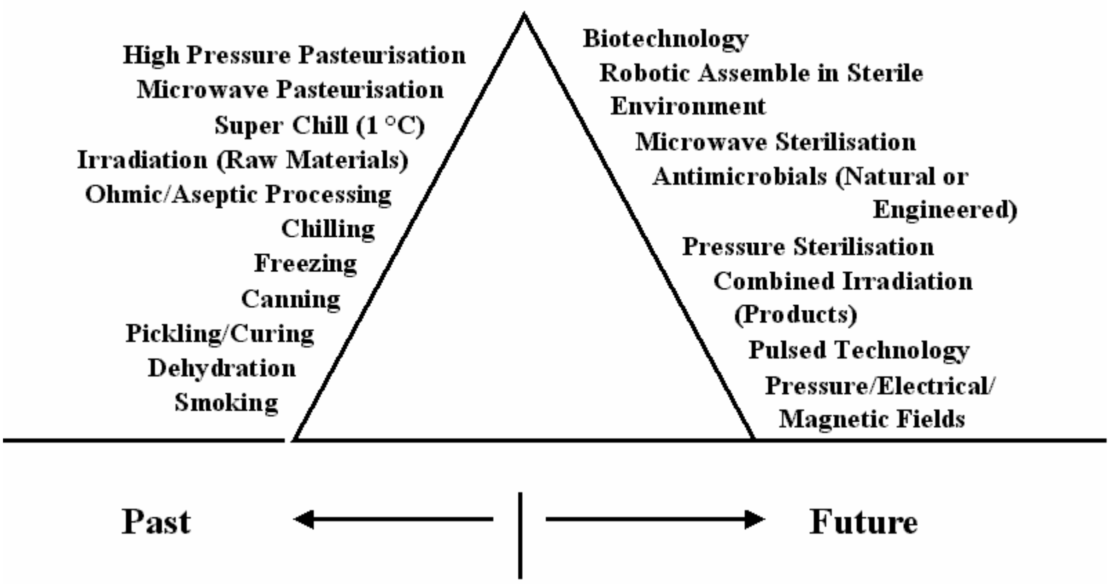

Figure 5. The technology hill (Knorr 1998)

Dense gases – Supercritical carbon dioxide

Supercritical carbon dioxide ($SCCO_2$) is already widely used by the food industry. The goal of using this technique is to extract desirable or unwanted food ingredients, to reduce microbiological activity, and to reduce enzyme activities. $SCCO_2$ can be used to remove caffeine from coffee beans; it is also suited to remove key aroma compounds from roasted coffee beans, and to add these compounds to the produced coffee powder. This technique improves the quality of the soluble coffee to a remarkable extent.

$SCCO_2$ is able to penetrate membranes of micro-organisms, and after being distributed in the micro-organisms, CO_2 is converted to carbonic acid if the a_w value is sufficiently high. The result of this conversion is a decrease of the pH value, and subsequently a reduction of microbial metabolism. An additional damage of the membranes occurs through extraction of lipid components by $SCCO_2$. Knorr reported that microbial activities of *Saccharomyces rouxii* are already strongly reduced after treatment with $SCCO_2$ for 20 min at a_w values ranging from 0.62 to 0.91 and almost totally eliminated after 30 min treatment (Knorr 1998).

High-pressure treatment

High-pressure (HP) treatment of foods was reactivated some 20 years ago in R & D laboratories, and the first commercial products were introduced on the Japanese market in 1991. The advantage of using HP treatment is to have a method in the third dimension, and to reduce the thermal stress. The goal of using HP is to extend the products' shelf life by inactivating microbial activities. The micro-organisms are converted from a stable state into an instable state by combining HP, time and temperature treatment (Hendrickx and Knorr 2002).

Spores are normally pressure-resistant, but it is possible to activate the germination process by using moderate pressure and temperature. Germinating spores are, however, not very resistant against HP so that it is possible to inactivate even spores by using HP. An immediate inactivation of *Bacillus subtilis* spores was immediately obtained at 70^{o} C and 150 MPa (Knorr 1998). HP treatment, however, also has effects on the modification of foods and food ingredients. The modification of proteins (for example gelatinization), polysaccharides and mixtures of both, as well as changes in the texture of foods by HP treatment have been studied intensively during the past few years.

One application of HP is blanching of vegetables. Plant cell walls are damaged through this treatment, and this effect influences the permeability of cell walls. Consequently, dehydration processes are improved and this effect makes dehydration processes easier.

High-intensity electric-field pulses

This is not really a novel technique because it was applied to foods as early as the beginning of the 20th century. Ohmic heating of foods has, however, been reintroduced in recent years. High-intensity electric-field pulses (HELP) with pulse durations in the millisecond to microsecond range, which allows pulse sequences up to 2,000 per second, are applied (Heinz et al. 2001; Van Loey, Verachtert and Hendrickx 2001). The effect of HELP is similar to HP treatment, viz., this technology leads to reversible or irreversible damage of microbial membranes or plant cell walls. The effect of HELP on spores is, however, limited. The damage depends, naturally, on the total energy applied. The energy can be applied by one pulse of high energy or by many pulses of low energy. The effect of HELP is also markedly dependent on the pulse geometries.

One possible application of HELP is to improve the permeability of plant cell walls in order to make the recovery of valuable ingredients easier. This can be helpful, for example, in producing fruit juices, by improving the yields of extractable ingredients so that enzyme treatment can be avoided or reduced and the quality of the juice can be improved.

Applications of novel processing techniques

Some examples of existing and intended applications of novel processing techniques may show the wide variety of benefits they bring. To preserve and/or to decontaminate macro- or micro-ingredients, micro-organisms, ready-to-eat meals or packaging material in order to extend the shelf life, high hydrostatic pressure, pressure-assisted freezing, high-voltage arc discharge, ultrasonics and high-intensity pulsed light can be used.

Using high hydrostatic pressure or high-intensity electric-field pulses, whole foods, micro- and/or macro-ingredients can be modified, for example gelatinization can be improved. High hydrostatic pressure and high-intensity electric-field impulses can also be used to induce stress, for example to increase the biosynthetic activities of micro-organisms, cell cultures or algae.

An important goal in producing foods is mass-transfer modification by extraction or expression in whole foods, micro-organisms, cell cultures, algae, raw materials for macro- or micro-ingredients or food waste. This aim can also be achieved by using techniques such as high hydrostatic pressure, high-intensity electric-field pulses and ultrasonics.

Non-thermal processes such as membrane processes (ultrafiltration and reverse osmosis) can be used to preserve and modify liquids, whilst biotechnical processes like fermentation or enzymes serve to transform foods in order to preserve or modify them.

Although novel processing techniques appear to be increasingly important in the food industry, there have been hardly any research projects that deal with the effect of these new techniques on the allergenic potency of treated food. Some experiments, however, have been undertaken to investigate the effect of HP treatment on allergenic potential. The results show that the influence of this treatment on allergenic potential is low, which is an astonishing result because not only HP treatment but also the other methods mentioned above modify the food proteins. It is, however, known from many other experiments that the modification of proteins may influence the allergic potency of foods.

Food allergy – genetic-modification technology

The genetic modification of plants and animals is a deeply controversial novel technology, and consumers, especially in Europe, are not yet ready to accept this technology being widely used in the food chain. There are many reasons why this technology has been rejected so far, especially safety concerns. One argument against using this novel technology is that a new allergenic potential can be introduced into the food chain by transferring proteins from one organism into another. The introduction of hitherto unknown allergens into the food chain, however, is not a specific problem of genetic-modification technology (GMT) but is a general breeding problem. Using GMT, only one or a few proteins are changed, and these proteins are normally very well-defined proteins. Conventional breeding technologies change far more proteins, which are normally unknown, and especially the allergenic potency of the newly introduced proteins is unknown.

The allergenic potency of proteins introduced into products by GMT can be estimated by a computer-based comparison of the protein’s structure with that of known allergens. An identical match of at least eight amino acids in a particular order indicates that the protein may be an allergen. In this case it is necessary to estimate the allergenic potency by using a test procedure, a so-called decision tree, which is a widely accepted technique. The scheme of this procedure is shown in Figure 6. By going through this procedure, it is possible to decide whether the engineered gene will cause food allergy or not. There are still other characteristics that can be used to estimate whether a new protein may have an allergenic potency or not, such as molecular mass, stability against proteolysis, pH-stability, glycosylation, and high amounts in foods. Table 1 compares such characteristics of engineered proteins (Jany and Greiner 1998).

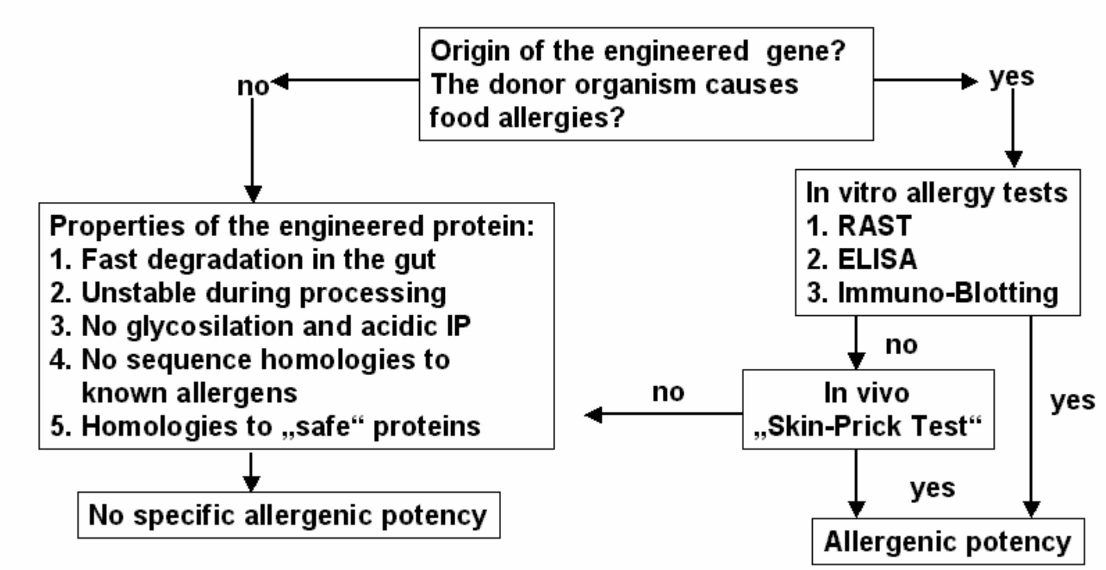

Figure 6. Test procedure to estimate the allergic potency of a protein (Jany and Greiner 1998)

Table 1. Characteristics of engineered proteins (Jany and Greiner 1998)

Engineered Proteins	Typical Allergens	CP4 EPSPS	NPT II	PAT	BT-HD-1 Toxin
Molecular weight 10-70 kD	+	+	+	+	+
Stable against proteolysis	+	-	-	-	-
pH stable	+	-	-	-	-
Glycosylation	+	-	-	-	-
High amount in food	+	-	-	-	-

CP4 EPSPS phosphoenolpyruvate shikimate synthesis
NPTII neomycin phosphotransferase
PAT phosphinothricin acetyltransferase
BT-HD-1 *Bt* toxin

One instance that demonstrates that it is possible to identify allergenic proteins transferred through GMT is the Brazil-nut protein 2S albumin, which was transferred into soybeans in order to improve their methionine content for food and feed purposes. It was known that the 2S albumin causes severe allergic reactions. Going through the decision tree for assessing potential allergenicity of GMT-derived products led to the determination that the transferred gene encoded a major allergen, hence the gene product was discarded immediately (Nordlee and Taylor 1995).

The benefits of GMT with regard to food allergy can be summarized as follows: The production of recombinant food allergens allows a successful characterization of allergens from different foods, the characterization of cross-allergies on a molecular level and is an important tool for diagnosing food allergens (Lorenz et al. 2001). By using antisense technology, Nakamura and Matsuda (1996) inactivated a major allergen in rice (inhibitor of the human α-amylase in saliva). In order to be more successful in this field, we need more information on the epitope and peritope structures. It is possible to inactivate one or a few allergenic proteins in a food by GMT, but in most cases there are more than just a few active allergenic proteins in a food, which cannot be changed so far by GMT.

Food allergy – novel processing technologies

As mentioned earlier there are only a few reports on the influence of novel processing technologies on allergenic potency in foods.

An important question in this connection is whether hidden allergens can be identified in processed food. We investigated whether residual allergenicity can be found in refined and non-refined soybean oils as well as in soy lecithins, compared to extracts from native soybeans (Paschke et al. 2001). By means of immunoblotting and EAST inhibition experiments no IgE-binding activity was detectable in refined soybean oils, which is probably due to thermal treatment during the refining process. The non-refined oils and soy lecithin, however, showed a residual IgE-binding activity. In addition, in the lecithin extracts a new IgE-binding structure of 16 kDa was detectable. Table 2 shows the C_{50} values and maximum inhibitions of the investigated soy products.

Table 2. C_{50} values and maximum inhibition of the investigated soy products; A6 and A7 = refined oils; HT21-23 = non-refined oils; LBN 401 E3 and E4 = lecithin extracts (Paschke et al. 2001)

Inhibitor	C_{50} concentration [µg/ml]	Max. inhibition [%]
Native soybean	0.3	94
Soybean oil A6	-	0
Soybean oil A7	-	0
Soybean oil HT21	-	36
Soybean oil HT22	-	25
Soybean oil HT23	46.3	53
Lecithin LBN 401 E3	10.3	67
Lecithin LBN 401 E4 73/98	9.8	84
Lecithin LBN 401 E4 75/98	15.7	54

Another example of such novel processing technologies is the use of enzymes in order to reduce the allergenic potency of proteins. Here we produced several mango juices by varying technology parameters like heating temperature and time and amount of enzymes in the mash. The result was that the addition of enzymes to the mash has no influence on the allergenicity of mango products, and that the allergens of mango are highly temperature-stable. The mango products have only a weakly reduced allergenicity (Dube et al. 2004).

Table 3 and Table 4 give an overview on the stability of food allergens of animal and plant origin against different technological treatments, and the presence of hidden allergens (Besler, Steinhart and Paschke 2001).

Table 3. Stability of food allergens of animal origin and presence of hidden allergens (Besler, Steinhart and Paschke 2001)

Allergens	Heating	Enzymic hydrolysis	Significance as hidden allergen
Milk and milk products	stable	partially stable	high
Eggs and egg products	stable	stable	high
Fish and fish products	stable	partially stable	low
Crustaceae and products	stable	no data	low
Meat and meat products	partially stable	low	low

Table 4. Stability of food allergens of plant origin and presence of hidden allergens (Besler, Steinhart and Paschke 2001)

Allergens	Heating	Enzymic hydrolysis	Significance as hidden allergen
Peanuts / peanut products	stable	partially stable	high
Soybean / soybean products	partially stable	partially stable	high
Tree nuts and products	partially stable	partially stable	high
Sesame seeds and products	no data	no data	high
Cereals and cereal products	partially stable	no data	high
Fruits of the *Rosaceae* family	mainly labile	labile	low
Latex-associated fruits	no data	no data	low
Celery and celery products	partially stable	mainly labile	high
Carrots and carrot products	labile	no data	low

Conclusions

Science, industry and authorities accept the challenges to make ‘novel foods’ safe. Is there really a threat caused by ‘novel and functional foods’ or by introducing novel processing techniques? I believe that the threat is very small, especially compared to other risks. But there remain a lot of problems concerning ‘novel and functional foods’ that have to be solved in the future.

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