

Food Product Innovation:

How to link Sustainability and Market

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Abstract

According to recent estimates close to half of all human impact on the environment, such as loss of bio-diversity, is directly and/or indirectly related to food production and consumption. If society wants to reduce this impact, changes in the production and consumption of meat are most challenging of all food product categories. It may be clear that on the one hand there is a need for society to make food production systems more sustainable. On the other hand food products are manufactured and sold in a market oriented system. Consequently new protein-rich products must have the characteristics and quality to appeal to the consumer. Many of the non-meat alternatives that are currently on the market do not meet these criteria. To be able to produce protein-rich products that meet consumer demands it is necessary to have a closer look at the changes that occur in the market and in consumer's perceptions and - preferences. New products should be defined that meet sustainability criteria and at the same time are attractive for consumers. A chain oriented approach should be followed in product innovation going from market via processing conditions up to raw material composition and properties. Using this approach large reductions in environmental impact of the supply chain will be accomplished but a coördinated approach is required and eventually the design of new supply chains. In this paper we will follow the product innovation route and in the end present a case study of how the need for sustainability can be linked to market demands.

Key words: ***Food, Product Innovation, Sustainability, Market***

Introduction

According to recent estimates close to half of all human impact on the environment such as loss of bio-diversity is directly and/or indirectly related to food production and consumption. These estimates are based on considering the whole production chain from primary production via processing to consumption, including multiple steps of storage, cooling, transport and waste streams.

Sustainability of production systems is often quantified with the use of systems such as Life Cycle Analysis (LCA's). LCA's are based on a systematic chain oriented inventory, analysis and evaluation of the use of raw material and energy of a product and/or a process and it's environmental impact starting with the raw material production up to processing of waste streams.

Important aspects that are taken into account are nitrification, abiotic depletion potential, ecotoxicity, acidification potential, global warming potential, ozone depletion potential etc. The LCA methodologies presently available have been developed and applied in various areas of industrial production but have not yet been systematically implemented in the food industry and in principle they provide a useful frame work for a systematic improvement of food production systems.

According to a recent report from the Food and Agribusiness Research Group from RABO at this moment about half of all grain produced is used for live-stock production although there are large regional differences ranging from 2% in India up to 75% in the USA. (RABO, Utrecht, 1998). Generally increasing well-fare results in increased consumption of meat products and according to a report of the Dutch Scientific Council for Government Policy (WRR) increased consumption of meat products is a crucial factor in the growing need for arable land (WRR,1994). In addition developing countries with growing economies increase their demands for grain. China has turned overnight from the world's third largest exporter of grain into the world's second largest importer of grain (Worldwatch Institute, 1996; FAO, 1995) This may serve to illustrate that the environmental impact of food production and consumption may become critical regarding the foreseeable growth of (1) the growing world population and (2) the consumption of live stock-based products

The negative environmental effects of meat production and consumption arise from the fact that the conversion of feed by animals into meat is an inefficient process. Moreover, huge waste streams are produced and a large proportion of the arable land is in use for the production of feed. Therefore if society wants to reduce this impact, changes in the production and consumption of meat are most challenging of all food product categories. However, meat is the most important source of proteins in a 'western' diet and is favoured by consumers all over the world. A strong reduction of the environmental impact of present and future food production systems can be realised if one is able to decrease the consumption of meat products considerably by the development of new (non-meat) protein rich products. In a recent desk study on the development of non-meat alternatives, the so-called Novel Protein Foods, commissioned by the Dutch governmental research programme DTO, it was concluded that on the long run production and marketing of non-meat alternatives to replace meat as an ingredient in fabricated foods is feasible provided that a number of technological and societal challenges will be met.

It may be clear that there is a need for society to make food production systems more sustainable. On the other hand food products are manufactured and sold in a market oriented system. In other words the consumer has the choice to select and buy those products that meet his or her demands. Consequently new protein rich products must have the characteristics and quality to appeal to the consumer. Many of the non-meat alternatives that are currently on the market do not meet these criteria. To be able to produce protein rich products that meet consumer demands it is necessary to have a closer look at the changes that occur in the market and in consumer's perceptions and - preferences.

The underlying concepts of current food production systems are primarily based on two distinct features (Jongen, 1996a):

1. The one-way communication through the chain from producers of raw materials and/or primary products to the users of end-products (The consumers)

2. The poor understanding of the concept of product quality. Quality was and, in a number of cases, still is predominantly based on technical criteria and producers focus(ed) in particular on costs and productivity.

In a growing market like we have known for some decades in most West-European countries this approach has been very successful. However in the last decade the market situation has changed drastically. Apart from market saturation we see a number of other developments that have a large influence on the situation in the market. The size of the market is limited by the reduction in the speed of population growth and in a number of countries the saturation point for caloric intake seems to be reached. Other important changes are demographic shifts towards an ageing population and major changes in household composition (Meulenberg and Viaene, 1998). Generally the consumer is better educated and more demanding with respect to product diversity. Consumers are less predictable in their purchase behaviour, eat more outside homes and are more conscious about health related aspects. (Popcorn, 1992). Also the perception of product quality is no longer restricted to physical product properties but also includes production methodology.

Beside this, scientific progress such as the development in biotechnology or the development of new processing technologies will result in product innovation. Improved analytical methodology will result in increased demands for improved product safety and quality requirements.

As a result of all this there is a continuous need for new products and a more differentiated food product assortment. Related to this development product life cycles become shorter (Meulenberg, 1997) hence efficiency and flexibility of food production systems become even more important.

The interdependency between consumers' wants and needs on the one hand and development of technologies and research on the other hand has been recognized by many food producing companies but is not implemented systematically yet, especially with respect to sustainable production systems.

The DTO-desk study has indicated that large scale production of non-meat alternatives requires societal innovation next to technological innovation. This requires that actors in specific food supply chains will have to develop new networks, flanking governmental policy is needed and not in the least competitive production systems have to be developed that meet market demands. A chain oriented approach integrating technological developments to societal innovation is required here.

In the following some aspects relevant to product innovation will be described and linked to the question of how to achieve sustainable production systems.

Chain Reversal as a Starting Point

The many changes in the market for both fresh and processed food products call for a repositioning of existing food production systems and raise the question whether the concepts currently used can survive the challenges of the future (Fuller, 1994). The large number of changes and the costs associated with product innovation make it necessary to develop a new approach towards the production of food products namely chain reversal in which the consumer has become the starting point of thinking. This makes it necessary to have good knowledge about the market and consumer preferences and to come to quality control throughout the chain (Meulenberg, 1997). Definition of product quality is the first step in this new approach and requires translation of consumers' perception and preferences into product characteristics that are measurable and can be specified (Grunert, 1995). With this knowledge the acceptable band width

of variation for specific quality criteria can be determined and processing conditions can be optimised. Also the demands for raw material properties can be (re)formulated. Using this concept raw material composition and -properties can be coupled directly to the quality of the end-product. Also a distinction can be made between the possibilities to achieve the desired end-product quality via modulation of processing conditions and optimisation of raw material properties e.g. via biotechnology (Jongen, 1996a). In figure I a schematic picture is drawn of the traditional(A) and innovative (B) chain oriented approach

Chain Approaches

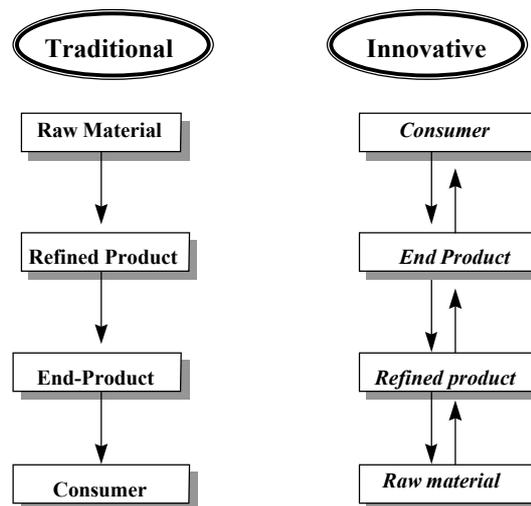


Figure I

Generally speaking improvement of sustainability from a chain perspective can be achieved in a number of ways. One possibility is that individual actors in a given food supply chain try to improve production and process technology in order to reduce waste streams and energy consumption. This will result in incremental improvements at the supply chain level and no coordinated approaches are required. Another way is to start by defining new products that meet sustainability criteria and at the same time are attractive for consumers. In that case the product innovation route from market via processing up to raw material composition and properties should be followed. Using this approach larger reductions in environmental impact of the supply chain will be accomplished but a coordinated approach is required and eventually the design of new supply chains. In this paper we will follow the route of product innovation and in the end present a case study of how these aims can be achieved.

Product quality

The understanding of the term ‘product quality’ has been subject of a large number of studies and the contributions of Juran, Deming, Crosby and many others to improve our thinking about quality are invaluable. Juran (1989) has included the consumer into his concept of product quality and prevention instead of control of quality. His definition is: ‘Quality is fitness for use’. With respect to the situation for food products a better wording would be: ‘Quality is to meet the expectations of the consumer’. Two important aspects should be underlined here. The first one is

that the consumer is the starting point of thinking about quality and the second is that the consumer does not work with accurate specifications. *The* consumer doesn't exist as such. There is no average consumer. There is a specific consumer who, in a specific situation and on a certain moment, has a specific need to which the producer can respond.

The consumer buys and consumes a product for a number of reasons. Partly these reasons refer to product properties for another part these refer to the production system. I propose to use here the terms intrinsic and extrinsic factors. Intrinsic factors refer to physical product properties such as flavour, texture, appearance, keepability and nutritional value. These properties are direct and/or indirect measurable and that can be objectivated. A food product as such has no quality, it has physical properties which are turned into quality attributes by the perception of the consumer. An example of this is the texture of an apple. From a physico-chemical point of view the texture of a product can be described in terms of cell wall composition and structure. The consumer perceives this during consumption and describes his experience in terms of crispiness or mealiness and toughness. The total of quality attributes (intrinsic factors) determines the quality of a given product. Extrinsic factors refer to the production system and include factors such as the amount of pesticides used during growing, the type of packaging material used, a specific processing technology or the use of biotechnology to modify product properties. They do not necessarily have a direct influence on physical product properties but influence the acceptance of the product for consumers. The total of intrinsic and extrinsic factors determines the purchase behaviour (Jongen, 1995). In figure II an attempt is made to visualize this concept.

Consumer Perception and Acceptance

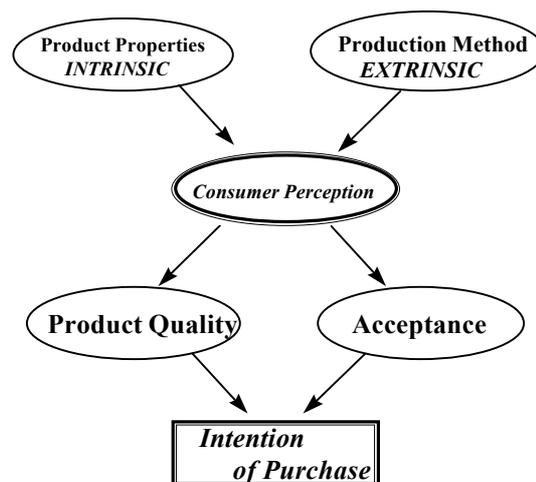


Figure II

The balance between the price of a given product, its perceived quality and the level of acceptance determines whether a product will be successful in a given market (van Trijp and Steenkamp, 1998). As numerous examples have shown, the mere fact that a product is manufactured on an environmentally friendly way is not sufficient to make it successful in the market. Although, generally, there is a growing awareness amongst consumers about the need for more sustainable production systems and willingness to pay a little extra money, recent studies have shown that product quality is still the main determinant for buying behaviour. A major challenge for the future is the question how sustainability of food products can be communicated to the consumer and turned into a marketing element.

Quality as steering factor for innovation in the supply chain

Production system characteristics

Product innovation in the food industry has to deal with a number of characteristics that are specific for food products and which make it complicated to achieve quality control throughout the chain.

1. Food products are perishable, and depending on the conditions, product properties can change very fast and result in spoilage. This means strict quality demands for production, storage and passage time throughout the production chain.
2. Production and harvest of plant foods is seasonally whereas consumers ask for constant availability. So there is a requirement for adequate storage and/or transport methods and facilities.
3. There is a clear awareness amongst consumers about the relationship between diet and health. This includes both the absence of unwanted components such as pathogens and toxicants either naturally present or added as well as assuring the levels of components that are wanted such as vitamins and minerals. Adequate risk prevention requires systematic quality control.
4. Small-scale production is an obvious characteristic of some sectors of the food industry and a complicating factor in assuring homogeneous products e.g. milk or raw materials for processing. It requires specialized organisational structures.
5. The number of retail outlets is very large which complicate an adequate control of distribution quality (service oriented). Beside that also retail outlets have to deal with a large number of wholesalers. This makes it virtually impossible to define accurate specifications with respect to quality demands for a given product.
6. Fresh food products are perishable and have only a very limited shelf-life. Beside it is too expensive for retailers to maintain large amounts of product on store. This has resulted in systems with very high delivery frequencies.
7. The primary aim of food industry is to provide the society with food products of good quality for a reasonable price. So generally food products have low added value. This is a major drawback in innovation.

Contrary to other production systems such as the computer and automobile industry where quality control is achieved by working with accurately described specifications, in the food supply chain the highest achievable level is to work with specified band widths for quality determinants. Sustainability strategies developed in those areas are not directly applicable to the food industry.

Also it should be kept in mind that quality control, especially in sustainable supply chains, is not restricted to measurement of composition and properties of raw materials and half-fabricates but also includes production methodology such as cultivar selection, agronomical conditions, storage and handling conditions and processing and packaging technologies.

Chain ruptures and product quality

One characteristic of the traditional supply chain is the use of differing concepts of product quality by actors in a specific production chain. In figure III an example is given of the large number of quality criteria a plant food product has to meet and how these differ going from the breeder to the consumer. From the figure it may become obvious that no single product can meet all the requirements indicated and that there is a clear need for one integrated concept of product quality throughout any specific supply chain.

Actors in the Chain and Quality Perception

Breeder	Vitality Seeds, Seed Yield
Grower	Productivity, Uniformity, Disease resistance
Auction	Uniformity, Reliable Supply, Constant Quality
Distribution	Keepability, Availability, Damage Sensitivity
Retailer	Good Shelf-life, Diversity, Appearance, Low waste
Consumer	Tasty, healthy, Sustainable Convenience, Constant Quality

Figure III

For a chain oriented system of quality control we need to have methods that can measure external and internal quality and predict keepability. Also we need methods that can relate raw material composition and end-product quality to the processing conditions (Jongen, 1996a). One excellent example comes from recent work of van Kooten and his coworkers (1995) on cucumber. Using the efficiency of the photosynthesis system as parameter they have developed a measurement system that can be used to measure temperature failure during storage and predict shelf-life in the chain.

Innovation cycles

As already mentioned in the introduction the market for plant food products has become more and more competitive and changing consumer demands have become a constant drive for companies to innovate. From a chain oriented perspective three major innovation cycles can be distinguished (Figure IV). The first one deals with developments in the market. Here we see a decreasing life cycle of products and fast changing preferences of consumers. The consumer generally behaves more impulsive and has become a moving target. The second innovation cycle

refers to the technologies associated with processing and production systems. New technologies and approaches such as high pressure cooking, hurdle technologies, minimal processing etc. will increase the potential to meet new consumers' demands. Generally innovation in technologies is more slow than changes in the market situation. The third cycle deals with primary production and is actually the slowest cycle even with the use of modern biotechnology. Short-term changes in the market are impossible to follow. From a chain oriented perspective it is of utmost importance for breeders to have a strategic view on market developments and to identify market niches where they can be strong and ahead of their competitors. Consequently it is of great importance to establish strategic collaboration within the chain.

Also developments in various areas of the production chain have to be considered on the basis of an integrated view. For example from an agronomical viewpoint it might be interesting to consider the use of a mix of cultivars to reduce the use of pesticides. From a processing point of view homogeneity of raw material composition and properties is of the greatest importance with respect to reproduction quality. Such conflicting demands have to be brought together in a balanced way.

Innovationcycli Plant Food Products

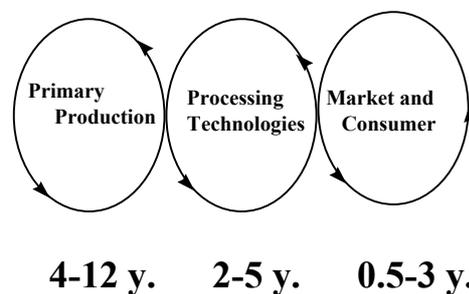


Figure IV

Linking consumers' wants to technologies and research

In the previous paragraphs we have seen that we are heading towards a situation in which continuous innovation has become a prerequisite for companies to stay into business. This raises the question how these changes can be turned into a challenge and whether the traditional innovation concepts are still valid. To answer these questions at a strategic level the **DFE** concept can be followed. The **DFE** concept is a three step approach which enables to establish a link between changes in the market and the consequences for production systems. The first step is the question about the **Desirability** of new products (market socio-economics and consumer preferences). The second deals with the **Feasibility** of the production (technological possibilities and barriers). The third one follows with the question of **Efficacy** (organisation of production chain).

When this concept is applied to the question of how we can make our food production systems more sustainable the following elements should be taken into consideration.

1. Technological innovations should be integrated with societal innovation processes. Insights should be made available about societal barriers and opportunities which are critical for a successful introduction of new products.
2. Consumer perception and - preferences are the starting point for technological innovations. Perceptions and preferences should be translated into physical product characteristics in a structured way. Technological innovations should be implemented along the line of the food supply chain from breeder to retailer.
3. The focus in innovation should be on (I) the developments of tools and concepts for the production of ingredients rather than focus on products and (II) design of competitive production chains
4. At the policy level tools should be made available that will predict the environmental impact of new systems and technologies and enable the development of long-term strategies.
5. The development of tools and concepts should be done together with relevant stakeholders.

CASE DESCRIPTION

Protein Foods: Environment, Technology and Society *a multi-disciplinary chain oriented research programme proposal*

Problem description

Estimates are that half of all human environmental impact is food-related. Analysis shows that if society wants to reduce this impact, changes in the production and consumption of meat are most challenging of all food product categories. The negative environmental effects of meat production and consumption arise from the fact that the conversion of feed by animals into meat is an inefficient process. As a result, huge waste streams are produced and a large proportion of the arable land is in use for the production of feed. However, meat is the most important source of proteins in a 'western' diet and is favoured by consumers all over the world. Consequently, a considerable reduction of the environmental impact of present and future food production systems can be realised if one is able to decrease the consumption of meat products considerably by the development of new (non-meat) protein rich products. These so called Novel Protein Foods (NPFs) should, however, appeal to consumers and be competitive in the food market. The most relevant source of proteins for NPFs are plants. In this way the inefficient conversion step from plant to animal is avoided.

In a desk study on NPFs (DTO, 1996) it was shown that the production of NPFs is a promising option for the agri-business and large-scale introduction seems possible within the next decades. Furthermore, it was concluded that it is technologically not feasible and from a consumer point of view not desirable to produce NPFs which mimic 'red meat'. But for NPFs as protein-containing food ingredients market opportunities are present. Already 45% of the total meat production is used as ingredients and it is expected that this percentage will grow in the near future.

At present the available non-meat protein rich products do not meet the expectations of most western-style consumers, and are, therefore, not a realistic alternative for meat. Essential (technological) scientific knowledge is lacking concerning the chain: consumer expectations — sensory preferences — product characteristics — processing technologies — protein properties — raw material production — breeding. Consequently only incremental product development takes place at this moment and the necessary breakthroughs are not foreseen. For such a breakthrough a considerable effort in fundamental technological research and product development will be necessary. The research programme **Protein Foods: Environment, Technology and Society** is aimed at providing a major input in that development process.

Programme approach

The developed research programme is elaborated from the next starting points:

1. The technological innovations aimed at should be placed in a societal context. Insight should be obtained in the societal threats and opportunities which influence a successful introduction of NPFs. Furthermore, governmental policy measures should be identified which facilitate this introduction.
2. Consumer expectations of NPFs are the starting point for the technological research projects. These expectations should be translated into product characteristics, which are

then the targets of the technological projects. The technological projects should address bottlenecks along the whole production chain down to plant breeding.

3. The focus should be (i) on the development of tools and concepts for the production of protein-rich ingredients and not at actual product development, and (ii) on the design of viable future production chains for NPFs.
4. Tools have to be developed and applied by which the expected reduction of the environmental impact of the food production system by the introduction of NPFs can be quantified and evaluated.
5. The development of tools and concepts, and the design of production chains should be performed in close co-operation with the main stake-holders in the production chain of NPFs.
6. The emphasis is on the Dutch agri-business and consumer-market, although in wider EU and global context.

Programme aim

The programme aims at answering the next questions:

1. Is the introduction of NPFs from a consumer and societal point of view *desirable*?
2. Is the production of desired NPFs technological *feasible*?
3. How *efficient* can the production chain of NPFs be organised using economical as well as environmental criteria?

General programme outline

The programme consists of 15 individual projects (7 PhD- and 8 post-doctoral projects) and the budget is Mfl 8. Participation is foreseen of 3 universities, 4 research institutes and 6 food companies. The Dutch National Science Foundation is asked to support this programme with a grant of Mfl 5. The expected starting date is September 1998.

Within the frame work of the programme a Strategy group will be set-up. The main task of this group is the design of viable production chains for NPFs. Among the members of this group are the main stakeholders.

In the programme research will be performed on: (i) the societal consequences of large scale introduction of NPFs, (ii) the present and future production networks of meat and NPFs, (iii) the technological and consumers issues of NPFs production processes and (iv) the effects of meat and NPFs production on the environment (see figure V). Besides the 'disciplinary' projects (13 projects in total), 2 'integrative' projects are formulated. These integrative projects should facilitate and support the 'chain design' work of the Strategy group, and are therefore very crucial for the success of the programme. The three main tasks of these integrative projects are (i) the development of appropriate design methodologies, (ii) the evaluation of design data, and (iii) the attuning of the individual research projects. In table 1 an overview of the individual projects is given. The projects dealing with the production process are discussed in more detail in the next paragraph as a example of the adopted approach.

Table 1. Research projects

<i>Research field</i>	<i>Project title</i>
1. Society	<ul style="list-style-type: none">- a sociocultural analysis of the potential for a shift from animal to plant protein foods in the context of modern lifestyles- the introduction of meat substitutes from vegetal protein: consequences for EU agriculture
2. Production network	<ul style="list-style-type: none">- protein politics: policy and socio-technical networks and their implications for protein production- the citizen-consumer: an exploration of citizens' strategies for influencing the supply side of food products and technology development
3. Production process	<ul style="list-style-type: none">- consumer and consumption behaviour with respect to meat and NPFs- translation of consumer sensory preferences into product characteristics- protein-induced texture formation in NPFs- protein-flavour interactions in relation to development of NPFs- designing sustainable plant protein production systems- modification of pea protein composition by genetic modification
4. Environment	<ul style="list-style-type: none">- development of a methodology to assess the full cycle of environmental effects of present and future food production and consumption systems- development of ecological indicators for sustainable food production- environmental economic assessment of the animal protein production and consumption chain and alternative options.
5. Chain design	<ul style="list-style-type: none">- protein foods, environment, technology and society: development of viable options for food policies- quantitative methodology for efficient chain design

In the programme peas are studied as a main raw material source for proteins. The DTO-NPF study concluded that at present in particular peas, lucerne and lupine are potential interesting sources of raw materials. Peas, lucerne and lupine can be grown locally and consequently successful application of these crops in the production of NPFs offers opportunities for the Dutch agriculture. For practical reasons a choice has been made for pea proteins, as the protein is (commercially) available as pea flour, pea concentrate and pea isolate. The additional advantage is that pea proteins have a large resemblance to soy proteins and it will thus be possible to generalise the results at least to some extent. Soy proteins are much used in the food industry, but cannot be grown in the Netherlands.

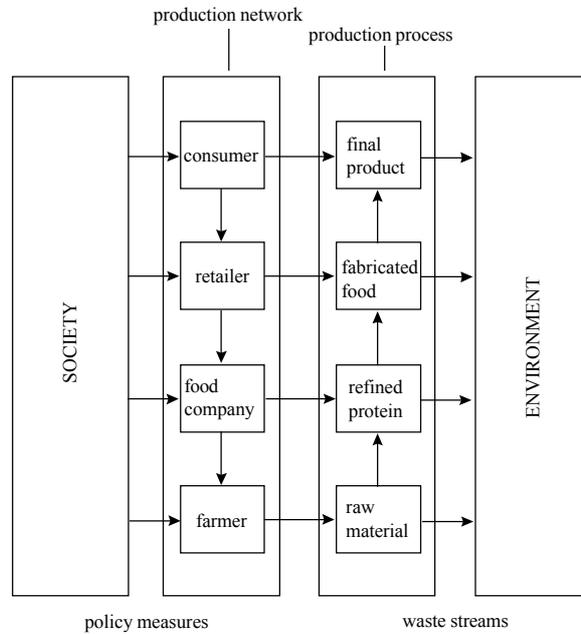


Figure V Programme outline

Production process: the technical and consumer sciences research projects

In this part of the programme 7 research projects are defined which cover the whole production chain, an overview is given in figure VI.

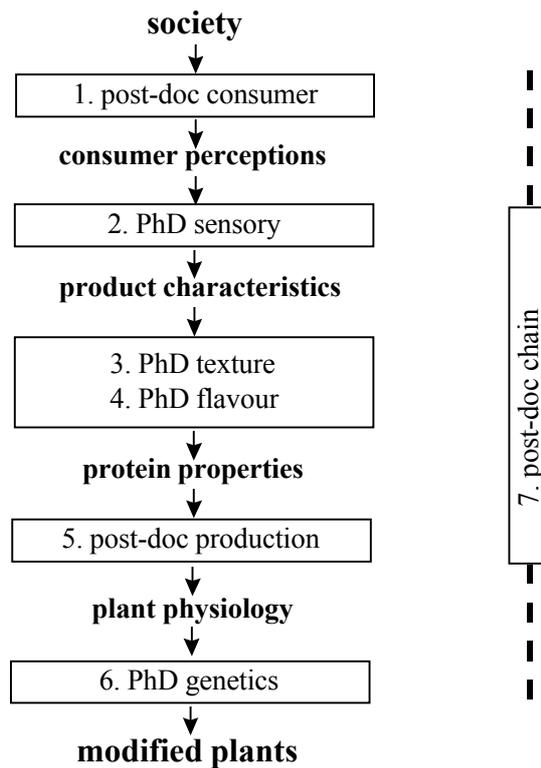


Figure VI. The chain oriented approach.

The main research issues are:

1. **Consumer (sensory) perceptions and preferences.** The success of NPFs in the market depends on how they fit with the preferences and life style of consumers. The post-doctoral project 'consumer' will provide incentives for potential successful NPF product concepts. To be able to make a translation of consumer wants into technological demands it is important to have a basic understanding of the relationship between physical and chemical product characteristics and sensory perceptions. In the PhD project 'sensory' sensory evaluations will be executed using descriptive and consumer panels and instrumental measurements will be carried out to determine the corresponding product characteristics. Finally predictive models will be developed.
2. **Processing of protein-rich raw materials.** Consumer surveys show that the taste and flavour of existing NPFs is unsatisfactory. For consumer acceptance, taste and flavour is the first quality criterion by which products are judged. In particular texture and flavour of present NPFs are inadequate. This inadequacy is caused by the fact that fundamental knowledge on the underlying processes is lacking. Texture formation and the interaction between the protein matrix and flavour components are covered by two PhD-projects 'texture' and 'flavour'.
3. **Plant breeding and dedicated protein production.** Breeding for increased protein content and improved protein properties with the intent to use these proteins to produce meat alternatives was so far not done. In the PhD-project 'genetics' the possibilities to modify protein properties are examined experimentally using genetic engineering. The post-doctoral project 'production' identifies the opportunities for large-scale production of protein-rich crops, using mathematical models which describe the growth of these crops. The opportunities of genetic engineering for large-scale production will be assessed.
4. **Optimal chain design.** In the design of a production chain for a specific protein ingredient, choices have to be made with respect to the selection of raw materials, process technologies to be used and treatment of side and waste streams. Moreover, assessment of costs and environmental effects have to take place. For an efficient generation and selection of alternatives it is necessary to incorporate the views of the stake-holders. In the post-doctoral project 'chain' an optimising methodology will be developed which can be used in the design of viable production chains. This project is one of the 2 integrative projects.

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