The Chain Information Model:

A Systematic Approach for Food Product Development

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Dit onderzoek is uitgevoerd binnen de onderzoeksschool VLAG (Voeding, Levensmiddelentechnologie, Agrobiotechnologie en Gezondheid)

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Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof.dr. M.J. Kropff,
in het openbaar te verdedigen
op woensdag 14 september 2005
des namiddags te half twee in de Aula

Benner, M.

The Chain Information Model: A Systematic Approach for Food Product Development

Ph.D. Thesis, Wageningen University, the Netherlands, 2005 – with summary in Dutch

ISBN: 90-8504-223-2

Abstract

New product development (NPD) is a necessary activity for food companies to survive in today's turbulent markets. However, the failure rate of new products is high in spite of the numerous possibilities. Therefore, a tool for structured NPD has been developed to increase the success rate of the NPD process. The tool has been based on two key elements: a chain approach and information management throughout the complete production chain. The tool, called the Chain Information Model (CIM), is based on the Quality Function Deployment method It was constructed using a hypothetical example on the development of a ready-to-eat meal with a health benefit.

The CIM consists of three phases: (1) the information gathering phase, in which all the information needed regarding the product and production process is identified and collected; (2) the information processing phase, in which all information is linked together to get insight into the effects of processing on the product, resulting in several scenarios; and (3) the information dissemination phase, in which the best scenario is selected and the required information is spread along the actors.

The use of the CIM is tested in an exploratory study in an actual production chain. This study dealt with the development of tomato ketchup with an increased amount of bioavailability of the anti-oxidant lycopene. The suitability and results were subsequently discussed with a panel of experts. This discussion showed that CIM was useful in identifying information gaps and can be used to draw a research agenda for the complete production chain.

The CIM has also been evaluated as a tool for knowledge management. By using an example on the development of apple juice with a health benefit it was demonstrated that the CIM is a suitable tool to make knowledge management operational. The CIM also provides the food industry with a tool to make implicit knowledge explicit, store the information and make it more easily available for future development projects.

In conclusion, the CIM provides the food industry with an effective tool to: (1) exploit the full potential of the production chain; (2) make NPD processes more efficient; (3) assure adherence to specifications; (4) make knowledge management operational in food production chains; (5) aid product developers in their communication processes.

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General introduction

Benner, M., A.R. Linnemann, W.M.F. Jongen and P. Folstar. *Submitted for publication.*

1.1 New product development (NPD) in the food industry

New product development (NPD) is necessary for companies to survive in the food market (Stewart-Knox and Mitchell, 2003). According to Hultink (1998), Dutch, English and American companies obtain between 28 and 46 % of their turnover and profit from new products. In common parlance and in literature, the terms new product and innovation are often used intermingled. Innovation is a frequently used concept, of which the meaning is not univocal. The dictionary defines innovation as '*the introduction of something new*' (Webster's Third New International Dictionary). According to Earle (1997a), innovation has three important principles: (1) an innovation is new in the eye of the beholder, (2) an innovation is a technological change and a social change, and (3) an innovation involves a wide range of people from designers to society. What one producer perceives as a new product may well be an imitation for another producer. This is because innovation is multi-dimensional – it can have an impact on a range of product attributes. Which attributes make a product innovative, depends on one's position in the production chain. From a manufacturers' point-of-view, innovation might be: new features, changed features and new technology, new target users, a complete new concept, marketing mix or cost efficiency and new organisation and management. For a retailer, innovations mostly are related to formats, loyalty cards, electronic commerce and category growth. A consumer would yet come up with another list (Anon., 1999).

If we approach innovation from the food manufacturer's point of view, new products can be classified into several categories (Fuller, 1994; Anon., 1999; Luning *et al.*, 2002):

- '*Me-too products*'. A 'me-too product' is a product that is basically the same as an existing one, but produced by another company. This category of new products represents the largest group of new food products.
- *Line extensions*. These are new variants of an established product. Typical examples are new flavours for existing products or new tastes in a family of products. The design process of these products can be characterised by relatively little effort and development time, small changes in the manufacturing process, little change in marketing strategy and a minor impact on storage and/or handling techniques.
- *Repositioned existing products*. These are current products that are again promoted in order to reposition the product. For example, by the increased attention for health products, a margarine brand was repositioned because of its natural high content of tocopherol. The development time for repositioned products can be minimal and only the marketing department should put efforts in capitalising the niche market.
- *New form of existing products*. These are existing products that have altered to another form (e.g. solved, granulated, concentrated, spreadable, dried or frozen). For instance, dried soups. These products may require an extensive development time because the physical properties of the product change drastically.
- *Reformulation of existing products*. This group concerns current products with a new formula. Reasons for reformulation can be reducing costs of ingredients, irregular supply of certain raw materials, or the availability of new ingredients with improved characteristics. Examples are products with better colour, improved flavour, more fibres,

less fat etc. The design process for these products is usually inexpensive and needs a relatively short development time. However, for food products minor changes in composition might have great consequences, for e.g. the chemical or microbial shelf life.

- *New packaging of existing products*. This involves accepted products with new packaging concepts. For example, the technique of modified atmosphere packaging created opportunities to extend the shelf life of many food products. With respect to the design process, products may have to be reformulated for the new application (e.g. microwave packaging). Moreover, new packaging concepts may require expensive packaging equipment.
- *Innovative products*. These are defined as products resulting from changes in an existing product otherwise than described above. The changes must have an added value. The design process is generally longer and more expensive when more product changes are required. Marketing can also be costly because consumers may have to be educated to the novelty. However, in some cases time and costs of innovation are relatively little, e.g. in the case of a successful innovative ready-to-cook product which was made by assembling frozen vegetables and a frozen pastry on a tray.
- *Creative products*; also called true new products. This type of products is described as one newly brought into existence, i.e. a never-before seen product. Typical examples are novel protein foods (or meat replacers) that are produced from vegetable proteins. Creative products commonly require extensive NPD, tend to be costly (much marketing effort, new equipment) and have a high failure chance.

Another way to distinguish new products is from a technical point of view. The research and development (R&D) department of a company is responsible for the technological skills and the technical innovations with respect to new products and processes. Three types of R&D are discerned (Table 1.1): (1) incremental, (2) radical, and (3) fundamental, each having its own characteristics and business purposes (Roussel *et al.*, 1991; Buisson, 1995).

The goal of incremental R&D is small advances in technology, typically based on an established foundation of scientific and engineering knowledge. The task is not uncovering and applying new knowledge but the application of existing knowledge. Incremental R&D is characterised by low risk and modest reward. This kind of innovation is often used to retain or improve the quality of a product through process innovation, use of new ingredients or packaging innovation. Incremental innovations allow the introduction of a greater variety of new products (Galizzi and Venturini, 1996a).

Radical R&D draws on a foundation of existing scientific and engineering knowledge that is insufficient by itself to arrive at the desired practical result. Radical R&D involves the development of new knowledge with the explicit goal of applying that knowledge to a useful purpose. Most radical R&D projects fail, but the few that are a success, are the projects that will provide the high-margin products or processes. Radical innovation results in new products for the consumer, an example are the Benecol[1] and Becel Pro-activ products.

[1] A range of food products containing the ingredient plant stanol ester. Which works with the body to lower cholesterol (www.benecol.co.uk)

Fundamental R&D is a scientific/technological reach into the unknown. It has two principal goals: (1) to develop in-depth research competence in fields of potential future technology that the company is convinced will have great strategic impact in the long term, and (2) to prepare for future commercial exploitation of these fields. Fundamental R&D is characterised by high risk and uncertain applicability to business needs (Roussel *et al.*, 1991; Buisson, 1995).

Table 1.1 Types of R&D (Roussel *et al.,* 1991)

Type of R&D	Percentage change of success	Period till commercial Success	Competitive advantage	Durability of competitive advantage
Incremental Line extensions and new applications	40 - 80 %	6 - 24 months	Medium	Short, typically imitable by competitors
Radical New ideas on basis of existing science and new technology	20 - 40 %	2 - 7 years	Strong	Long, often protectable by patents
Fundamental New science as a basis for unknown commercial successes	Difficult to measure	4 - 10 years	Very strong	Long, often protectable by patents

Innovation processes in the food industry are in general characterised by low levels of expenditure on R&D (Galizzi and Venturini, 1996b; Earle and Earle, 1997; Mark-Herbert, 2003). For instance, according to Mark-Herbert (2003), the Swedish food industry spends less than 2 % of the annual turnover on R&D activities. In spite of the low R&D expenditures, food innovations show a relatively high productivity growth. This is explained by the fact that most inventions and innovations in food manufacturing originate from outside the food industry (Galizzi and Venturini, 1996b). According to Earle and Earle (1997), the low spending on R&D in the food industry can also be explained by takeovers, leading to combinations of R&D departments and a reduction in R&D funding. Other reasons are its only recent emergence as a science-based industry, the marketing domination in many food companies, the difficulty of establishing intellectual property rights in the food industry, and the small margins on which the food industry has to operate (Earle and Earle, 1997).

The food NPD process is characterised by a high failure rate. Two out of three new products never live to see their second year on the shelves (Anon., 1999). The number of products that never make it through the first stages of the NPD process is even higher. According to Lord (2000), 72 % of true new products and 55 % of line extensions fail. From the 1935 new products introduced by the biggest 20 US food companies with the most new product introductions in 1995, 174 were truly new and 1761 were line extensions. The new items experienced a success rate of 52 % while line extensions had a 78 % success rate, combining

for an overall success rate of 76 %. Non-leading, smaller companies introduced 14 298 products and achieved a success rate of only 12 %, leading to the conclusion that bigger companies have a higher success rate with new products than smaller companies (Lord, 2000).
If the failure rate of the NPD process is so high, why would companies continue to spend money on it? One reason is that NPD is essential for food companies to stay in business. All products have life cycles, made up of five phases, namely (1) introduction: characterised by low sales and high marketing spending; (2) increasing growth: new consumers and repeat-buyers, promotional costs are still high; (3) declining growth: market for products begins to saturate; (4) maturity: stable period in sales, stagnating market; (5) decline: competing products adversely affect sales (Figure 1.1). Each product will go through these phases and eventually sales, and hence profit, will diminish. Therefore, companies should always have products in the early phases of their life cycles. It is essential for companies to initiate new life cycles regularly by introducing new products to maintain the overall profitability (Fuller, 1994; Dekker and Linnemann, 1998). Certain companies have made a strategic commitment to develop new products on a regular basis in order to remain the best in the market. Other reasons for companies to develop new products are changes in national or international legislation, health programs, agricultural policy, globalisation, or material cost and availability (Urban and Hauser, 1993; Fuller, 1994).

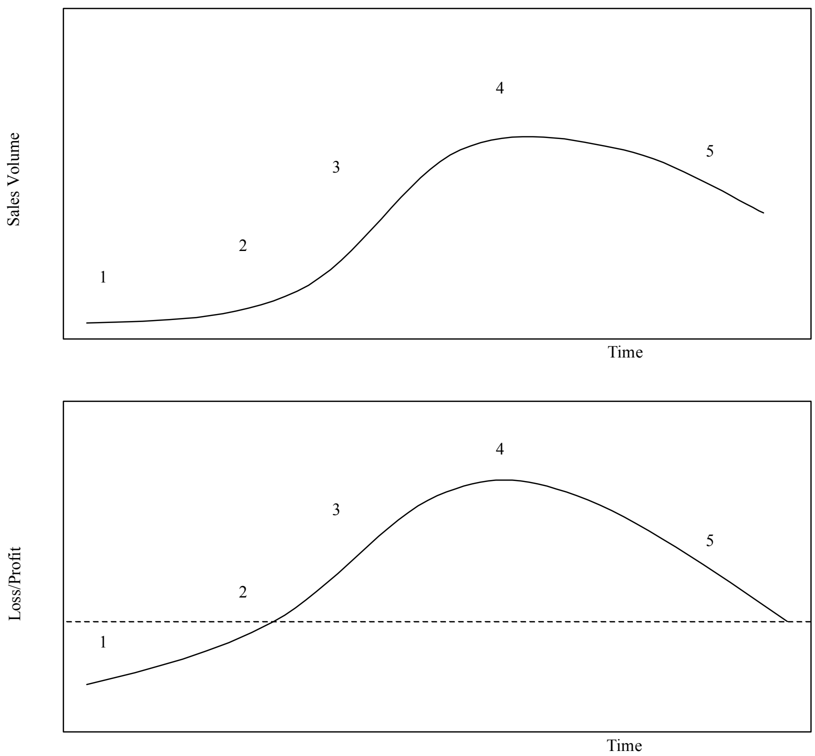

Figure 1.1 Product life cycle in terms of sales volume and profit (1) Introduction, (2) Increasing growth, (3) Declining growth, (4) Maturity, (5) Decline (Fuller, 1994)

1.2 The process of new product development (NPD)

According to Earle (1997b), the NPD process was first outlined in the 1960s. Buzzell and Nourse (1967) researched the NPD process between 1954 and 1964. At that time they only identified (sequential) technical stages in the NPD process (i.e. product & process development, product testing, market testing and product launch). In 1968, Earle *et al.* (1968) introduced the consumer into the process, and they also added go-no-go decisions and management involvement. NPD used to be done by the so-called over-the-wall approach in which the product was developed by the functional disciplines of the company successively. If a discipline had finished its part, the product was passed on to the next. Such an approach proved highly inefficient and time-consuming.

The NPD process consists of a series of activities that all have to be completed (Table 1.2). The point at which a NPD project starts is arbitrary; some say it starts with defining the company strategy, while others say the process starts with the generation of ideas, and defining market opportunities. The process ends with the launch of the product on the market and the evaluation of the product. According to Fuller (1994), the numbers, the order, or the names of the activities do not matter as long as one understands that they are not necessarily sequential; the activities overlap and are concurrent.

A possible approach for NPD is concurrent or simultaneous engineering (Figure 1.2). Concurrent Engineering is defined as follows: *'A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements'* (Institute of Defense Analysis in the USA, according to Jónsdóttir *et al.*, 1998). This is an organisational tool that can facilitate integration by creating cross-functional teams. According to Noori and Radford (1995), it is necessary to change the manner of operating and communicating in the functional areas in order to make concurrent engineering successful. Functional managers must delegate decision-making authority to their representative in the team so that the team is able to review, modify and approve new products rapidly.

Screening should be used after each stage in the NPD process to prevent NPD spending on a product that will eventually not make it, becomes too high. According to Rudder *et al.* (2001), it is crucial that after the identification of potential new products and their initial development an assessment is made of their feasibility before the financial costs become unacceptable. After idea generation, the number of ideas should be reduced by a screening phase. Fuller (1994) mentions three parallel screening criteria that are used: (1) *feasibility*: is the idea feasible within the time frame required? The manufacturing, engineering, and R&D departments should check the feasibility; (2) *desirability*: does the idea fulfil perceived consumer needs? This question should be answered by marketing and consumer research; (3) *profitability*: will a financial sound business plan based on these new products stand up to critical analysis?

Table 1.2 Stages in the NPD process

Booz, Allen & Hamilton (1982)	**Kotler and Armstrong (1991)**	**Graf and Saguy (1991)**	**Urban and Hauser (1993)**	**Fuller (1994)**	**MacFie (1994)**	**Rudolph (1995)**	**Earle (1997a)**
Exploration	Idea generation	Screening	Opportunity identification	Idea screening	Concept generation	Strategic plan	Product strategy and planning
Screening	Idea screening	Feasibility	Design	Screening of ideas	Concept screening	Market opportunity assessment	Creation, design and development of the product
Business analysis	Concept development & testing	Development	Testing	Development	Product development	Product business plan	Production process, marketing strategy, quality assurance, commercial product
Development	Marketing strategy development	Commer-cialisation	Introduction	Production	Product testing	Product definition	Launch and post-launch
Testing	Business analysis	Maintenance	Life-cycle management	Consumer trials	Packaging development	Prototype development	
Commer-cialisation	Product development			Test market	First production run	Market strategy and testing	
	Test marketing				Launch	Scale-up and trial production	
	Commer-cialisation					Production introduction	
						Product support	

Rudolph (1995) states that a good NPD process is flexible and continuously evolving. The author describes a milestone-driven NPD process as developed by Arthur D. Little. This model is based on establishing clear, consistent milestones for the entire development process and identifying the required deliverables by each of the elements contributing to NPD within the firm. Milestones are viewed as an opportunity to monitor progress against a planned set of goals, to review the next tasks and anticipate problems, and to initiate program changes.
Cooper (2001) has developed a Stage-Gate process as a tool for moving a new product project from idea to launch. This Stage-Gate process is a blueprint for managing the NPD process to improve effectiveness and efficiency. The Stage-Gate model breaks the development process into a predetermined set of stages, each stage consisting of a set of prescribed, cross-functional, and parallel activities. The entrance to each stage is a gate. These gates control the process and serve as the quality control and go/kill checkpoints. The key stages are: *discovery* (pre-work to discover and uncover opportunities and generate ideas), *scoping* (a quick, preliminary investigation of the project), *building the business case* (a much more detailed investigation involving primary research, including product and project definition, project justification, and a project plan), *development* (the actual detailed design and development of the new product, and the design of the operations or production process), *testing and validation* (tests or trials in the market place, lab, and plant), and *launch* (commercialisation – beginning of full operations or production, marketing, and selling). Each stage is designed to gather information needed to progress the project to the next stage or decision point. Each stage is cross-functional. Preceding each stage is a gate or a go/kill decision point. Gates consist of the following: a set of required deliverables, criteria against which the project is judged, defined outputs.
Although there is not one unambiguous outline for the NPD process it is clear that all activities (Table 1.2) have to be completed. From literature it is clear that NPD cannot be treated as a simple sequential process.

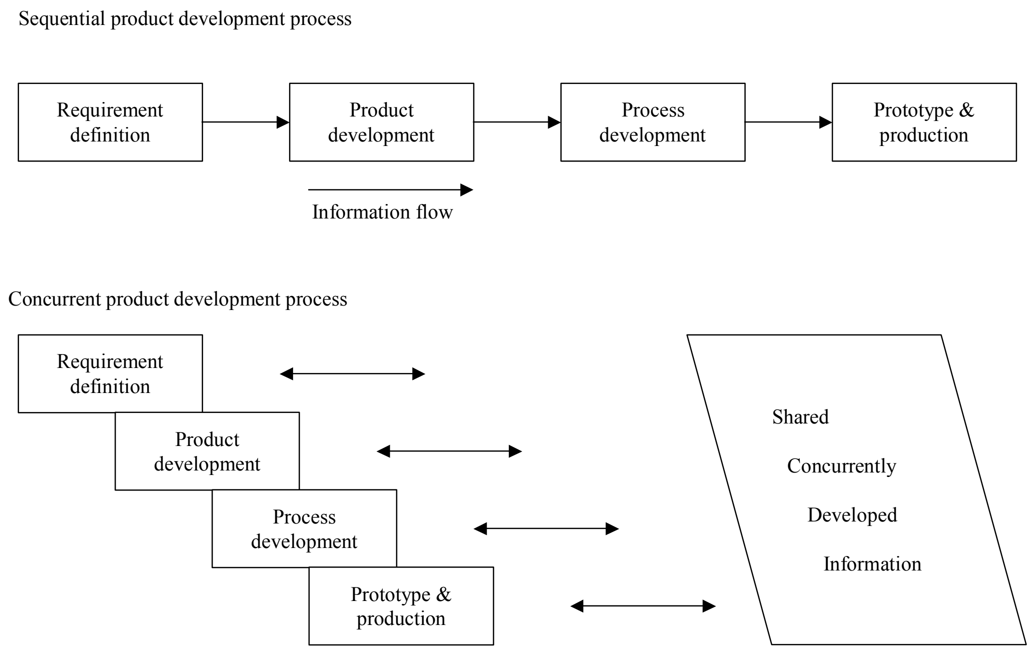

Figure 1.2 Concurrent Engineering versus sequential NPD (Jónsdóttir *et al.*, 1998)

1.3 Societal and technological changes affecting NPD

Demographic changes, like migration, ageing populations and a changing household composition, have a large influence on the demand for food products and should therefore be taken into consideration in the NPD process. Eating habits altered, for example, in households in which both partners have full-time jobs and also in the growing number of one-person households. Eating together at a fixed time of the day is gradually being replaced by more individual meals at less specific times. In addition, many consumers tend to spend less time on preparing their meals because of a higher work pressure, and more time allocated to sports and recreation (Tabaksblat, 1995; De Rooij, 2000). These developments have created opportunities for healthy, tasteful foods with a minimal preparation time: the so-called convenience foods. The food industry has reacted to this change with the production of a variety of home meal replacements (HMR) varying from ready-to-cook to read-to-eat (Costa *et al.*, 2001b). The number of ready-to-eat meals and take away meals consumed in the Netherlands increased from 10 % in 1984 to 33 % in 2000 (Anon., 2000). In addition, people consume more meals outdoors, resulting in a higher demand for semi-finished products and processed ingredients (Folstar, 2001).

An equally significant and important trend is the shift in age profile of the consumer in both the US and Europe. The age group over 45 years will become the largest group by 2010 (Tabaksblat, 1995). This group can afford (and is willing) to spend more money on food products and has a growing interest in quality, service, security and safety. The younger generation has a different lifestyle with eating habits like grazing, snacking and on-the-run consumption. Youngsters are critical buyers, looking for value for money, but above all they expect service and the opportunity to buy things anytime, anywhere. This group is very individualistic and can therefore be considered as a fragmented market (Tabaksblat, 1995). These shifts in age profiles and changing eating habits have large implications for the food industry. The main result is that the demand for food products nowadays is diverse and constantly varying. The reaction of the industry to this kind of behaviour is mass-individualisation; the production of mass goods for niche markets. In practice this means that the consumer demand initiates the production of goods (Wijers, 1995).

Another development that is important for an effective NPD process is that the awareness of consumers has changed. According to Jongen (1995), consumers are better educated and better informed than before, resulting in higher requirements towards product assortment and product quality. The way consumers perceive quality has also changed. Acceptation of a product no longer only depends on the quality of a product itself but also on the way a product is produced (Jongen, 1995). In this respect environmental care and sustainable production are becoming important factors. The change in consumer awareness led, amongst others, to a growing demand for functional foods, lower meat consumption and the growing market for organic foods (De Rooij, 2000). Functional foods are foods that are demonstrated by scientific research to affect beneficially one or more target functions in the body (Plaami *et al.*, 2001). Examples of functional foods are foods that contain higher amounts of certain functional ingredients, like micro-nutrients and anti-oxidants, or contain reduced levels of certain undesirable components. Functional foods can be natural foods to which certain components have been added, or removed from. It can also be a food where the nature of the components has been modified, or where the bio-availability has been modified.

The conscious consumers of today also expect purchased foods to be safe. The food safety issue of greatest concern is still that of reducing the risk of pathogenic food-borne illness. In the USA, each year 9 000 deaths and up to 33 million or more cases of illness are attributed to food poisoning (Brody *et al.*, 2000). The trend towards fresher produce and minimally processed foods, and the growth in markets for minimally processed and no- or less-preservative foods increases the risk of food poisoning, if the products are not carefully handled. All these developments call for a coordinated approach to food safety and quality systems in the whole production chain. Besides, consumers want to buy their food products at the time and place they choose at a reasonable price. This puts pressure on the logistic capacities of retail outlets and producers (Brody and Lord, 2000).

In addition to the above-mentioned changes on the demand side, there are technological developments that influence the NPD process. Though still at an early stage of development, the following, new (mild) processing techniques like Electric Field Pulsing (EFP) and High Pressure (HP) technology or new packaging concepts offer possibilities for new and improved products, and demand different handling techniques from producers, distributors, retailers, and consumers. They also call for quality control in the production chain. Other new techniques, like biotechnology and genetic modification offer possibilities both in new products and in new production processes, but they are not widely accepted by the consumer at present (Frewer, 1998). Senorans *et al.* (2003) mention several new trends in food manufacturing: functional foods, food enriched with natural ingredients, and probiotics and prebiotics.

Through advances in logistics innovation in the food service area has become of great significance. The consumer's need for convenience not only calls for different processing techniques, but also calls for a secure chilling segment through the whole production and distribution chain. The food industry has responded to this with new logistic concepts. The increased demand for minimally processed foods also calls for a secure quality control system in the whole chain because of the increased risk of food-borne illnesses. For convenience products, availability plays a major role; this has resulted in a change in opening hours and floor layout of supermarkets (Kinsey and Senauer, 1996).

Retail outlets, supermarkets are experimenting with shops at petrol stations and with ordering via the Internet. The main reason is to relieve the consumer from spending much time shopping (Kinsey and Senauer, 1996). In addition, supermarkets have created shops within the shop to respond to the consumer demand for the convenience of one-shop shopping and to the need for quality and variety. Retail companies benefit from new opportunities by introducing innovative retail formulas. Recent developments include home-delivery, ordering via the Internet, drive-ins, automatic food dispensers, and the already mentioned food shops in petrol and railway stations. These new distribution formulas offer a wide variety of choice and respond to the demand for availability of food wherever and whenever the consumer wishes (Meulenberg and Viaene, 1998).

Manufacturers of packaging materials can also be a driving force in the NPD process. New techniques, like modified atmosphere packaging and controlled atmosphere packaging have triggered the development of new products with improved quality and improved shelf life. Several packaging innovations have been quickly accepted by food manufacturers, because of reductions in production costs, and the attractiveness on the supermarket shelves (Earle, 1997a).

In most Western countries, markets for foods have become saturated, because of high production levels in combination with reaching the saturation point of human caloric intake (Jongen *et al.*, 1996). Consequently, the competition among food companies became stronger and forces the time-to-market to be short without consolidating to product quality. Consolidation in the food industry is an international trend, and more producers enter the market with competitive products. Globalisation makes it easier for foreign companies to enter domestic markets. Expectations are that it will become difficult for some domestic producers to keep or even enlarge their market share due to globalisation. On the other hand, globalisation also offers new opportunities for producers: new export markets can be explored and entered.

In conclusion, the demand for food products is more variable and diverse than ever before, while in the meantime the competition has become stronger, thus challenging the food industry to design and produce an array of food products that are perfectly tuned to the constantly altering wishes of individual consumers. Moreover, the technological possibilities with respect to food production have increased tremendously over the past decades and, as a consequence, it is more difficult for companies than ever before to select and apply the most efficient and effective procedures to add value to their products. However, the current NPD process is not capable of utilising the many possibilities offered for new products and too much time and money is spent on the production and introduction of new products and new technologies that do not comply with the market demands and hence do not raise the needed return on investment. Alignment of markets and technologies and the capability to translate this into profitable products is the greatest challenge. This requires a more systematic approach in food NPD. Such a systematic NPD process should be able to effectively translate (changing) consumer demands into new products and product properties and apply technological and scientific knowledge into new products to provide the company with a continuous flow of new products. In addition, the NPD process should be able to develop and produce new products in an efficient way, meaning with short time-to-market and with minimal loss of resources. Therefore, current NPD procedures need to be improved to increase the success rate.

1.4 NPD to meet tomorrow's demand

1.4.1 Consumer orientation

An effective NPD process results in a successful product. In the course of time, several attempts have been made to improve the success rate of the NPD process. In the 1950s, two approaches existed in food NPD: one dominated by marketing and one dominated by R&D, in which the latter developed the products as directed by marketing. Product failure at that time was high due to the neglect of the consumer in both systems. This eventually led to the concept of consumer-orientated NPD, in which the consumer is the starting point of the development process (Earle, 1997b). Buisson (1995) observed a similar change in thinking and approach of the NPD process over the past three decades. In the 1960s, companies that believed they had the resources within the company for successful NPD, created products internally. In the 1970s, some companies started to conduct market research to identify consumers' needs in search for high growth markets and niches. In the 1980s and 1990s these two approaches were combined, allowing companies to produce products that meet consumer needs and at the same time meet strategic objectives. An important consequence of consumer orientation in NPD is the reversal of production chains. Where food production (and development) chains used to be characterised by one-way communication from producers of raw materials to consumers, nowadays the starting point is the consumer (Dekker and Linnemann, 1998).

On a practical level the necessity for consumer orientation in NPD was made explicit when Juran in 1988 advocated that the design process should start with customer needs. In his 'Quality Planning Roadmap' the first step includes identifying customers and discovering customer needs. According to Grunert *et al.* (1997), the key determinant of NPD success is the degree of fit between a product and consumer needs. Consumer-orientated NPD takes consumer needs as the starting point for the NPD process and the product and production process as a derivative thereof. The new product and its production technology are not seen as a goal in themselves, but as a means to realise consumer demands (Van Trijp and Steenkamp, 1998). According to Costa (2003), the main principles of consumer-orientated NPD are that: (1) consumers' needs should be the starting point of the NPD process; (2) the goals of NPD should be the fulfilment of consumers' needs and the realisation of consumer value; rather than the development of products or enabling technologies per se; (3) sales and satisfactory returns on investments can only be achieved by anticipating, identifying and satisfying consumer needs; thus the NPD process's measure of success should be the degree of fit between the new or improved product and the consumer needs (Urban and Hauser, 1993; Grunert *et al.*, 1997; Van Trijp and Steenkamp, 1998; Lord, 2000).

In assessing the wishes of the consumer, food choice behaviour and food perception are important. Sijtsema (2003) reviewed variables influencing food perception and developed a food perception model for use in food NPD. The model uses four determinants to describe food perception: (1) individual, like demographic variables, physiological factors, psychological factors, and attitudes; (2) food, like food characteristics, and the production system; (3) context, like consumption moment, time and place; (4) environment, like family characteristics, and society characteristics. This model is intended for the first NPD stage, i.e. translation of consumer wishes into tangible product characteristics. This translation is not easy (Costa, 2003; Sijtsema, 2003) and is accompanied by another 'translation' problem, namely the communication between the marketing department and the R&D department within a company. According to Souder (1987), many factors contribute to the problematic communication and cooperation between marketing and R&D, for instance different time horizons, mutual negative stereotyping, and differences in terminology (Kotler, 1994; Griffin and Hauser, 1996; Van Trijp and Steenkamp, 1998).

Costa (2003) has tested several tools and methods for use in the early stages of consumer-orientated food NPD. The main obstacles noted by the author are: (1) the lack of sufficient evidence demonstrating that consumer-orientation leads to more successful NPD; (2) a prevailing clan mentality, preventing the existence of empathy and cooperation necessary to the successful implementation of cross-functional approaches; (3) few concrete implementation guidelines and methodologies.

According to De Rooij (2000), the key to innovation in the food industry will be the integration of knowledge of consumer behaviour, perception, neurosciences, biochemistry, physiology and genetics and the link to NPD. A thorough understanding of consumer preferences and the principles behind them will be an important prerequisite for future product success. The food NPD organisation has to move from isolated disciplines and sequential processes to interdisciplinary and concurrent ways of working to realise this. A systems approach based on knowledge management will be necessary to deal with the complexity of such a challenge.

Van Kleef *et al.* (2002), stress that successful NPD depends on the quality and quantity of new product ideas. The authors have developed a framework, which allows the use of relevant consumer and expert input in the early stages of functional food development, to realise a continuous flow of new ideas. Its purpose is to have a structural screening method for functional food concepts to prevent that high potential opportunities are overlooked. The results indicated a disagreement between experts and consumers in their evaluation of concepts. Possible reasons for these disagreements are that experts are too distant from the market place and therefore do not have the right idea of what the consumer wants. Another reason can be that consumers lag behind in terms of what can be delivered. This uncertainty of realisation of new concepts can result in early rejection, also because consumers lack a useful frame of reference for evaluating really new concepts (Van Kleef *et al.*, 2002).

Table 1.3 Future consumer prototypes (Linnemann *et al.*, 1999; Meulenberg, 1996)

The environment-conscious consumer	Prefers unprocessed foods (fresh) or foods from short production chains, foods from organic farming, focuses on technological efficiency.
The nature and animal-loving consumer	Interested in methods of primary production, concerned about genetic modification, animal welfare an important issue, focuses on ethical efficiency of production systems.
The health-conscious consumer	Prefers fresh products that support health trends, e.g. low-calorie, low-fat, rich in vitamins and minerals, and all other sorts of foods with alleged health-protecting or health-promoting properties.
The convenience consumer	Goes for snacks, fast food, take-out meals, ready-to-eat meals, foods that are easy to prepare, restaurant food.
The hedonic consumer	Prefers (exotic) specialties, delicacies, foods with added value, food as entertainment and pleasant pastime, restaurant food, foods of high sensory quality.
The price-conscious consumer	Prefers homemade meals, with ingredients of a favourable price/quality ratio (e.g. products from large-scale production, or alternative, cheaper raw materials).
The variety-seeking consumer	Seeks diversity in raw materials, ingredients and fabricated foods for homemade meals, as well as diversity in the type of meal (from elaborate homemade meals to convenient dining out).

In an attempt to structure the preferences of Dutch consumers Meulenberg (1996) analysed the Western consumers and their buying behaviour in relation to social-cultural, technological, economical, political and ecological developments. He proposed seven prototypes of future consumers (Table 1.3). The applicability of these prototypes in consumer-orientated NPD is restricted by the fact that most consumers do not follow one single trend but look for a combination (Meulenberg, 1996).

We can conclude that the importance of consumer-orientation in food NPD has become widely accepted as the way to successful products. However, putting this concept into practice is not yet fully established.

1.4.2 Chain approach

An efficient NPD process is able to deliver a new product with short time-to-market and with little waste of raw materials. Therefore, a production chain approach is necessary.

Beers *et al.* (1998) define a production chain as a network of connected organisations aimed at the fulfilment of specific customer needs in the first place, in conjunction with the fulfilment of the needs of other stakeholders of such an entity. Zuurbier *et al.* (1996) define a chain as collaboration between two or more companies or actors that take positions in successive stages of production.

Food production (or supply) chains comprise actors that are responsible for the production and distribution of vegetable or animal-based products (Zuurbier *et al.*, 1996 according to Van der Vorst, 2000). In general, two main types of food supply chains can be distinguished: (1) s*upply chains for fresh agricultural products* (e.g. fresh vegetables, fruit). In general, the actors in these kinds of supply chains are growers, auctions, wholesalers, importers and exporters, retailers and specialty shops. Basically, the quality characteristics of the product are not altered by the actors. The main processes are handling, storing, packing, transportation, and trading of the product; and (2) s*upply chains for processed food products* (e.g. snacks, desserts, canned products). In this type of supply chains, agricultural products are used as raw materials for the production of products with high added value.

Den Ouden *et al.* (1996) discusses three types of vertical coordination in production-marketing chains: (1) in market exchange, control is fully located at the separate stages and coordinated solely by market prices; (2) with full vertical integration, control is completely shared or transferred to central management leaving the different actors without separate control; (3) vertical cooperation which is a mix of the first two extremes.

Chains can be approached from three perspectives (Beers *et al.*, 1998; Trienekens, 1999): (1) the *institutional perspective*, which focuses on the possible ways of linking partners together. This can vary from very rigid to very loose; (2) the *process perspective* focuses on chain processes. A process is a set of related activities performed to achieve a certain goal. In a chain a distinction can be made between physical processes (production and distribution processes), administrative processes (supporting physical processes) and management processes (planning and control of physical and administrative processes); (3) the *performance perspective*. Performance of the chain refers to the relation between a chain and its environment. As such the performance of a chain can be described as the chain output as it is perceived by its stakeholders (e.g. customers, governmental organisations, financial organisations, social/political organisations, etc.).

Chain cooperation in the food production chain has proven its benefits in many ways. For instance, supply chain management has proven its use for many years in terms of money, time and labour (Van der Vorst, 2000). Also, for food quality management a chain-orientated approach has been advocated (Luning *et al.*, 2002). For tracing and tracking of food products the chain approach is evident (Van Dorp, 2004). However, for the NPD process there are very few examples of chain cooperation. Although some authors have recommended it, it never seems to grow further than close cooperation between two parties in the production chain. Examples are co-innovation between food producers and packaging producers as well as between food producers and ingredient suppliers. Often, ingredient suppliers develop new ingredients accompanied by product applications and recipes. Also, strategic partnerships between food producers and retailers are mentioned (Hood *et al.*, 1995; Hughes, 1996; Suwannaporn and Speece, 1998).

In food production chains, several types of cooperation can be distinguished, each influencing the success of the cooperation. Zuurbier *et al.* (1996) distinguish the following types of cooperation: (1) joint improvement of secondary processes (information, planning and control) aimed at improved attunement between output of one company and input of another company; (2) joint research projects with a pre-competitive character by shielding the tasks organisationally; (3) joint sales with a pre-competitive or complementary character; (4) joint acquiring of knowledge, people, means; (5) premature involvement of suppliers and buyers in the primary production process; (6) co-makership, supplier and buyer are involved in the R&D-phase and the primary production process.

The importance of chain cooperation for the food and agribusiness is due to the specific characteristics of this business sector, like (1) the limited shelf life of some products, (2) the natural variation in quality and quantity, (3) the variation in speed of the production process of the actors in the chain, (4) the scale differences between the actors, (5) the complementary character of agricultural raw materials, (6) the intrinsic quality of fresh products, (7) the improved awareness of consumers towards food production systems, and (8) the need for and availability of capital (Zuurbier *et al.*, 1996; Den Ouden, 1996). Vertical integration provides advantages for the actors in the production chain. These include lower transaction costs, a reduction of risk with respect to the constant supply of (raw) materials, more possibilities for innovation, more continuity, more added value products, a bigger market share and more efficient production processes (Ziggers and Trienekens, 1999). On the other hand, vertical integration can have disadvantages. According to Ziggers and Trienekens (1999), motives against vertical integration can be: dissipation of resources, high demand of capital, reduced flexibility and rigidity of organisational structures.

The degree and success of cooperation between actors depends on many factors. Vertical cooperation in a production chain, for instance, is more difficult than horizontal cooperation, since more actors are involved, each of them having their own demands and culture. According to Stijnen *et al.* (2002), the following factors influence the degree and quality of cooperation between companies in a production chain: (1) the level of uncertainty and to what

extent this uncertainty can be lowered by intensive cooperation; (2) the dependency of companies of each other in the production chain; (3) the strategic fit; (4) the cost of cooperation versus other kinds of coordination; (5) trust.
Although available literature does not specifically include NPD, the arguments presented in this section in favour of chain cooperation also seem to be valid for effective and efficient NPD in the food industry.

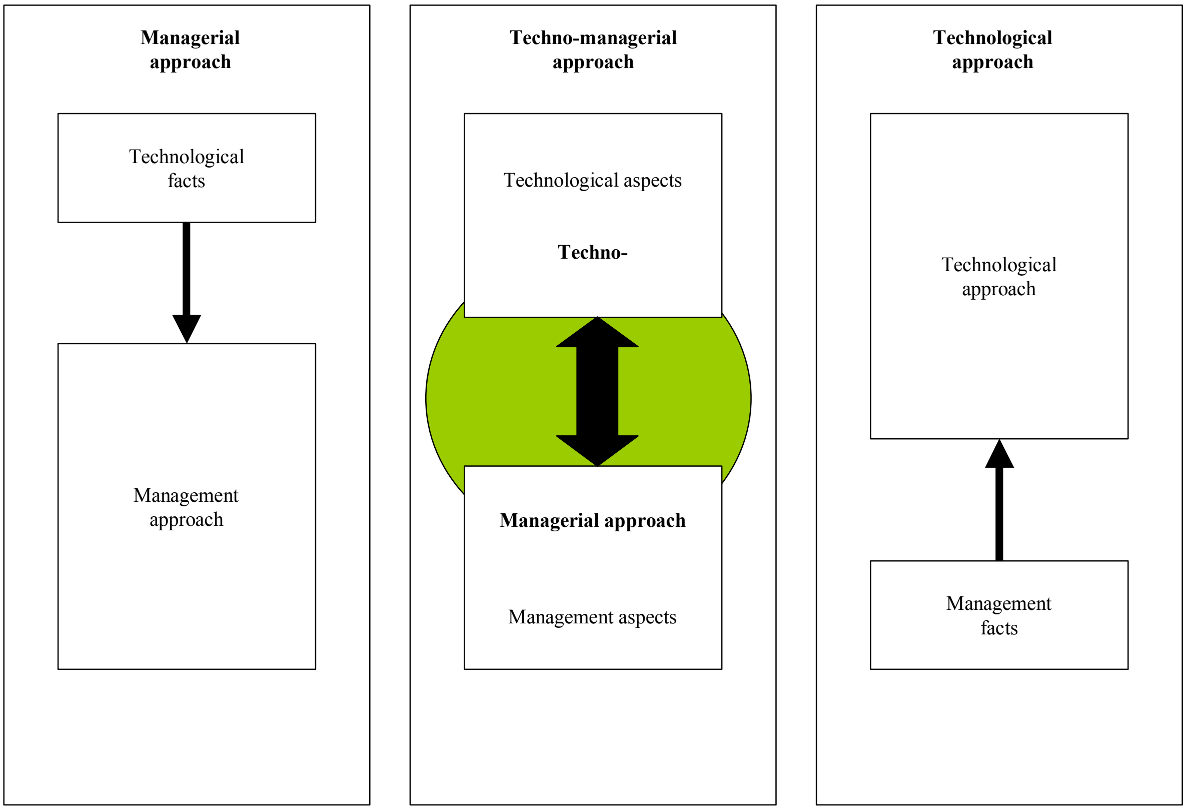

Figure 1.3 The Techno-Managerial approach (Luning *et al.*, 2002)

1.4.3 The techno-managerial approach

Much research on NPD, as presented in earlier sections of this thesis, was conducted from either an economic or a management point of view. In those cases technology is treated as a given fact, an enabling tool to facilitate the managerial approach. Innovation in food production systems and NPD is habitually dealt with from either an economic, managerial or a technological point-of-view (Jongen and Meulenberg, 1998).
Obviously, management plays an important role in the functioning of a food production chain and creating the preconditions for innovations. However, food products and the raw materials and ingredients used for their production are living materials that change constantly in time because of (bio)chemical, physical and microbiological influences. Therefore, technology plays also a relevant role in managing innovation in the food production chain (Luning *et al.*,

2002). According to Jongen and Meulenberg (1998), studies that integrate the economic, managerial and technological elements of the innovation process, are scarce and lacking; therefore these authors have adopted the techno-managerial approach. Luning *et al.* (2002) used this techno-managerial approach as an integrated way to describe food quality management. According to Luning *et al.* (2002) three different types of approaches are possible (Figure 1.3). The difference between these is the level of integration. The shortcomings of both a single managerial as well as a single technological approach are that they consider the other points of view as facts. The techno-managerial approach integrates both aspects from a system's perspective. Such an approach is not commonly applied to the NPD process, but is likely to be beneficial in that area too.

1.4.4 Decision-making

In any NPD process, many decisions have to be taken like which products to develop, which consumers to target on, which ingredients to use, and how to allocate resources. There are two main factors that have a great influence on decision-making (Luning *et al.,* 2002): (1) the availability of information, and (2) the existence of interests (Figure 1.4). Information is needed to reduce uncertainty in the decision-making process. In an ideal situation, all the information needed to take decisions with certainty would be available. However, in most business situations information is incomplete or ambiguous.

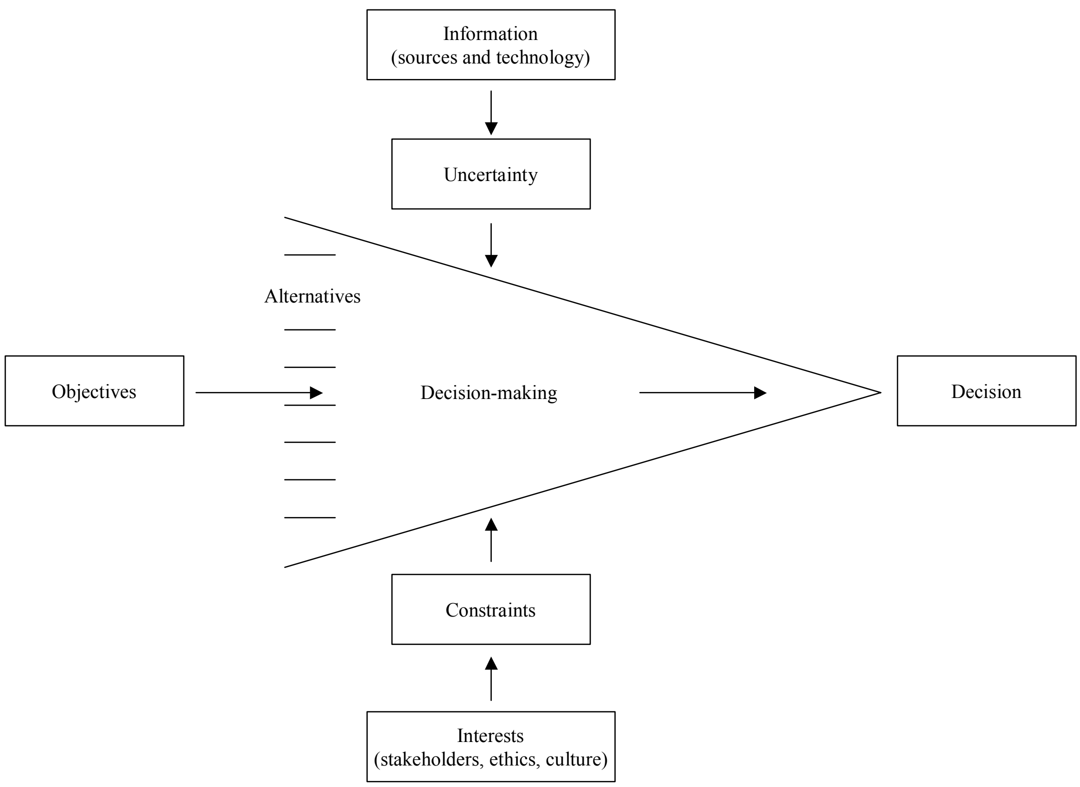

Figure 1.4 Factors influencing decision-making (Luning *et al.*, 2002)

With respect to the availability of information, three major situations can be distinguished (Luning *et al.*, 2002): (1) *certainty*: certainty is the situation that exists when decisions are made in a context of being fully informed about a problem, its alternative solutions and their respective outcomes. Under this condition one can anticipate and even exercise some control over events and their outcome. However, this situation almost never occurs; (2) *uncertainty*: this is the situation that exists when decisions are made in a context of being incompletely and improperly informed about a problem, its alternative solutions and their respective outcomes; (3) *risk*: risk is the situation that exists when decisions are made in the context of incomplete, yet reliable information. Under a state of risk, one does not know with certainty the future outcomes associated with alternative courses of action.

Another condition affecting decision-making that also reduces the room for decision is interests (Figure 1.5). When a decision is made, interests of persons or groups will be served. At the same time interests of others might be neglected.

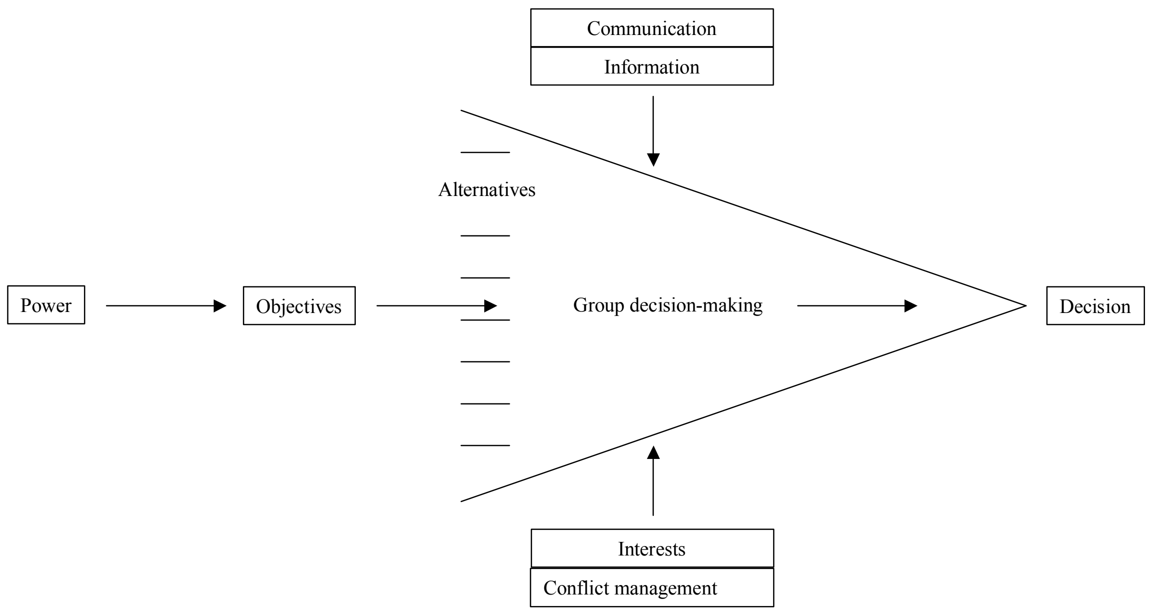

Figure 1.5 Factors influencing group decision-making (Luning *et al.*, 2002)

For NPD in a food production chain multiple actors will be involved in the decision-making process. According to Luning *et al.* (2002), the major advantages of group decision-making are use of more information and knowledge, and a greater acceptance and legitimacy.

Disadvantages are longer time periods for decision-making and the risk of group thinking, which is the tendency of highly cohesive groups to minimise evaluation and criticism. The

main difference between individual and group decision-making is the immediate interaction between participants in the latter. This interaction can be complex caused by the different motivations, perceptions, and experiences of the participants. In a group decision-making process, information and interests are also important influencing factors, but there exists some differences as compared to individual processes. Figure 1.5 shows that the main differences between individual decision-making and group decision making are the contribution of communication to provide group members with information, conflict management to deal with conflicting interests and power, which is the ability to drive others in a direction you prefer and the way you want it (Luning *et al.*, 2002).
An important part in decision-making with regard to innovation projects is risk management. The ability to assess and manage risk associated with the innovation project is vital to success of the project (Ganguly, 1999). Risk management is meant to better ensure the outcome of end results as they are planned. Technical and business risks change with project types. In general, innovation projects are defined as high risk under the following circumstances:

- if they are classified as 'breakthrough' (radical R&D);
- if they involve high capital spending and major supply changes;
- if they have to conform to certain industry standards;
- if they involve significant changes in sourcing.

For effective risk management four generic steps can be distinguished (Ganguly, 1999):

- risk identification;
- risk evaluation and assessment;
- risk reduction;
- risk control.

According to Luning *et al.* (2002) risk communication should also be an integral part of the process.

1.4.5 Information

Information is needed to take decisions and to reduce uncertainty in the NPD process (Cooper, 1986; Urban and Hauser, 1993; Court *et al.*, 1997; Court, 1998). Besides, information is needed to improve systems and procedures systematically (Woodcock *et al.*, 2000). Court *et al.* (1997) also acknowledge this; their research shows that access, distribution and subsequent usage of information by the design team has a major influence on the result of the NPD process. Although Court *et al.* (1997) have executed their research in the non-food business; there is no reason to assume that this does not apply to the food industry.
Literature gives many definitions of information. Benyon (1990) proposes that information may be viewed from two perspectives. On the one hand, information is viewed objectively as a measure of the relative frequencies of signals emanating from a source. On the other hand, information is viewed subjectively as a measure of its usefulness to a specific task being performed – relevance, accuracy, location of delivery, presentation, cost etc. Key concepts for information in NPD are considered to be: data, knowledge, memory and communication (Court, 1997).

Information and data are often used interchangeably, as synonyms or with only slight differences (Court, 1997). According to Benyon (1990), data are raw facts that have not been organised or cannot possibly be interpreted. Court (1997) classes information as the combination of the raw data itself and the meaning to provide the user with understanding.
Also, information and knowledge are often used as synonyms. Machlup (1980) defines information and knowledge as follows: '*information is the activity or process of informing and getting informed*' and '*knowledge is the state of knowing*' (Court, 1997). With respect to knowledge in the design domain, a distinction has been made by Eder (1989) between prescriptive knowledge and descriptive knowledge. Prescriptive knowledge is the *'know-how'* and includes:

- design knowledge related to the technical system to be designed (knowledge about natural phenomena, knowledge about how to apply that science, etc.);
- design knowledge related to the design process (knowledge about the general strategic approach to designing, knowledge about tactics and methods for designing, etc.).

Descriptive knowledge is the *'know-that'* and includes:

- design knowledge related to the technical system to be designed (knowledge about properties and constituents, knowledge of theories of properties);
- design knowledge related to the design process (knowledge about design processes, knowledge about using working means).

Holsapple and Singh (2001) describe information as '*the name commonly given to one type of knowledge: descriptive knowledge, which refers to characterisations of past, current, or hypothetical states of some world of interest.*'
The factors influencing the value of information include its accuracy, availability, accessibility, applicability, and quantity rather than just its content (Court *et al.*, 1997).
Not the possession of information is the key but knowing how to use information and translate it into something useable and understandable for the company is the true value of information (Court *et al.*, 1997). In this respect NPD teams are involved in knowledge creation based on available information and exchanging this knowledge to support the NPD process (Madhavan and Grover, 1998).
A factor that is important in the treatment of knowledge is the role of tacit knowledge. Tacit knowledge is the knowledge that cannot be explicated fully even by an expert, and can only be transferred from one person to another through a long process of apprenticeship. In contrast, explicit knowledge is relatively easy to articulate and communicate and thus easily transferred between individuals and organisations (Madhaven and Grover, 1998). Especially in the food industry, with its high level of domain-specific knowledge and experts, the role of tacit knowledge and how to capture it is extremely relevant and of high importance.
In some fields information exchange is common practice, like supply chain management and tracking & tracing. However, information exchange and close cooperation in strategic projects, like product innovation projects, is not common practice in the food industry yet (Van Dalen *et al.*, 1997; Stijnen *et al.*, 2002). At present this information is scattered throughout the food production chain, and all actors try to organise the information flows in their own direction. Every actor collects as much information as possible in his direct surroundings. Research shows that the sources of information, and knowledge, mostly used

for innovative ideas by small and medium-sized enterprises (SME) in the food area are its direct chain partners (suppliers and buyers) (Van Dalen *et al.*, 1997). This information supply, however, is not structured and agreements concerning the sharing of the information are not made.

1.4.6 NPD tools

One way to structure the NPD process and hence create a more professional approach of NPD projects is the use of NPD tools. Many techniques and tools have been developed to aid the product developer in the NPD process. The use of such tools does not guarantee an increased success rate of new products, but their use may assist companies to create a more successful NPD process (Nijssen and Lieshout, 1995). NPD tools may help to identify problems at an early stage and assist in directing the NPD effort in the right direction. NPD tools can be used to decrease development times, predict shelf life of products, ensure consumer wishes are met in the product, etc. If one considers all possible versions and modifications of NPD tools, over 600 different types can be identified (Nijssen and Lieshout, 1995). The whole set of NPD tools represents the efforts of academics, specialised companies and industry (Araujo, 2001). Although most of these tools have been designed to exclusively facilitate a specific part of the NPD process, research shows that managers use them in a rather unfocused way (Nijssen and Frambach, 2000).

Nijssen and Lieshout (1995) have classified the most popular NPD tools based on four basic NPD questions: (1) which product should be designed?; (2) how must the product be designed?; (3) how should the product be introduced on the market?; (4) what is the anticipated success rate of the new product? These questions relate to four underlying NPD problems, namely: (1) the idea generation problem; (2) the product optimisation problem; (3) the marketing mix optimisation problem; (4) the prediction of success problem. The results of their classification are presented in Table 1.4.

Gonzalez and Palacios (2002) have classified available NPD tools into five generic categories: (1) design techniques; (2) organisative techniques; (3) manufacturing techniques; (4) information technologies, and (5) supplier techniques. In Table 1.5 only the tools most often cited are included.

Table 1.4 Classification according to Nijssen and Lieshout (1995)

Idea generation	Creative	Brainstorming Synectics Morphological analysis
	Not creative	Focus group Interview/survey Observation of users Delphi method Scenario Expert opinion Product life cycle
Product optimisation		Conjoint analysis Quality function deployment Concept testing Prototype testing Pilot plant/in-home use test
Marketing-mix optimisation		Simulated test marketing Mini-market Limited roll-out Scanner market Test marketing
Prediction		Computer prediction models Diffusion models Economic models (ROI/BE – analysis/pay-back time

Araujo (2001) divides the NPD tools in two broad categories: the paper based (or soft) tools and the computer-enabled (or hard) tools. The paper-based are likely to include all of the available approaches, concepts, diagrams, guidelines, models, working principles, procedures, representations, standards, steps, techniques, methods, and methodologies. The computer-enabled will include the whole range of computer-aided systems such as CAD, CAM, CAE, etc. and computer-based implementations of the paper-based tools. Both types of tools are designed to support either the core activities in NPD (those activities directly leading into transformations in the state of the product being developed), or the organisational issues involved in it (cross-functional coordination, planning, multi-disciplinary team work, project management, etc.).

Rosenthal (1992) has adopted an information processing perspective for classifying NPD tools. The adoption of such an approach can facilitate the strategic assessment of the different design technologies. Rosenthal classifies design technologies into six categories (Table 1.6).

According to Araujo (2001), other possibilities to classify NPD tools can be: - *according to the type of tasks (process based)*; in an ideal situation the NPD process could be divided into a finite number of activities. For each of these elements there could exist one or more well specified NPD tool; - *according to the type of effects of the tool*; this classification is independent of the pool of possible tasks. Instead, the classification is based on the effect of the tool, in its interaction to its user. An example are tools stimulating and streamlining the creativity process; - *according to the type (or range) of products*; the difficulty with this way of classifying tools is that it appears difficult for a tool developer to customise the tool for each type of product it can be applied to; - *according to the characteristics of the operators and the context*; according to this type of classification, the following classes of NPD tools could be distinguished: (1) tools directed at certain individuals or groups who hold specific skills or types of knowledge; (2) tools in which the application is conditional to the availability of certain working means, such as computer software, hardware, infrastructure, organisation; (3) tools that describe certain definite working conditions, making their application restrictive to certain situations.

Table 1.5 Classification according to Gonzalez and Palacios (2002)

Design Techniques	Quick product specification Quality Function Deployment Conjoint Analysis Design for Excellence Robust Design Design optimisation Modular design Incremental innovation Rapid design transfer Group Technology (GT) Rapid prototyping and tooling Failure Mode and Effect Analysis
Organisative Techniques	Concurrent activities management Stage-Gate process Multifunctional design teams
Manufacturing Techniques	Manufacturing Resource Planning Just in time Optimal Product Technology Statistical Process Control
Information Technologies	Computer Aided Design (CAD) Computer Aided Manufacturing (CAM) Computer Aided Engineering (CAE) Computer Integrated Manufacturing Internet and Intranets Electronic Data Interchange Expert systems Groupware Product data management
Supplier Involvement	

Table 1.6 Classification according to Rosenthal (1992)

Translation	**Productivity enhancement**
Quality Function Deployment (QFD) Design for assembly (DFM) Customer use information test requirements Target cost into yield objectivities Computer-aided process planning (CAPP) Planning bills of materials (BOM) Value engineering	Drafting computer-aided design (CAD) Computer-aided software engineering (CASE) Project evaluation review technique (PERT) Computer-aided engineering (CAE) Group technology (GT) Computer-aided manufacturing (CAM)
Focused Information Assembly	**Analytical Enhancement**
Early vendor involvement Early manufacturer involvement Simultaneous engineering Co-location of design and manufacturing engineers Quality Function Deployment (QFD) Design for assembly (DFA) Design reviews Manufacturing systems simulation	Manufacturing simulation Learning curve analysis Computer-aided design (CAD) Finite element analysis Robust engineering Statistical design of experiments Taguchi methods
Communication Acceleration	**Management Support**
Computer-aided design (CAD) Group technology (GT) Early specification of vendors Computer-integrated manufacturing (CIM) Planning bills of materials (BOM) Preliminary prototypes Rapid prototyping Early product information to field service Early product information to marketing/sales	Gantt charts Project evaluation review technique (PERT) Contract books Formal performance reviews Milestone gate reviews Design for manufacturing (DFM) checklists Manufacturing sign-offs Group sign-offs

Cooper (2003) says that the key challenge faced by NPD projects is how to acquire knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the project or the resulting product. Multiple NPD tools are available to facilitate this process, in which three categories can be distinguished: design tools, collaborative tools, and knowledge management systems.

The many attempts to classify NPD tools show that it is difficult to give an unambiguous definition of a NPD tool. According to Araujo (2001), the understanding and definition for the term are far from being homogeneous among academics and practitioners. Based on an extensive review, Araujo (2001) defines NPD tools as: '*Any artificial means that are available to manufacturing organisations (and individuals within it), in order to support them* *in understanding, establishing, executing, and controlling tasks and activities, and solving problems, in the context of product development.'*

According to Court *et al.* (1997), the main purpose of a NPD tool is to improve the use, flow and quality of information as well as to assist the NPD team in the efficient execution of their work. In this research project we will use the following definition of a NPD tool: '*A technique, tool, methodology, procedure or model that is purposely constructed to improve the use, flow and quality of information, as well as to assist in the efficient execution of the NPD process.'*

1.5 This thesis

The foregoing sections illustrate that NPD is a necessary activity for food companies. However, the failure rate of the current NPD processes is too high in spite of the numerous technological possibilities and opportunities offered by demands from the market. Earlier research and experiences of the last years indicate that successful products are the result of a combination of technology push and consumer pull; so not necessarily only the one or the other. To lower the failure rate, the food NPD process has to be more effective and efficient. This calls for a systematic approach. One way to realise this is by using NPD tools. However, current tools are not able to adequately fulfil this demand. Therefore, a new tool to structure the NPD process has to be developed. Two elements are crucial in realising this objective, namely:

1. A chain approach; for an effective NPD process a chain approach is essential. NPD efforts should be in accordance with all actors to prevent counter productivity during the production process and to fully exploit all possibilities for optimisation.
2. Information management; information and information exchange are needed to reduce the risk in decision-making in the NPD process. Information is also essential to structure the NPD process and to align development and production processes among actors.

The aim of this Ph.D. project is to develop a NPD tool that is based on the two key elements mentioned above. The tool is based on an existing tool for systematic, consumer-orientated NPD: the Quality Function Deployment method.

Chapter 2 presents a review of the QFD method for its use for food NPD. In its current format the QFD method appeared not to be usable for NPD in food following a chain approach. Therefore, we have modified the existing QFD method to develop a chain-based tool for information supply. This tool was developed using the example of the production of ready-to-eat meals with a high amount of glucosinolates (Chapter 3). The resulting conceptual tool was tested for its intended use by means of an explorative study on the production of tomato ketchup with a higher amount of lycopene (Chapter 4). Finally, in Chapter 5 the use of the tool is evaluated for knowledge management in food NPD. Chapter 6 reflects on the results of this research project and discusses the implications and use of the tool for future food NPD.

2

Quality Function Deployment (QFD) – can it be used to develop food products?

M. Benner, A.R. Linnemann, W.M.F. Jongen, P. Folstar (2003). Quality Function Deployment (QFD) – can it be used to develop food products? *Food Quality and Preference, 14*: 327-339.

2.1 Introduction

The first issue in developing a systematic NPD process is establishing a link between the characteristics of a product and the actors in the food production process. One method nowadays strongly advocated to systematically translate quality characteristics (or consumer wishes) into technological characteristics is the Quality Function Deployment method (Hofmeister, 1991; Charteris, 1993). Quality Function Deployment (QFD) is an adaptation of some tools used in Total Quality Management (TQM). It is a method to encourage NPD team members to communicate more effectively with each other using a complex set of data. It enables teams to formulate business problems and possible solutions (Cohen, 1995). QFD was invented in the late sixties in Japan to support the product design process. It originated at Mitsubishi’s Kobe shipyard. At first it was used for the design of large ships. As it evolved it became clear that it could also be used to support service development. QFD has been extended to apply to any planning process where a team wants to systematically prioritise their possible solutions to a given set of objectives (Urban and Hauser, 1993). Since the introduction of QFD in the USA in the beginning of the eighties, it has been widely spread among industries in the western world. Among the early users of QFD are companies like Ford Motor Company, Procter and Gamble, Campbell’s soup, IBM, Xerox, Hewlett-Packard, Kodak, and 3M Corporation (Griffin and Hauser, 1993; Cohen, 1995). Examples of products and services that have been developed using QFD are: retail outlets, apartment layouts, cars, computers, software, printers, cameras, airline services, paints, surgical instruments, diagnostic instruments, office equipment, consumer products, tools, retirement plans, movie theatres, health insurances, financial services, telephone services, gas and electrical services, distribution networks (Hauser and Clausing, 1988; Griffin and Hauser, 1993).

Literature states that QFD has reduced design time by 40% and design costs by 60%. These improvements are caused by the increased communication among functional groups early in the new product development (NPD) process and by assuring that the voice of the customer is built into the development process (Hauser and Clausing, 1988; Urban and Hauser, 1993).

The major benefits of using QFD are that (Sullivan, 1986; Hauser and Clausing, 1988; Barnard, 1992; Griffin, 1992; Hauser, 1993; Govers, 1996):

- QFD enables companies to make the key trade-offs between what the customer demands and what the company can afford to produce;
- QFD improves effective communication between company divisions and enhances team work;
- Quality is built in upstream;
- QFD increases customer satisfaction by making sure that customer demands are brought into the NPD process;
- Important production control points are not overlooked;
- QFD brings together all the data required for the development of a good product and the development team sees very quickly where additional information is needed during the process. Moreover, the information is better used and documented;
- QFD shortens time-to-market.

According to Hofmeister (1991) the quality function deployment method has been used in the food industry since 1987. Since the beginning of the nineties of the last century articles have been published on the advantages that the QFD method has to offer especially in the area of consumer-oriented food NPD. The question arises whether it is possible to apply this method, originating from the heavy industries, without changes to the food industry? Is it necessary to tailor the method to account for the large differences between the often still metabolically active and thus changing, food ingredients instead of the, exactly specified and not changing, components used in the electronic and mechanical industries? Moreover, the many actors in the food production chain also influence the quality of the ingredients and thus of the final product.
In order to test the QFD method on its usefulness for the development of food products we have applied the method, as it is described in literature, for the development of a food product. Before doing so we have conducted a critical review of the literature dealing with the use of QFD in food NPD.

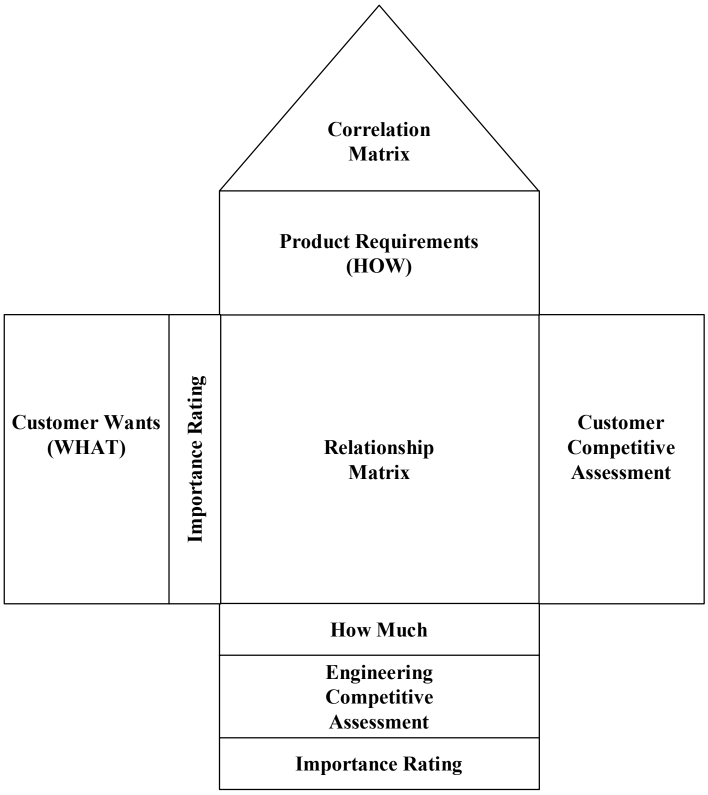

Figure 2.1 The House of Quality, the first matrix of the QFD method

2.2 Applying QFD from a general point of view

QFD is a method for structured product planning and development that enables a development team to specify the consumer's demands and needs, and to evaluate the proposed product systematically in order to determine its impact on meeting these needs. The QFD method consists of the construction of one or more matrices.

The first matrix of the QFD method is called the House of Quality (HoQ), because its appearance with the roof-like structure resembles a house. The House of Quality consists of several so-called rooms, each containing information concerning the product. The main goal is to translate the Customer Demands into Product Requirements. According to Hauser and Clausing (1988) it is a kind of conceptual map that provides the means for inter-functional planning and communications. The basic structure of the House of Quality is shown in Figure 2.1. The construction of the House of Quality starts with the determination of the customer demands, often called the WHATs. Other terms used are voice of the customer, or quality characteristics. This list is usually obtained by qualitative market research. These WHATs are generally reproduced in the customers' own words (Hauser and Clausing, 1988). The customer demands are rated against each other to quantify their importance in realising the success of the product. This Importance Rating can help to set priorities for the NPD process and provide guidelines to allocate the necessary resources.

On the right hand side of the house is the Customer Competitive Assessment section, which contains information on the customer's perception of the company's product compared to competitor's products (Barnard, 1992).

The room on the upper side of the House of Quality is the Product Requirements section, which gives a technical description of how to realise the consumer demands in the product. These product requirements are also called the HOWs, or substitute quality characteristics, and represent a translation from the customer's language into the company's technical language. To get the most out of QFD, the language of the WHATs should be in more abstract terms than the language of the HOWs. These HOWs may still be abstract. In later phases of QFD they are expressed in more detail (Barnard, 1992; Cohen, 1995).

The centre part of the House of Quality contains the relationships, and depicts the relationship and strength between each WHAT and HOW. This Relationship Matrix also provides a crosscheck: blank rows or columns indicate that a WHAT has inadequately been translated into a HOW (Barnard, 1992).

The Correlation Matrix, put in the roof of the House of Quality, contains the correlations between the HOWs and shows what HOWs influence each other. Its use is to show where trade-off decisions have to be made. Positive correlations between HOWs show that they support each other. Negative correlations show that the HOWs adversely affect each other (Hauser and Clausing, 1988; Barnard, 1992; Cohen, 1995).

The bottom of the House of Quality contains several rooms with different types of information. One section contains the HOW MUCHs; these are the measurements for the HOWs. The use of the HOW MUCH section is to determine priorities and directions for improvements of the HOWs and to provide an objective means of assuring that requirements have been met (Govers, 1996). Moreover, they provide target values for further detailed development. According to the ASI (American Supplier Institute) awareness seminar (Barnard, 1992) these target values should represent how good we have to be to satisfy the customer and not current performance levels. The HOW MUCHs should be measurable as much as possible, because measurable targets provide more opportunity for analysis and optimisation.

Other rooms on the bottom of the House of Quality are the technical competitive assessment, showing the technical benchmarking of the product. The technical importance rating provides a relative importance of each HOW in achieving the collective WHATs (Hauser and Clausing, 1988; Barnard, 1992; Cohen, 1995).

Once the House of Quality has been constructed, additional matrices can be made to further guide the decisions that the development team has to make. In practice many development teams do not use the matrices after the House of Quality, but by doing so they miss a lot of information (Cohen, 1995). The House of Quality only provides a company with the goals they should try to reach in the intended product, but it does not tell what part, processes or production plan the company needs to realise these goals (Hauser and Clausing, 1988).

According to Cohen (1995) most organisations stop after developing their customised version of the House of Quality, even in Japan. Cohen (1995) explains this by the fact that there is a lack of specificity in the literature on how to go beyond the first matrix. Real case studies are hard to find, because companies are reluctant to share this kind of information because of confidentiality reasons.

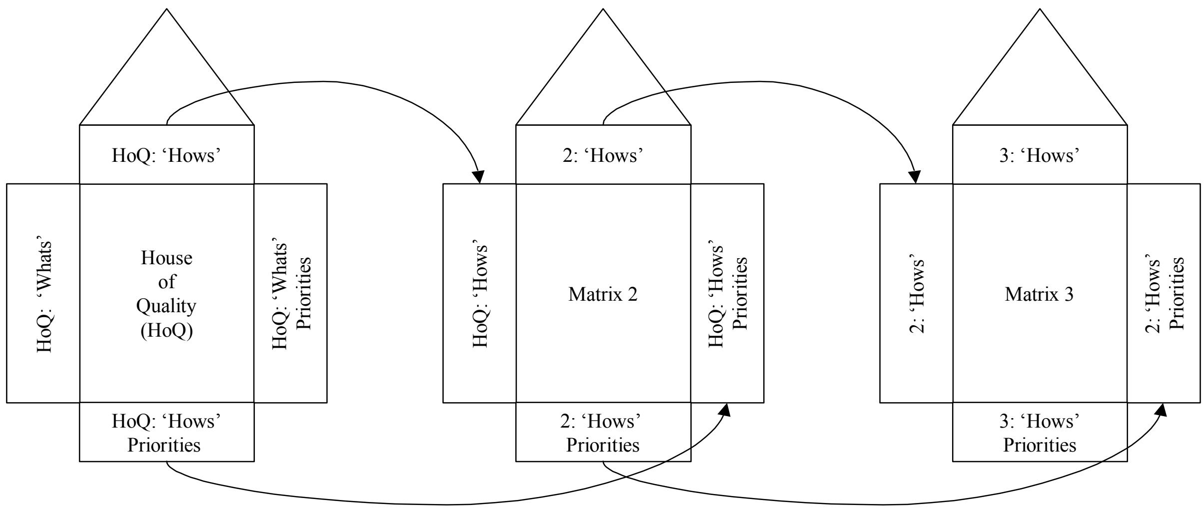

Figure 2.2 Interrelated matrices as resulting from the application of the QFD method

The construction of the next matrix is started by placing all or the most important HOWs of the House of Quality on the left-hand side of the second matrix and their priorities on the right hand side. The HOW MUCHs are also placed in the next matrix to facilitate communication, ensuring that the target values are not lost. Only those HOWs which are new, important, or difficult and therefore high risk to the company are taken into the next phase of the QFD method (Barnard, 1992). In this way the HOWs of the first matrix become the WHATs of the second matrix (Figure 2.2). Every matrix along the cascading process contains more detailed information concerning the product.

The most used and described QFD model to go beyond the House of Quality is the Four-Phase model, also known as the ASI model or Clausing model. The model consists of four phases: (I) the product planning matrix (the House of Quality); (II) the design deployment matrix (part deployment); (III) the manufacturing planning matrix (process planning); (IV) the production planning matrix (production operations planning) (Sullivan, 1986; Hauser and Clausing, 1988; Barnard, 1992; Hauser, 1993; Cohen, 1995).

The total product is broken down into subsystems and these are broken into parts to construct the design deployment matrix. Next, for each part the important characteristics are listed. These part characteristics are the descriptions of the parts that are critical to the design and hence are the drivers of customer satisfaction. The part characteristics are placed into the matrix and the matrix is completed in the same way as the House of Quality (Cohen, 1995).

Subsequently the main process flow is broken down into subassembly processes and operations to construct the manufacturing planning matrix. Next, the design team identifies the key operations process parameters related to performing the subassemblies. The process parameters are placed in the HOW section of the matrix and are prioritised according to their influence on the part characteristics (Figure 2.3) (Cohen, 1995).

In the fourth phase, the production planning phase, the key operations are the input and the production requirements – like knob controls, operator training and maintenance – become the output or the HOWs (Hauser and Clausing, 1988). According to Cohen (1995) the fourth phase is, instead of a matrix, a table containing a checklist of topics or issues that should be considered in planning production steps. Examples of these steps are machine setting, control methods, sampling size and frequency, control documents, operator training, and preventive maintenance tasks. These kinds of topics are listed in the table and the most important process parameters are arranged along the side. By completing the fourth phase, production planning can be linked to the starting point: the voice of the customer (Cohen, 1995).

Another way to go beyond the House of Quality is by using the Matrix-of-Matrices model, also known as the Akao QFD model. This model consists of a system of thirty matrices, charts, tables, or other diagrams. The entire system contains several phases of NPD, with a strong continuous improvement emphasis. This QFD model is intended to open up possibilities to a NPD team. The team is expected to create its own QFD model, because every organisation is different and no two development projects are the same. Compared to the Four-Phase model, the Matrix-of-Matrices model makes explicit activities that are implicit or optional in the first model (Cohen, 1995). However, not much is published about the use of this model and the effort to complete this many houses might prevent companies from applying the Akao QFD model.

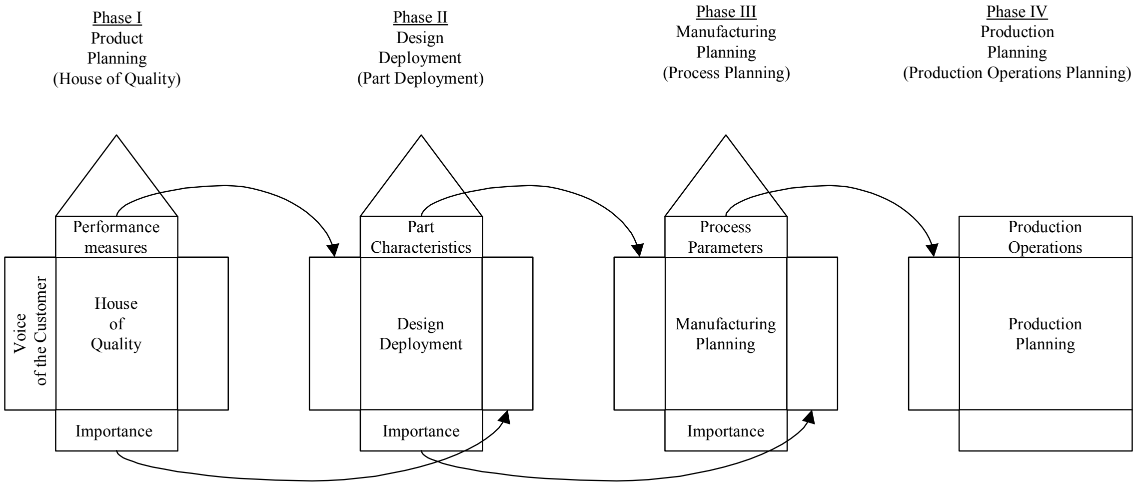

Figure 2.3 The Four-Phase model

2.3 Application of QFD in the food industry

The literature about application of QFD in the food industry is limited. The few articles that have been published claim that QFD is a suitable and promising method to facilitate the food NPD process. However, it has been reported that QFD still needs a lot of development and understanding before the method can be applied (Dekker and Linnemann, 1998; Costa *et al.*, 2001a). In spite of the claimed benefits of QFD for the development of food products only limited examples are documented. The strategic importance of the NPD process for the industry may explain the reluctance of companies to share information on QFD: this would partly explain the absence of examples (Charteris, 1993; Govers, 1996). The few examples of application of QFD to food NPD refer to the same publications and they report only general descriptions of how QFD should be applied. Their main focus is on the first matrix: the House of Quality. Few articles describe how QFD has been used on actual products and discuss own experiences. This complies with the conclusions of other authors. Costa *et al.* (2001a) conclude from their research that most of the relevant information has only been published as scientific working papers, theses and reports. This kind of information is not readily available for the public.

Moreover, after a thorough examination of the limited examples published, it becomes clear that the information is not as useful as it seemed at first glance. Especially with respect to the Four-Phase model, examples of applications are limited. Some publications mention the Four-Phase approach, but only a limited number actually go beyond the first matrix, i.e. the product planning matrix (Table 2.1).
Hofmeister (1991) mentions the QFD Food Industry Roadmap in which two alternative roads are defined for deploying the voice of the customer through the NPD process (Figure 2.4). These two roads are the packaging deployment road and the food deployment road, each containing the four phases as discussed in the Four-Phase model. In the food deployment road the phases II and III are combined, because in the food industry both ingredient and the manufacturing process define the end product characteristics. Hofmeister (1991), however, only deploys one customer demand into the next houses. In this way the interactions between the consumer demands are neglected. These interactions combined with the fact that some of the HOWs affect more than one WHAT, as well as the large list of customer demands are often seen as the major bottlenecks of using QFD on food product improvement (Hofmeister, 1991; Dekker and Linnemann, 1998). Charteris (1993) mentions a 7-stage QFD process and the QFD Food Industry Roadmap. However no example is given of the actual use of QFD. Reference is made to articles that have not been published as far as we know.

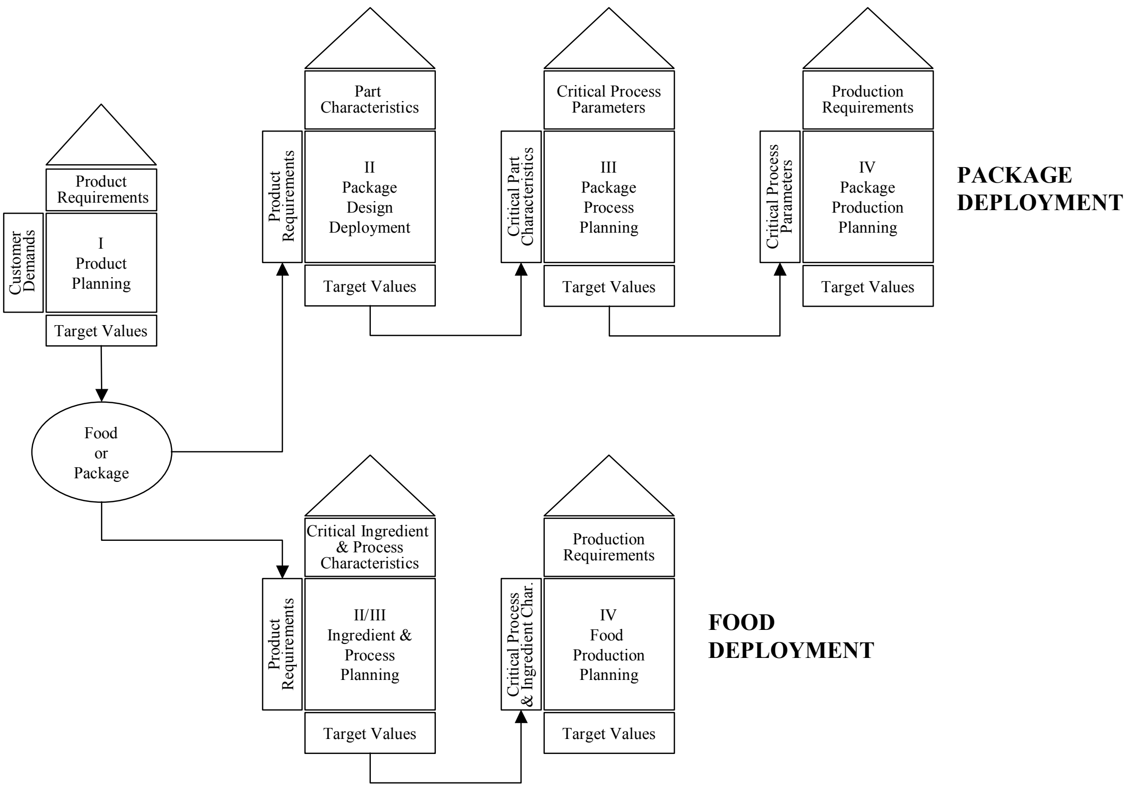

Figure 2.4 The QFD Food Industry Roadmap

Table 2.1 Literature review of the use of QFD in the food industry

Reference	Product used	Notes	Modification to the House of Quality?	More matrices used?
Anon. (1991)	Flavour enhancers based on yeast extracts	No example given.	-	-
Barnard (1992)	Chocolate cake mix	Only show the House of Quality.	No	Mention Four-Phase model
Bech et al. (1994)	Butter cookies	Authors give a theoretical explanation of QFD.	The HOWs are divided into a technical and a sensory part	No
Bech et al. (1997a)	Smoked eel	The aim of the article is to link consumer demands for taste quality to attributes from conventional sensory profiling by using the House of Quality.	The authors have divided the HOWs into a sensorial and a technical part.	No
Bech et al. (1997b)	Peas	Article focuses on how the House of Quality can be used to translate sensory consumer needs into measurable sensory attributes.	The authors have divided the HOWs into a technical and a sensory part.	No
Charteris et al. (1992)	Low fat table spread	Article does not tell or show how QFD has been used.	-	-
Charteris (1993)	-	Author refers to own unpublished work and quotes the ASI workshop.	No	Mentions a 7 stage QFD process and shows the QFD Food Industry Roadmap (ASI)
Costa (1996)	Tomato ketchup	Author has built a House of Quality for tomato ketchup.	No	Author mentions the Four-Phase model.
Costa et al. (2001a)	Tomato ketchup	The authors give a review of QFD in the food industry and explain the method by an example based on earlier work (Costa, 1996).	No	No
Dalen (1996)	Beef	Author has built a simplified House of Quality.	No	No
Dekker and Linnemann (1998)	Tomato ketchup	Based on thesis by Costa (1996).	No	Authors mention the QFD Food Industry Roadmap.
Faeth and Bradshaw (1997)	-	Authors only mention QFD as a strategy	No	No

		to speed up and simplify NPD.		
Hofmeister (1991)	Chocolate cake mix	Author uses an example given on the ASI workshop held in 1987.	No	Discusses QFD Food Industry Roadmap (ASI)
Holmen and Kristensen (1996)	Sugar-free butter cookies	Authors use QFD to define inter-company involvement in the development process.	The authors divide the WHATs in intermediate user wants and end-user wants. They suggest that an incompatibility triangle be added to the House of Quality.	Authors use the Four-Phase model (Hauser & Clausing, 1988) at a conceptual level; they do not give an example of it. They also divide the deployment process in 'Content of the packaging' and 'Packaging' at the level of the primary wants.
Holmen and Kristensen (1998)	Sugar-free butter cookies	The article is based on the MAPP working paper (Holmen and Kristensen, 1996).	-	-
Juttelstad (1996)	-	Author discusses what other publications say about QFD.	-	-
Pedi and Moesta (1993)	-	Authors only give an explanation of QFD, they do not give an example.	No	No
Rudolph (1995)	-	Author only givens a theoretical explanation of QFD.	No	No
Sterrenburg and Rutten (1998)	Beef	Authors have built a House of Quality for beef.	No	No
Swackhamer (1995)	Industrial fryers	-	No	No
Terwindt (1998)	PET bottle	The author has used QFD for packaging development.	No	The author shows four houses. He also mentions that the number of houses is dependent of the complexity of the product.
Viaene and Januszewska (1999)	Chocolate couverture	-	The authors have divided the HOWs into a technical and a sensory part.	No

Table 2.2 Strengths and weaknesses of QFD (Hofmeister, 1991; Griffin, 1992; Januszewska, 2001; Dekker and Linnemann, 1998; Dalen, 1996; Costa *et al.*, 2001a; Bech *et al.*, 1994; Bech *et al.*, 1997; Kaulio, 1998; Juttelstad, 1996; Grunert *et al.*, 1997)

Strengths	**Weaknesses**
Improves communication.	Customer involvement only in the initial phase of the development process. Feedback from customers in the latter stages is not explicitly supported.
Provides a link between consumer wishes and product(ion) characteristics.	Customer wants can be very diverse and variable. This can result in very large lists of WHAT's and HOW's which are difficult to capture in a very precise target value.
Matrices permit very complex relationships to be documented and facilitate interpretation.	Food ingredients show a natural variation that may require continuous adaptation based on their specifications.
Helps NPD teams to set targets for product characteristics.	Many ingredients show interactions and affect the way processes should be designed and optimised. This gives rise to a very large and complicated relationship matrix.
Helps NPD teams to make trade-off decisions.	It is very time consuming to complete the matrices.
Helps NPD teams to gather and structure all the relevant information for the development of a successful product.	Process-related improvements are more difficult to achieve than product-related ones.
Makes decisions explicit and it documents why certain decisions have been made.	Benefits service developers more than product developers.
Helps a company to get rid of the over the wall approach.	Improvements increasingly difficult with increasing product complexity.
Allows simultaneous development across functions and all functions participate from the start.	Improvements more difficult to achieve in projects concerning true innovations.
Enables to compare a product with competing products on relevant consumer wishes.	More suitable for products which are assemblies of individual components.
Reduces the final production cost because of the high degree of conceptual research.	It can be very hard to establish (and interpret) the consumer wishes. Once you have the wrong consumer wishes, your product will not be successful.

Increases the potential market share at moment of launch because of the consumer segmentation and the consumer analysis.	It is very hard to approach the functional properties of food products as detached from each other. Neither can a food product be divided in parts (except into packing and content of the packing).
Empowers the NPD team to make decisions.	By putting the emphasis on the 'Voice of the consumer', the interests of the company (policy and profitability) are getting less importance.
	Development of QFD usually involves communication of information about skills and resources, future strategies, costs and current production approaches and, therefore, the company may not be willing or even able to afford the whole QFD process.
	It demands a whole new line of thinking and corporate structure.
	A lot of food product requirements, as mentioned by the consumer, are sensory requirements. Although a lot of research has been conducted in this field it is still difficult to measure them. Besides it is difficult to control them, since they are dependent of multiple variables related to product, production process, consumer, or the surroundings.
	Sensory analysis usually consists of about 20 sensory dimensions per product. This is a large number for a consumer to evaluate.

Holmen and Kristensen (1998) also mention the Four-Phase model. They presume that compared to the 'Akao matrix of matrices' it is the easiest to implement, especially for electronics, engineering and automobile industries. According to the authors the reason that it may be more complex to apply the Four-Phase model for food products is that in the more mechanical industries the physical product can be described as several components assembled to a finished product. This is not the case for food products where many ingredients show many interactions. In addition they say that general guidelines for using QFD are absent to emphasise the necessity that the technique is custom designed to the individual company. In their article they have constructed two Houses of Quality. The first one translates consumer demands into objectively measurable quality characteristics. These quality characteristics are transferred to a second House of Quality and subsequently translated into ingredient and process characteristics (phase II and III from the Four-Phase model). They do not discuss the last matrix, i.e. the food production planning matrix.

Many publications only focus on the collection of the consumer wishes and their importance. Only few publications deal with the translation of these consumer wishes into design characteristics and how to carry these on to the next houses. Bech *et al.* (1997a; 1997b) mainly focus on how the House of Quality can be used to translate sensory consumer demands into measurable sensory attributes for sensorial profiling. The result is that the practical use of these examples is limited if one intends to use the complete QFD method for a NPD process.

Some adaptations to the House of Quality are suggested. Bech *et al.* (1994) have made a subdivision of the design characteristics in a technical and a sensory part. By doing so they can place sensory analysis in relation to the firm's other production criteria and draw attention to the difference between sensory analysis and traditional market analysis. This subdivision has been used by Bech *et al.* (1997a; 1997b) in the development process of smoked eel and peas and by Viaene and Januszewska (1999) in the development of chocolate couverture.

Holmen and Kristensen (1996) have divided the customer demands into the WHATs of the intermediate users and the WHATs of the end-users. In order to reveal and show incompatibilities between these WHATs they have added an incompatibility matrix to the right side of the relationship matrix. They also suggested some downstream extensions to the House of Quality to identify supplier involvement in the NPD process (Holmen and Kristensen, 1996; 1998).

The following conclusions of the available literature on the application of QFD on food NPD can be drawn:

- Not many (complete) examples are published;
- In most of the literature only the House of Quality is discussed;
- The House of Quality used is the standard House as discussed in the second section, in some cases the HOWs are divided into a sensory and a technical part;
- Some articles refer to the QFD Food Industry Roadmap as presented on a workshop of the American Supplier Institute, although an example of an application of the method is not published to our knowledge;
- QFD should be custom designed for applying it in a company.

2.4 The use of QFD for the development of a ready-to-eat meal with a health benefit

We have tried to use the QFD method for the development of a food product from a production chain perspective. Costa *et al.* (2001a) mention that in food NPD, using QFD to realise improvements in projects seeking true innovation is difficult. Therefore we have used the method for the improvement of an existing product. The intended improved product is a ready-to-eat meal with a health benefit. The meal contains broccoli, potato gratin and marinated salmon. The health benefit originates from the presence of glucosinolates in the raw broccoli. Research indicates that these phytochemicals play an important role in the prevention of various diseases, most importantly ageing diseases like cancer (Dekker *et al.*, 2000). The authors demonstrate that many steps in the food production chain of vegetable products can influence the final intake of these glucosinolates (Figure 2.5).

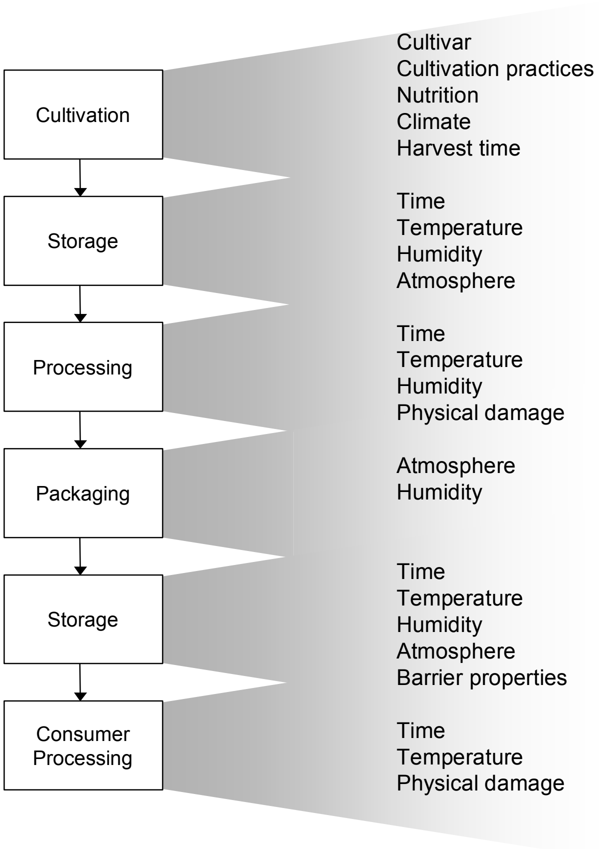

Figure 2.5 Influences of actors in the production chain on the glucosinolate content (adapted from Dekker *et al.*, 2000)

To produce the intended improved product the influence of the actors in the production chain on the product has to be known and quantified. Options for the production of the improved product can be formulated based on this information. However, changing production processes will also influence other quality characteristics of the product (WHATs). This may result in a product that is less attractive to the consumer. Consequently, the relationships between glucosinolate content of the broccoli and the other quality characteristics have to be established to determine what options provide the best opportunities for the development of this product from a chain-oriented approach and to provide all the information needed to make well founded trade-off decisions. Moreover, the relationships between quality characteristics and processes in the production chain have to be known. To establish these relationships we have tried to use the QFD Food Industry Roadmap (Figure 2.4). We have used the food deployment road only to simplify the process.

			Time to cook meal	Force to open package	Concentration fat in meal	Concentration glucosinolates*	Crispiness	Bitterness	Shelf life	Colour of the meal	Use of raw ingredients
Convenience	Preparation time		•			•	•	•		•	•
	Easy to open			•							
Healthiness	Fat content				•						
	Health promoting					•					
	Freshness										•
Sensory characteristics	Mouthfeel		•				•				•
	Taste				•	•		•			•
	Colour		•							•	•
Safety	No bacteria		•						•		•
	Not toxic					•					

* In the meal at the moment of consumption

Figure 2.6 The House of Quality for ready-to-eat meals (Phase I) showing the consumer demands, the product requirements and the relationship matrix

The application started with the construction of the House of Quality with the following rooms: consumer demands (WHATs), ranking of the consumer demands, product requirements (HOWs), relationship matrix, correlation matrix, and the target values (HOW MUCH). We did not use the other sections (Figure 2.1), because this was beyond the scope of the project. We did not conduct consumer research to determine the consumer demands. Instead we used the literature available and expert opinions to get an approximate list of these demands. The reason for this is that the scope of the project was to determine whether the QFD Food Industry Roadmap could be used to relate consumer demands (or quality characteristics) to processes (and thus actors) in the production chain. The product requirements were determined using our own expertise and by discussing the solutions with experts. The relationship and correlation matrices were completed in the same way.

First, the consumer demands for a ready-to-eat meal were established (Figure 2.6). The main reason for consumers to buy ready-to-eat meals is convenience. Consumers either do not have the time for cooking their own meals, or they do not want to spend time on cooking. At the moment health is a popular topic for all food products. Consumers are more than ever concerned with their health and are looking for healthy foods. Health attributes are also sought for in the new generation of ready-to-eat meals that go beyond the tv-diners. Consumers are asking more and more for the so-called chill-fresh meals that have had little or no industrial pre-heating. Another important and often criticised characteristic of ready-to-eat meals is the taste. According to the Central Agency of Food Products (CBL) in the Netherlands 60% of the consumers that buy ready-to-eat meals are not satisfied with the taste. Another important consumer demand is safety of the product (Anon., 1996a; Anon., 1998; Zuurbier and Migchels, 1998; Samuelsson, 1999).

In the House of Quality the primary consumer demands have to be made operational by translating them into secondary, more specific demands (Figure 2.6). The design team has added the consumer demand ‘Not toxic’, since a too high amount of glucosinolates can be toxic.

The next step in the construction of the House of Quality is to determine the product requirements or HOWs. Hofmeister (1991) states that it is important that the HOWs represent ‘how to measure’ and not ‘how to accomplish’. The HOWs are shown in Figure 2.6. This figure also shows the relationships between consumer demands and product requirements. The strength of the relationships is not indicated, since at this moment we were only interested in whether there was a relationship at all. In the roof the correlations between the product requirements are shown.

The problems with applying the QFD method started when we tried to complete the HOW MUCH section, because the important product requirements were related with multiple consumer demands. Different optimal target values are required for every consumer demand related to the product requirement. QFD does not provide a solution for this problem. For example, the product requirement ‘Concentration of glucosinolates’ has relationships with the consumer demands ‘Preparation time’, ‘Health promoting’, ‘Taste’, and ‘Not toxic’. For each of these consumer demands another optimal concentration of glucosinolates is required, and therefore a single target value (or HOW MUCH) cannot be given. Literature does not mention these problems and no examples can be found dealing with this difficulty. Hofmeister (1991) gives an example of establishing a HOW MUCH value for one product requirement, but he leaves out the fact that this product requirement influences two consumer wishes, as he mentioned earlier.

Figure 2.7 shows the ingredient and process-planning matrix (phase II/III). The product requirements related with the packaging have been left out, since these are deployed in the packaging deployment route (Figure 2.4). In this matrix we encounter the same problem with assigning the target values. Again all the product requirements are related to multiple WHATs, each having its own optimal target value.

		Broccoli			Potato gratin				Marinated salmon			
		Heat treatment	Cutting size	Broccoli variety	Other ingredients	Heat treatment	Cutting size	Potato variety	Other ingredients	Heat treatment	Cutting size	Salmon variety
Time to cook meal		•	•	•	•	•	•	•	•	•	•	•
Conc. fat in meal					•				•			
Conc. glucosinolates in meal		•	•	•								
Crispiness		•	•	•	•	•	•	•	•	•	•	•
Bitterness		•	•	•								
Shelf life		•	•		•	•	•		•	•	•	
Colour of the meal		•		•	•	•		•	•	•		•
Use of raw ingredients		•				•				•		

Figure 2.7 The ingredient and process planning matrix for ready-to-eat meals

2.5 Conclusions

The strengths and the weaknesses of QFD for food NPD have been analysed based on the available literature and our own experience (Table 2.2). This table confirms that QFD is more suitable for product improvements at this moment and not for the development of truly innovative products. The QFD approach ensures that the product is developed according to the wishes of the target group. It takes a large effort and a lot of time to conduct QFD for the first time. However, once it has been executed it will speed up the time-to-market and enable the company to improve the product at less cost. Moreover, the QFD approach will enable the company to produce a better product with a higher chance of success once the right consumer wishes have been determined.

A major drawback of the Four-Phase QFD method is that it might be very hard, or even impossible, to use the Four-Phase model for the improvement of food products. This is due to the complexity of food products, the many interactions between the ingredients and the influence of processes on functional properties of the product. This results in the fact that it is not possible to give precise target values (HOW MUCH) for the product requirements (HOWs). Besides, many ingredients are still physiologically active, leading to a change in the quality of the ingredients during the production process. Food ingredients also show a natural variation in composition. This results in the fact that food ingredients have a larger standard deviation compared to the standard deviation of parts used in other industries. For instance, a screw can be precisely and reproducibly specified on all characteristics e.g. length, weight, and composition of the material, whereas the milk of a cow differs per cow and even during the day. Moreover, one is forced to deploy only the most important consumer demands and the demands new to the company since there are so many consumer demands and design characteristics for each product (Barnard, 1992). The risk is that interactions are overlooked and that, as a result, the final product is not what the consumer asked for. However, the first matrix, namely the House of Quality, is useful to get insight in what information is necessary to make trade-off decisions and to improve the product. A positive feature of using QFD is that the matrices can provide a link between the quality characteristics as demanded by the consumer and the actors in the production chain. In our case study, for instance, they can be linked to the breeder via the product requirement ‘Broccoli variety’.

In spite of the fact that many authors proclaim QFD as a useful tool for food NPD, only few publications are available describing the application of the complete QFD method and go beyond the House of Quality. Most of the publications only give an example of the House of Quality, if there is an example given at all. Combined with our own experiences of using QFD on the development of an improved food product, we conclude that the technique as it is used in other industries cannot be applied in food industries without changes. It has to be realised that in food products the final quality of the product is not only dependent of the quality of the ingredients but also on the processes that are used by the actors in the food production chain. Besides, the interactions between the actors have to be taken into account. If QFD is going to be used for food NPD it is important that we are able to simplify the matrix in such a way that the desired product quality is still achievable and the matrices are manageable. These simplifications have to be underpinned, based on the R&D knowledge of the actors of the complete production chain. Another necessary adjustment is that the target values (or HOW MUCHs) have to be replaced by target intervals. This is due to the fact that the food ingredients are often still physiologically active materials and are subject to changes in time. Based on the foregoing we can say that if QFD can be applied for the development of food products, the method has to be customised.

3

The Chain Information Model (CIM): a tool for systematic product development

M. Benner, R.F.R. Geerts, A.R. Linnemann, W.M.F. Jongen, P. Folstar, H.J. Cnossen (2003). A chain information model for structured knowledge management: towards effective and efficient food product improvement. *Trends in Food Science & Technology, 14* (9): 469-477.

3.1 Introduction

In an attempt to apply the QFD method (Hofmeister, 1991) to an actual case in food product development (NPD), it was concluded that in its present form this approach is not suitable for the development of food products (Chapter 2). The impossibility to set the target values for the product requirements obstructs the translation to the next matrices and therefore QFD in its current format is not suitable to develop a systematic approach to gather and disseminate the information needed for systematic food NPD from a chain-orientated approach. Several authors proposed modifications to the QFD method to make it applicable for use in the food NPD process (Bech *et al.*, 1997a; Bech *et al.*, 1997b; Holmen and Kristensen, 1998). Bech *et al.* (1997a, 1997b) have divided the relationship matrix into a technical relations matrix and a sensory relations matrix, but they only discuss the first matrix (the House of Quality) and do not consider the other matrices. Holmen and Kristensen (1998) encountered the problem that some quality characteristics could not be transformed into ingredients and process characteristics and therefore delegated them to suppliers capable of making these transformations. They introduced separate Supplier-Houses of Quality to the four-house ASI model. However, these adaptations did not prove suitable to solve the problems described in Chapter 2.

Based on the findings in Chapter 2, we set out to develop a tool that facilitates a systematic food NPD process. Elements of the QFD method have been used as a basis for the tool. The NPD tool to be developed, should be a controlled approach to (1) gather, (2) analyse, and (3) disseminate the information needed by each actor in the production chain to contribute maximally in realising an effective and efficient NPD process. We consider a NPD process to be effective if the product is successful from the consumer's point of view, *i.e.* the product is according to the wishes of the consumer. Whether the NPD process is efficient, is considered from the producer's point-of-view. A NPD process is efficient if it is able to develop and produce the product with minimal losses and is able to respond to changes from either the demand side or from the production side, in a rapid way. The tool should be able to support the NPD team to make a founded decision on how to produce the intended product and what resources to use. Several research questions arise from this goal:

- First, to be effective: what are the quality characteristics of a successfully improved product?
- How can the actors in the production chain contribute to this improvement?
- Which scenarios are available to realise the intended product?
- Which scenario is the best?
- Who needs which information from whom to make a decision on how to realise the best scenario?

Basically, the success of a product is determined by the profit a company or a production chain makes by selling the product. This profit depends on the development, production and marketing costs of the product on the one hand, and the revenues from the sales of that product on the other hand. Not only does the consumer have to buy the product once but it should fulfil certain needs of the consumer in order for him or her to buy it again. The product also has to be better in fulfilling these needs than similar products on the market. A possible

way to accomplish this goal is by introducing a new, wanted product feature in an existing, popular product.
For the construction of our tool we used a hypothetical example, namely of the development of a ready-to-eat meal with a new product feature. The new feature chosen for our case is a health benefit, which is realised by incorporating a high amount of glucosinolates (health-supporting secondary plant metabolites) in the broccoli that is part of the ready-to-eat meal. In practice, desired quality characteristics should be determined by means of qualitative and quantitative consumer research. However, for the tool development we used available data on consumer preferences from literature and earlier research conducted at Wageningen University and TNO Nutrition and Food Research in the Netherlands.

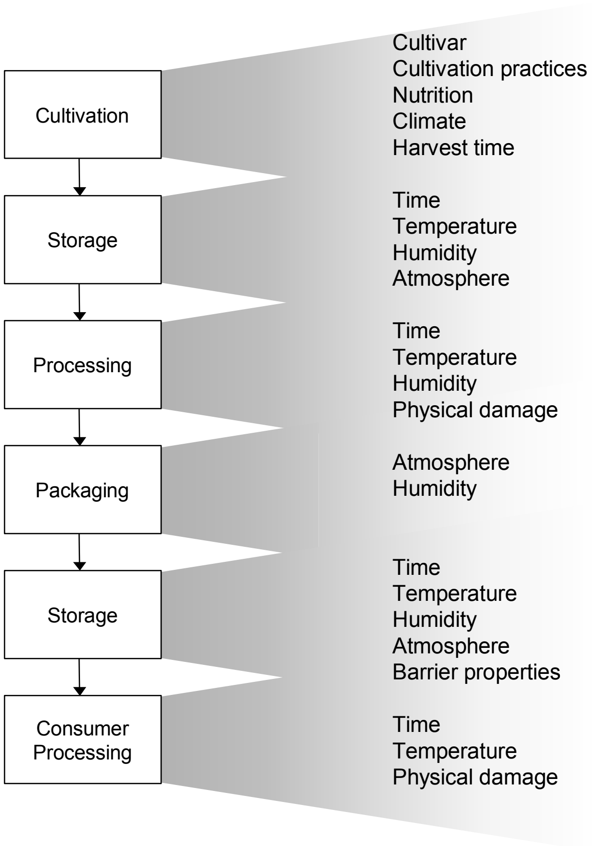

Figure 3.1 Influences of actors in the production chain on the glucosinolate content of Brassica vegetables (adapted from Dekker *et al.*, 2000)

3.2 The hypothetical ready-to-eat meal with a health benefit

The health benefit of the ready-to-eat meal is based on the presence of glucosinolates in the vegetables that are an ingredient of the meal. Glucosinolates are a group of secondary plant metabolites that are present in the *Cruciferae,* a family of plants that includes the Brassica vegetables such as cabbage, Brussels sprouts, broccoli and cauliflower. Glucosinolates co-exist with, but are physically separated from, the hydrolytic enzyme myrosinase in the intact

Brassica plant. Upon mechanical injury of the tissue, the enzyme and substrate come into contact, resulting in hydrolysis. The features of the hydrolysis environment such as pH, temperature and the presence of co-factors determine the proportion and nature of the various breakdown products. Substantial evidence suggests that these hydrolysed glucosinolate products possess important protective properties against cancer. This protective effect against cancer is caused by an induction of already existing protective detoxification systems in the human body (Dekker *et al.*, 2000). These protective compounds can reach the human body in two ways, either directly by consumption of breakdown products of glucosinolates that are hydrolysed by the myrosinase present in the vegetable, or indirectly by consumption of glucosinolates that are present in the vegetable and subsequently hydrolysed into protective compounds by the gut flora.

Verkerk (2002) has researched the amount of glucosinolates and breakdown products in several kinds of ready-to-eat meals. These meals showed a negligible amount of both groups, although there was a difference between the several kinds of ready-to-eat meals (frozen, cook & steam, chill fresh). These differences can be explained by the different processing steps and the preparation by the consumer (microwave versus oven or conventional heating). Dekker *et al.* (2000) demonstrate that many steps in the food production chain of Brassica vegetable products can influence the final intake of glucosinolates or their breakdown products. Some breakdown products are volatile, which means that if they are produced at the beginning of the food production chain they are most likely gone by the time of consumption. Thus, the best way to assure a high amount of health-protecting compounds in the cabbage is to have a high amount of intact glucosinolates in the final product.

Figure 3.1 gives a schematic overview of a food production chain of Brassica vegetables. It shows that all steps in this chain can have an effect on the level of the glucosinolates or their breakdown products. It starts with the cultivation of the vegetable. At this stage both genetic and environmental factors contribute to the variation in levels of glucosinolates. The next important step in the production chain is the post-harvest treatment. As a result of ageing, some hydrolysis of the glucosinolates can take place during harvest and storage, resulting in a loss of glucosinolates and their breakdown products. Also during transportation the amount of glucosinolates is influenced, namely by gas conditions, humidity, and temperature.

Vegetables used in ready-to-eat meals undergo different types of processing before consumption. These processing activities may comprise, in the case of usage in ready-to-eat meals: washing, cutting, and blanching (or a less mild heat treatment). In the case of the Brassica vegetables, any process that disrupts cellular integrity may result in some glucosinolate hydrolysis. Besides the breakdown of glucosinolates by hydrolysis, Verkerk *et al.* (2001) found that cutting of several Brassica vegetables and storage in air resulted in a remarkable increase of some glucosinolates.

With respect to the heating process of the vegetables, cooking in water results in a substantial loss of protective compounds by leakage in the cooking water. Mild heat treatment of the vegetables, like microwave heating, results in high retention of the glucosinolates and limited inactivation of the hydrolytic enzyme myrosinase. Subsequently, hydrolysis of the glucosinolates can take place either by plant myrosinase during mastication in the mouth or by colonic microflora in the gut.

In conclusion, the variation in glucosinolate content in cabbage in ready-to-eat meals as affected by the production chain depends on: (1) genetic and environmental factors during primary production (determining the quantity of glucosinolates in the original raw foods), (2) the extent and nature of processing (industrial and domestic), and (3) the packaging and storage conditions.

Dekker *et al.* (2000) estimate that glucosinolate levels in consumed food products easily can have a 5 – 10 fold variation at raw material level (e.g. due to cultivar differences), a 5 – 10 fold variation caused by differences in industrial processing and storage, and a 5 – 10 fold variation due to household preparation (e.g., cooking practices). Consequently, the authors expect an intake variation of at least 100 fold between individual consumers.

3.3 The construction of the NPD tool

In general, the main reason for consumers to buy ready-to-eat meals is convenience. Consumers either do not have the time for cooking their own meals, or they do not want to spend time on cooking (Anon., 1998). Moreover, at the moment health is a popular topic for all food products. Consumers are more than ever concerned with their health and are looking for healthy foods (Anon., 1996a; Anon., 1996b). This health attribute is also sought for in the new generation of ready-to-eat meals that go beyond the TV dinners. Consumers are asking for the so-called chill-fresh meals that have had little or no industrial pre-heating. An often criticised characteristic of ready-to-eat meals is the taste. According to the Central Agency for Food Products (CBL) in the Netherlands 60 % of the consumers that buy ready-to-eat meals are not satisfied with the taste (Anon., 1996b). An additional consumer demand is safety of the product (Samuelsson, 1999; Zuurbier and Migchels, 1998; Anon., 1998; Anon., 1996a). Consequently, important primary consumer demands are convenience, healthiness, taste, and product safety. These primary consumer demands have to be made operational by translating them into secondary, more specific demands (Table 3.1).

Table 3.1 Consumer demands for ready to eat meals

Convenience	Short preparation time
	Easy to open package
Healthiness	Low fat content of the meal
	Contains health promoting ingredients
	Freshness of ingredients used
Sensory characteristics	Mouthfeel
	Taste
	Colour
Safety	Microbial safety
	Chemical safety Physical safety

The matrix structure and some elements of the first house (the House of Quality) of the QFD method have been used to construct a new matrix (Figure 3.2). We left out the target values (or how much), the customer competitive assessment, the engineering competitive assessment, and the roof of the matrix because these parts were not necessary for our goal, which was to provide a relationship between the quality characteristics of the product and the actors in the production chain. We replaced the product requirements with the actors of the production chain in order to get a direct link between the quality characteristics of the product and the actors. In the central matrix the relationships between the quality characteristics and the actors are given. Also from the central matrix the correlations (or dependencies) between the actors can be derived for one quality characteristic.

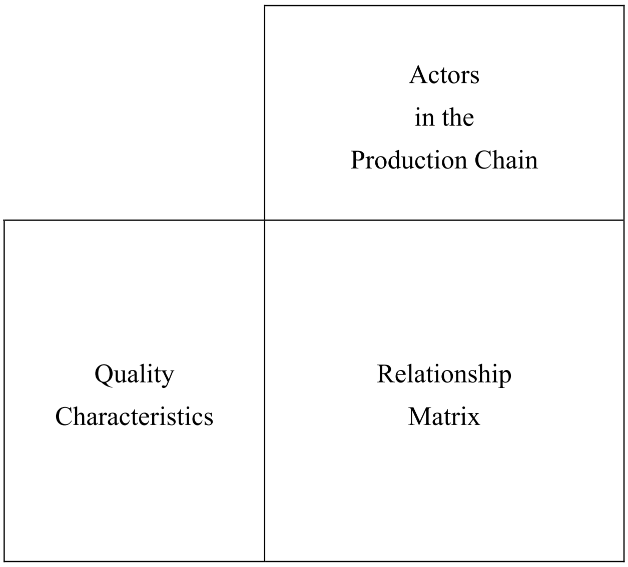

Figure 3.2 The information matrix

The production chain and production processes have to be analysed before determining the influence of the actors on the quality characteristics of the product. Figure 3.3 shows a production chain of ready-to-eat meals. Experts within Wageningen University and literature analysis have been used to systematically determine what processes in the production chain can influence the quality characteristics. This systematic approach can be visualised in Quality Dependence Diagrams (QDD) (Figures 3.4 - 3.7). In the QDDs some actors are indicated with a dotted line, because these actors are supposed to follow the proper instructions coming with the product. The handling by these actors does not have a large influence on the product and the glucosinolate content will not be affected much. Moreover, the throughput time is rather high and therefore not much influence is expected. An exception is the household situation, since by application of wrong heating practices the glucosinolate content of the meal can be lowered dramatically. It is assumed that such a negative effect can be diminished by correct and clear instructions on the package.

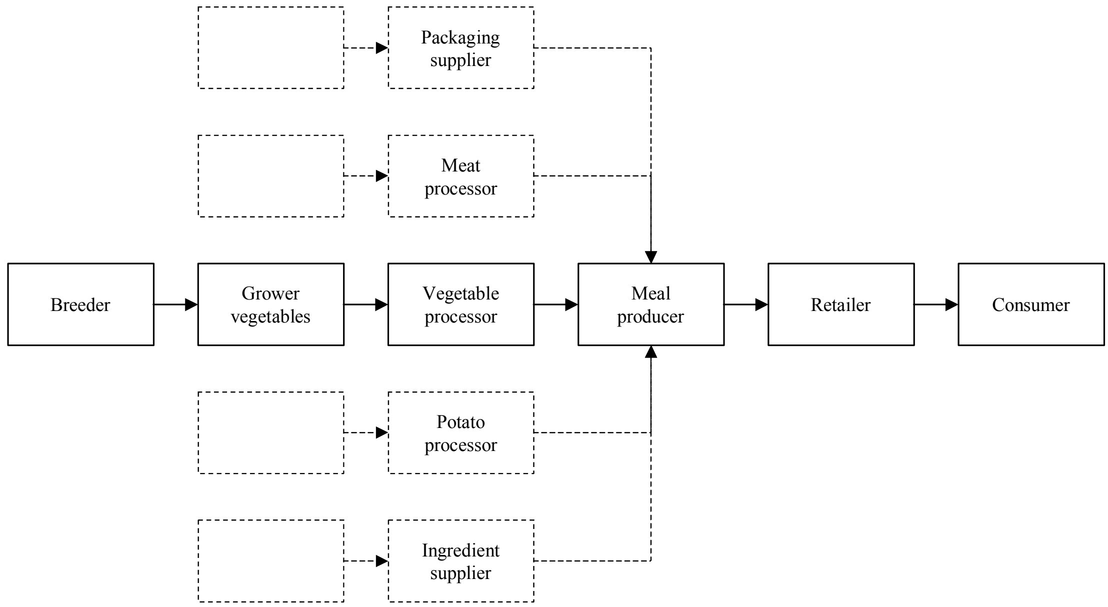

Figure 3.3 Production chain ready-to-eat meals

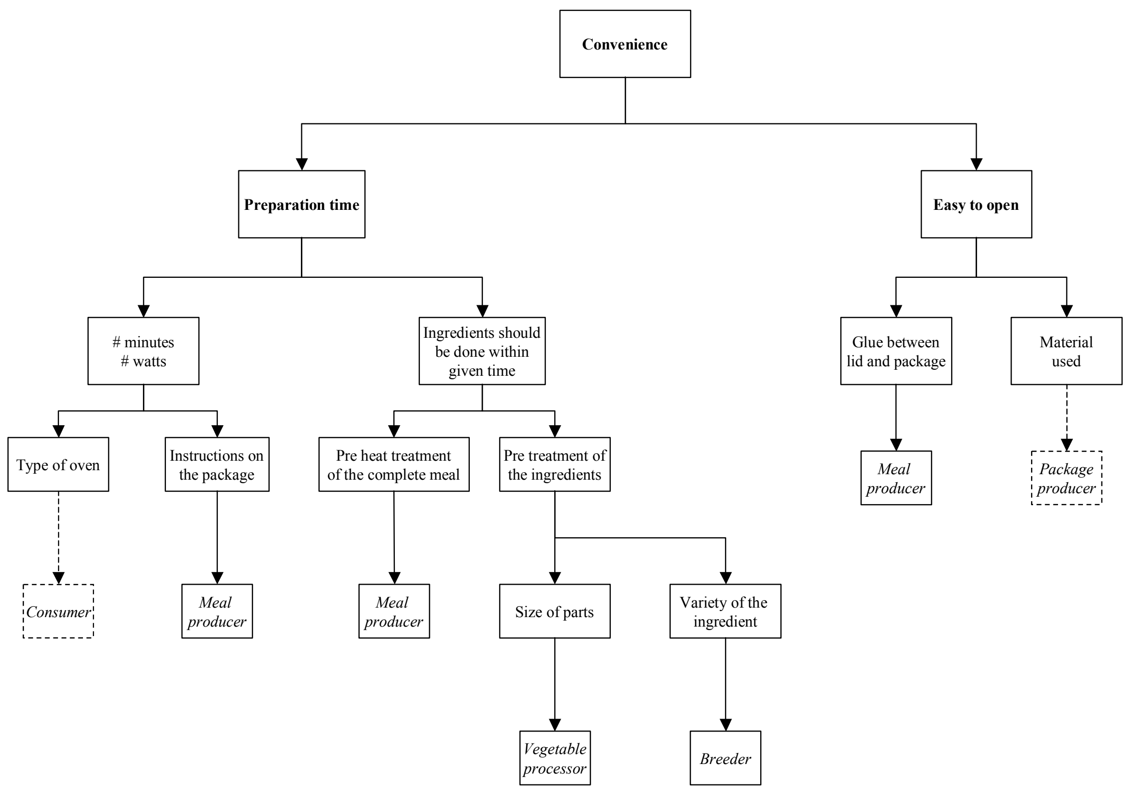

Figure 3.4 The Quality Dependence Diagram (QDD) for the quality characteristic ‘convenience’

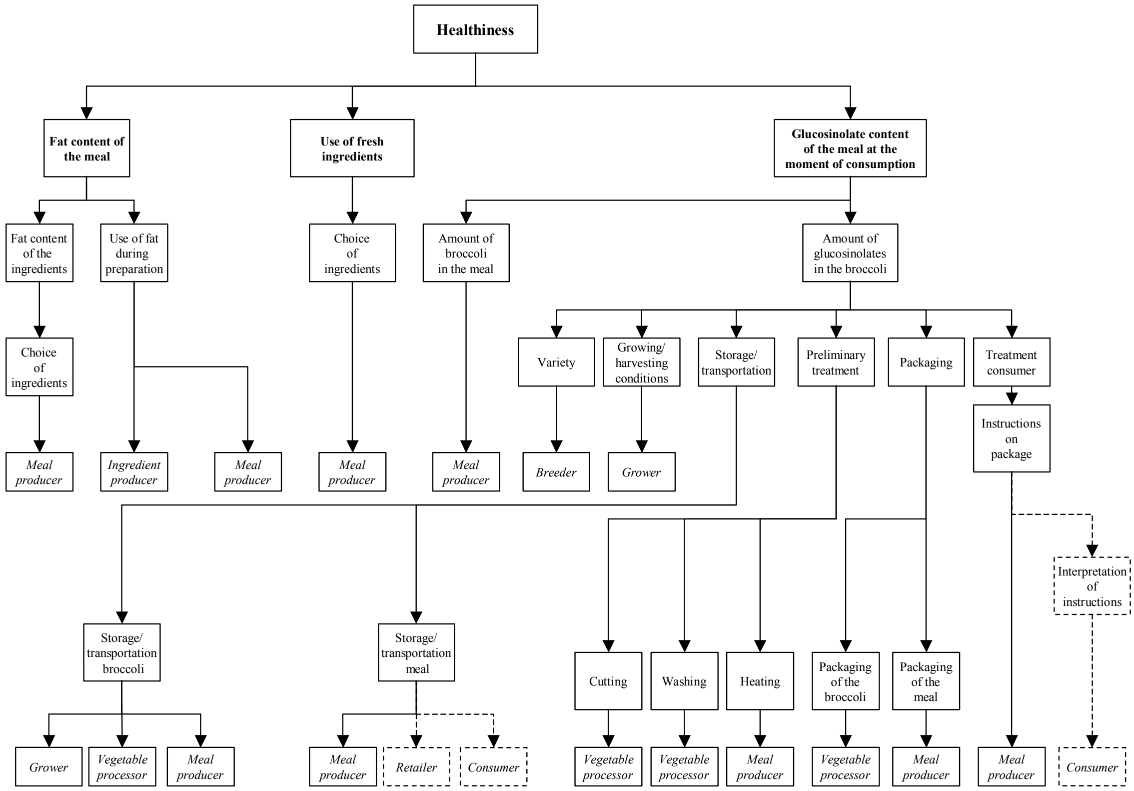

Figure 3.5 The Quality Dependence Diagram (QDD) for the quality characteristic 'healthiness'

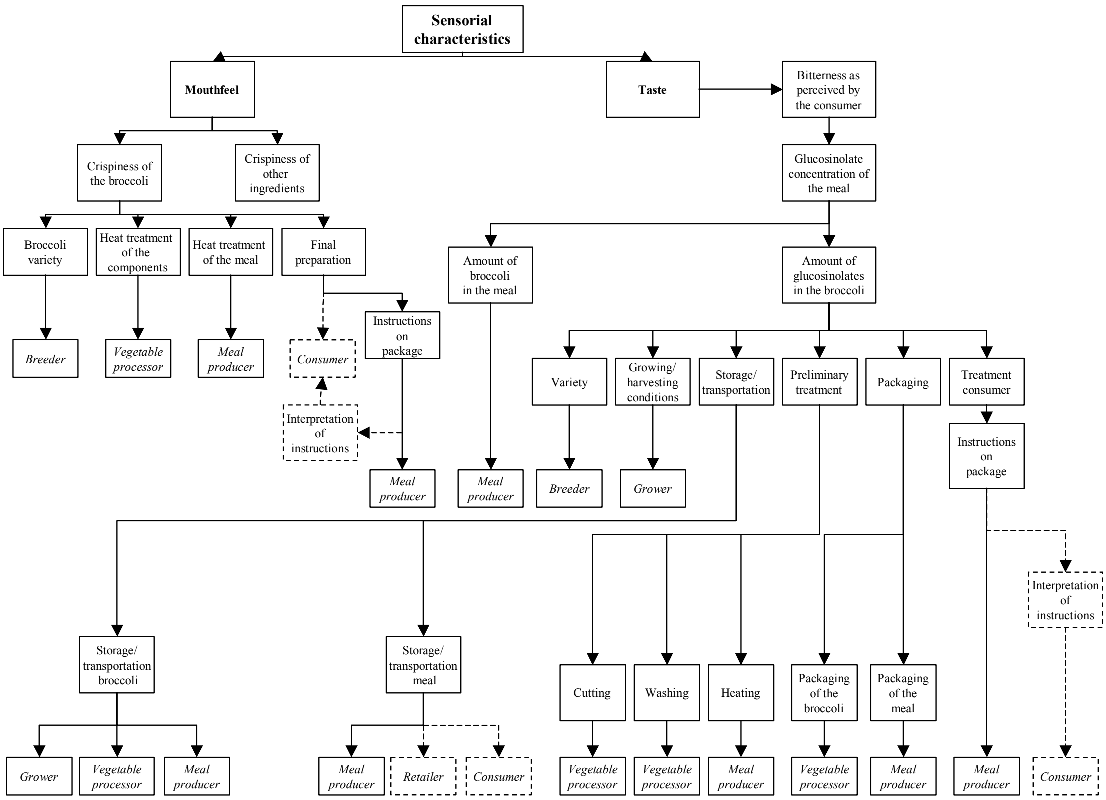

Figure 3.6 The Quality Dependence Diagram (QDD) for the quality characteristic 'sensorial characteristics'

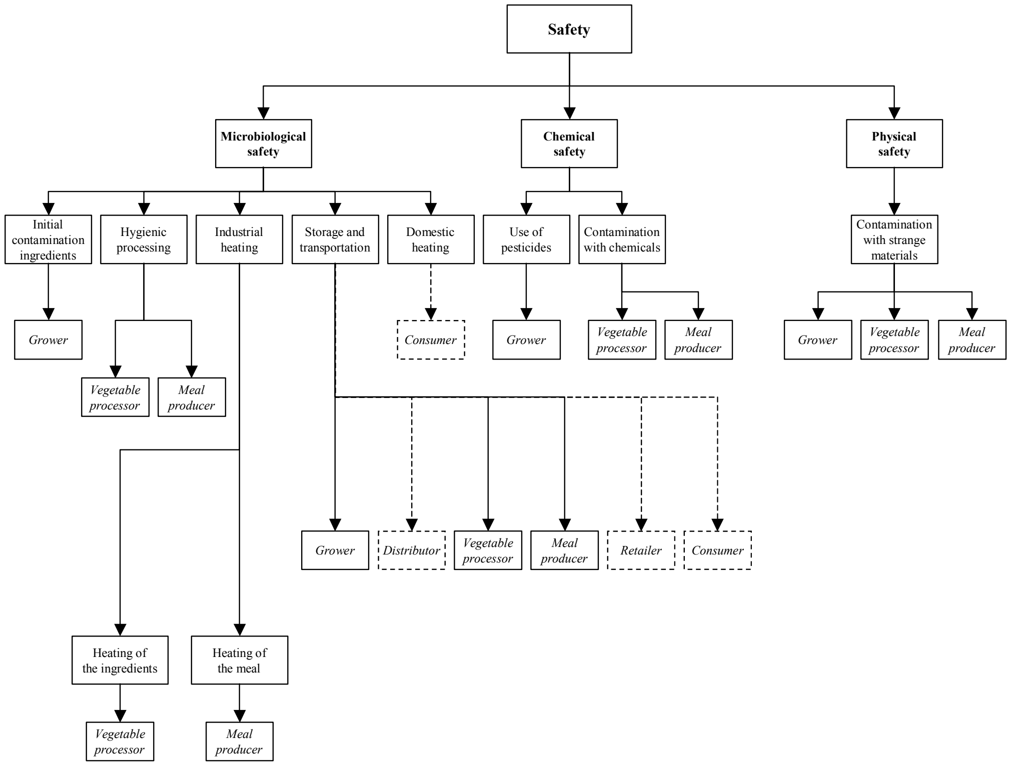

Figure 3.7 The Quality Dependence Diagram (QDD) for the quality characteristic 'safety'

With the information from the Quality Dependence Diagrams, the relationship matrix in Figure 3.2 can be completed (see Figure 3.8). A distinction has been made between strong and weak relationships. Strong relationships are with actors that have a direct influence on the quality characteristics. Actors that do not directly or actively influence the quality characteristics have a weak relationship. These actors are supposed to follow the procedures given with the product, for instance for handling and temperature.

Now that all the required information is gathered, it has to be combined to determine the possible scenarios for realisation of the intended product. These scenarios are formulated following a systematic analysis of the options for every actor in the production chain to realise the desired amount of glucosinolates in the meal. For every possible change made by an actor, the consequences for the other quality characteristics and for the other actors have to be identified. Decision trees have been developed to systematise the scenarios.

Consumer Demands	Actors	Breeder	Grower	Vegetable processor	Meal producer	Retailer	Consumer
Convenience	Preparation time	●		●	●		○
	Easy to open				●		
Healthiness	Fat content				●		
	Glucosinolate content	●	●	●	●	○	○
	Use of fresh ingredients				●		
Sensory characteristics	Taste (bitterness)	●	●	●	●		○
	Mouthfeel	●	●	●	●		○
	Colour	●			●	○	○
Safety	Microbiological safety		●	●	●	○	○
	Chemical safety		●	●	●		
	Physical safety		●	●	●		

Figure 3.8 The Information Matrix for ready-to-eat meals (●: strong relationship, ○: weak relationship)

From the Information Matrix (Figure 3.8) it is clear that all the actors can influence the glucosinolate content, resulting in a higher amount at the moment of consumption. We start with the possibilities the *vegetable breeder* has to influence the glucosinolate content. From Dekker *et al.* (2000) it is clear that the breeder has three options to raise the glucosinolate content: (1) by selection of an existing variety with a higher glucosinolate content, (2) by cross breeding, and (3) by genetic modification. For each option the consequences for other quality characteristics have to be examined before a choice regarding the best option can be made. First we suppose that the breeder has another broccoli variety at his disposal with the desired amount of glucosinolates. Figure 3.8 shows that broccoli varieties may differ with respect to the following quality characteristics: 'preparation time', 'taste (bitterness)', 'mouth-feel', and 'colour'. The preparation time of the meal can change, because the alternative variety might have a more firm texture. Whether this change in preparation time is acceptable, has to be checked with the consumer, and therefore consumer acceptability intervals for the quality characteristics have to be defined. If there is no change in the preparation time or if the change is within the acceptability interval, the development team has to check the other quality characteristics for changes. If there is a change in the preparation time, the production chain has to be checked for solutions to counterbalance this change. For instance, the cooking time of the broccoli can be shortened by cutting the broccoli in smaller pieces. This results in the need for an information flow from the breeder to the vegetable processor. However, cutting the broccoli in smaller pieces can also result in loss of glucosinolates. This solution therefore has to be checked for its consequences on the other quality characteristics to find the desired equilibrium. If the combined efforts of all actors in the production chain cannot compensate for the changes, using an alternative broccoli variety is no option to enhance the glucosinolate content in the ready-to-eat meal, and other possibilities have to be considered. This systematic approach is depicted in Figure 3.9.

After the suitable broccoli variety is obtained, the *grower* cultivates the vegetable to maturity. The grower can influence the amount of glucosinolates in the vegetable by changing the cultivation conditions. Literature states that the following factors can influence the glucosinolate amount: cultivation practices, fertilisation, climate, and harvesting time (Dekker *et al.*, 2000). In Figure 3.10 the decision tree for the grower is given.

The *vegetable processor* can influence the glucosinolate content of the broccoli by the procedures that are used for cutting, washing and storage (Dekker *et al.*, 2000). By cutting the vegetable, the enzyme myrosinase can get into contact with the glucosinolates and breakdown products are formed. Since these breakdown products are volatile, they will be lost at the moment of consumption (De Vos and Blijleven, 1988). Verkerk *et al.* (2001) observed increased levels of indolyl glucosinolates after chopping and storage under ambient conditions.

Washing conditions can influence the glucosinolate content in several ways, since the glucosinolates are soluble in water. For instance, the timing of the washing is relevant; washing before or after cutting the broccoli can influence the glucosinolate level. The temperature also influences the levels; hot water will result in a higher loss. The washing method can influence the loss too. Usually vegetables are washed by spraying or by dipping into water. Dipping prolongs the contact time between vegetable and water, and hence results in higher losses of glucosinolates (Verkerk, 2002). In addition, storage conditions influence the glucosinolate content. Hansen *et al.* (1995) report a 42 % increase of the amount of glucosinolates in broccoli after a 7 days storage under air and a 21 % increase after storing the vegetable for 7 days under 0.5 % O_2 + 20 % CO_2, and a 15 % decrease after storing under 20 % CO_2. Before one of these options can be applied, the consequences for the consumer have to be examined.

Figure 3.8 indicates that the vegetable processor can influence the consumer demands ‘preparation time’, ‘mouth-feel’, ‘microbiological safety’, ‘chemical safety’, and ‘physical safety’. If the vegetable processor changes the cutting procedure by cutting the vegetable in larger pieces, this can influence the preparation time for the consumer. However, the meal producer can compensate this by applying a mild heat treatment. Another way to counterbalance the longer preparation time is by applying a higher energy level during the microwave heating by the consumer, and therefore the information on the package has to be adjusted to provide the consumer with the right preparation instructions. Figure 3.11 shows the systematic analysis for the scenarios for the vegetable processor.

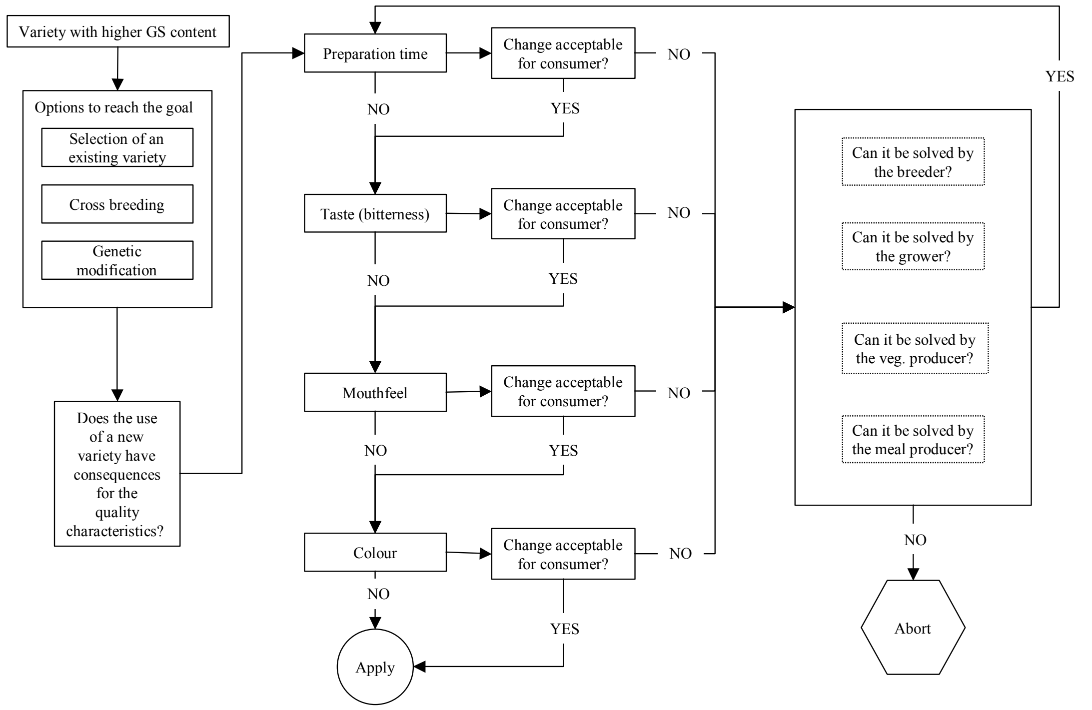

Figure 3.9 The decision tree for the breeder

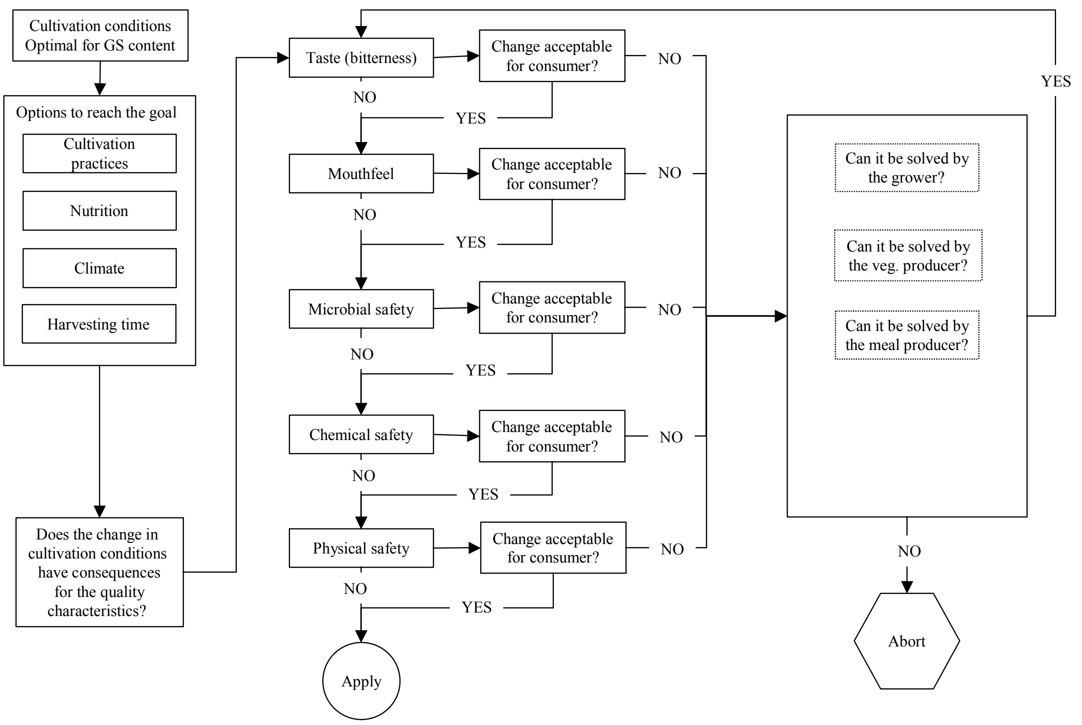

Figure 3.10 The decision tree for the grower

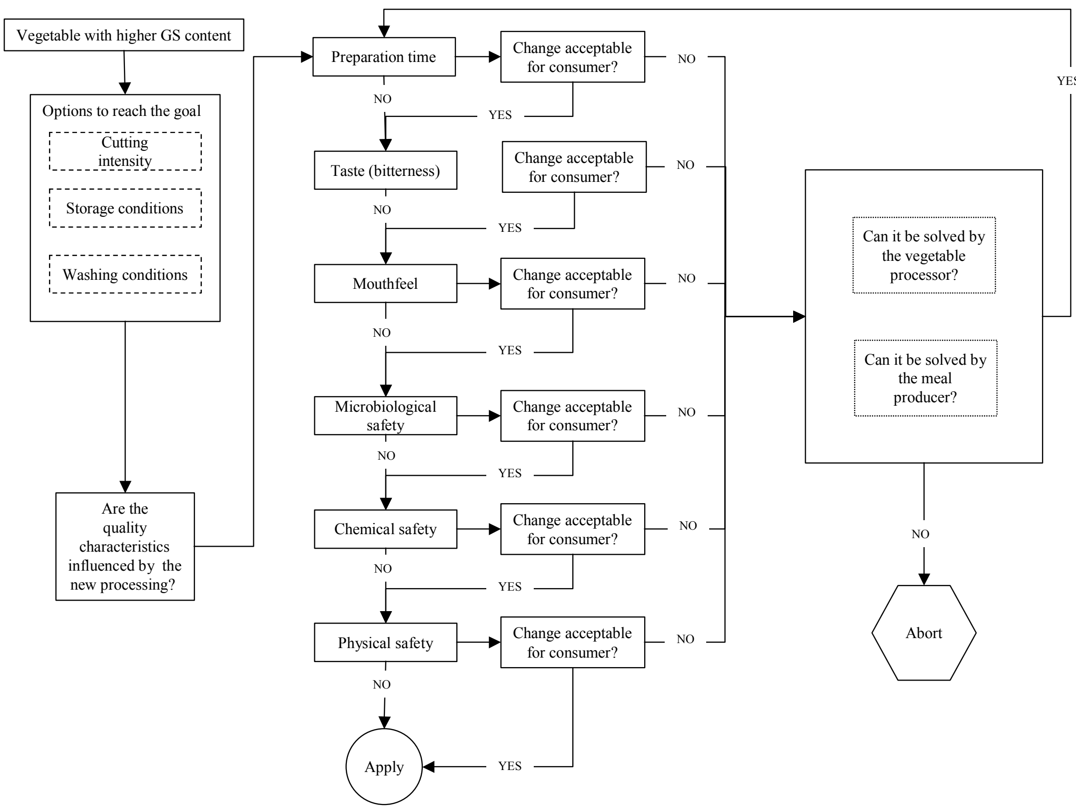

Figure 3.11 The decision tree for the vegetable processor

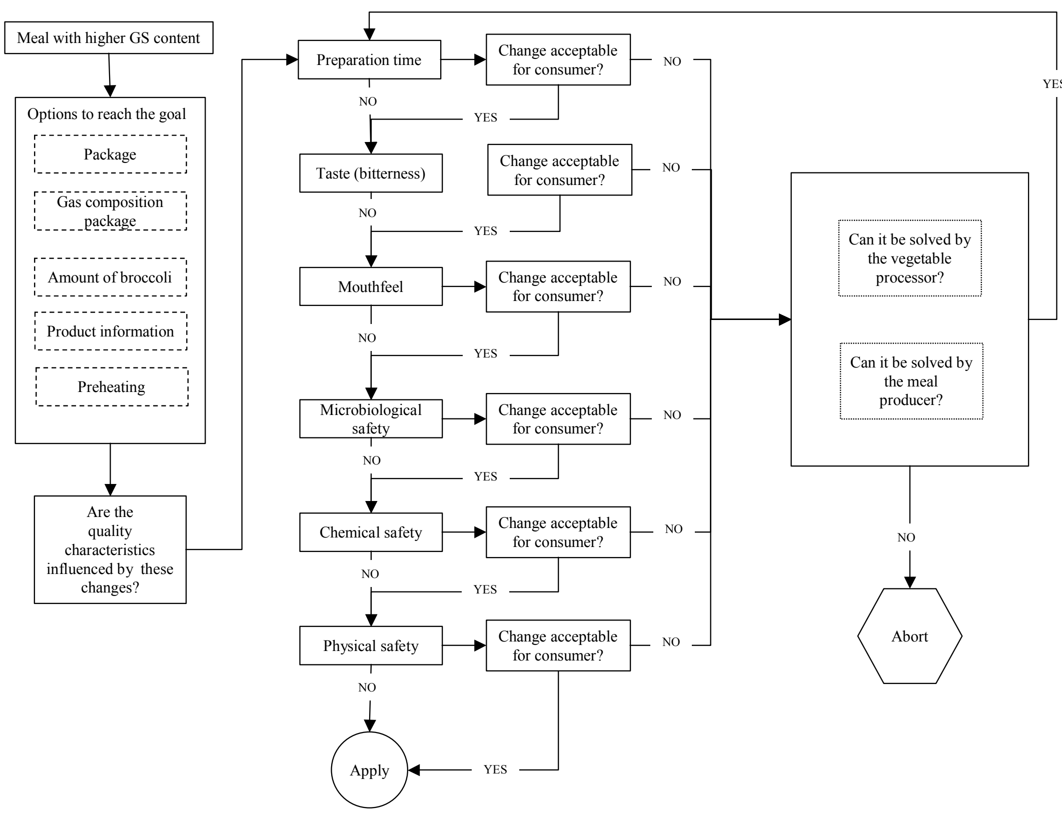

Figure 3.12 The decision tree for the meal producer

After the vegetable has been processed, it is transported to the *meal producer*, who assembles, packages and processes the ingredients into a ready-to-eat meal. Figure 3.12 shows the decision tree for the meal producer. The meal producer has several options to deliver a meal with a higher amount of glucosinolates at the moment of consumption. Depending on the treatment the meal is given to extend the shelf-life, the product is heated. Heat treatment reduces the amount of glucosinolates considerably (Dekker *et al.*, 2000). Processes that can take place during cooking are:

- (partial) inactivation of myrosinase;
- heat degradation of glucosinolates and breakdown products;
- enzymatic breakdown of glucosinolates;
- loss of enzymatic co-factors (ascorbic acid, iron);
- leaching of glucosinolates and breakdown product in cooking water.

A different heating method, like micro-wave heating, can result in a smaller loss of glucosinolates. In order to prevent any possible effect of a different heating method on the other quality characteristics (Figure 3.8), these have to be cross-checked. Another possibility within the meal producer's power is to change the amount of broccoli in the meal.

When all decision trees for all the actors that have a strong relationship with the quality characteristic 'glucosinolate content' have been constructed, the best scenario to increase the glucosinolate content of the meal has to be chosen. Therefore the alternatives have to be prioritised against criteria that are defined by the actors in the production chain. Profitability and technological feasibility are important criteria to select the most preferable scenario. An optimal situation for the production chain as a whole does not imply an optimal situation for all individual actors. Producing a successful product might imply that some actors have to invest more and get less in return on the short term. Once the best scenario has been determined, it has to be incorporated into the production chain by informing each actor accordingly.

3.4 The NPD tool

Based on the theoretical development of the improved ready-to-eat meal, we propose to use this systematic approach as a tool to gather and disseminate the information needed by each actor in the production chain to realise an effective and efficient NPD process (Figure 3.13).

We have divided the tool into three phases according to the required activities. Phase 1 encompasses the collection of information needed to formulate the possible scenarios to realise the intended product. Three different kinds of information are needed:

A. Information regarding the actors (= companies) involved in the production process of the current product on which the improved product is based, and information regarding the processes the product is subject to. Output is a list of actors and a process scheme of the current production process from seed to final product.
B. The consumer wishes regarding the current product.
C. The new product feature on which the improvement is based.

In phase 2, the information that is gathered in phase 1 is processed (Figure 3.13D) into scenarios. To do so, one has to know, not only how the production process influences the new product feature, but also how the other quality characteristics depend on the production process. Knowledge from experts and literature together with the Quality Characteristics, process schemes and information regarding the new product feature from Phase 1 is used to create Quality Dependence Diagrams (QDD) to systematically determine these influences (Figure 3.14). By constructing QDDs for each quality characteristic, relationships between actors and quality characteristics can be determined. However, this will generate much information that is hard to comprehend. Therefore, the information of the QDDs is put in an Information Matrix, which enables the NPD practitioners to comprehend the information at one glance. The Information Matrix indicates which actors can influence the new product feature. This information together with information from phase 1 (Figure 3.13C) is used to construct Decision Trees (Figure 3.15), which are the scenarios with possible options to realise the intended product. These scenarios contain all the information needed for the actors for an efficient and effective production process (Figure 3.13E). Once the possible scenarios have been obtained, the 'best' scenario has to be selected (Figure 3.13F: Selection best scenario) and the information needed by each actor to implement this scenario has to be distributed (Figure 3.13G: Essential information flows). This is depicted in Figure 3.13 in phase 3.

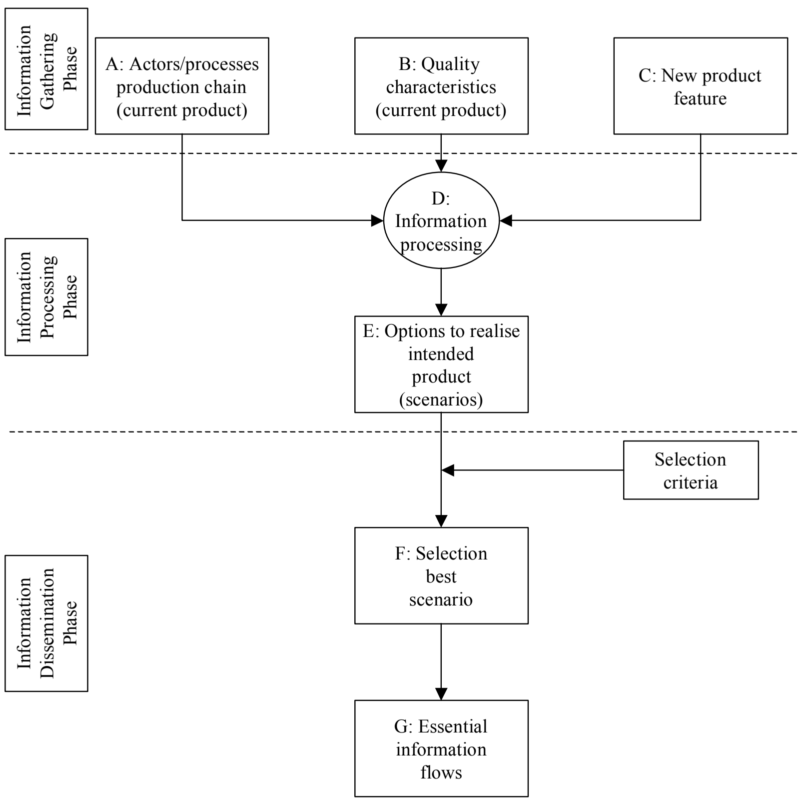

Figure 3.13 The Chain Information Model (CIM)

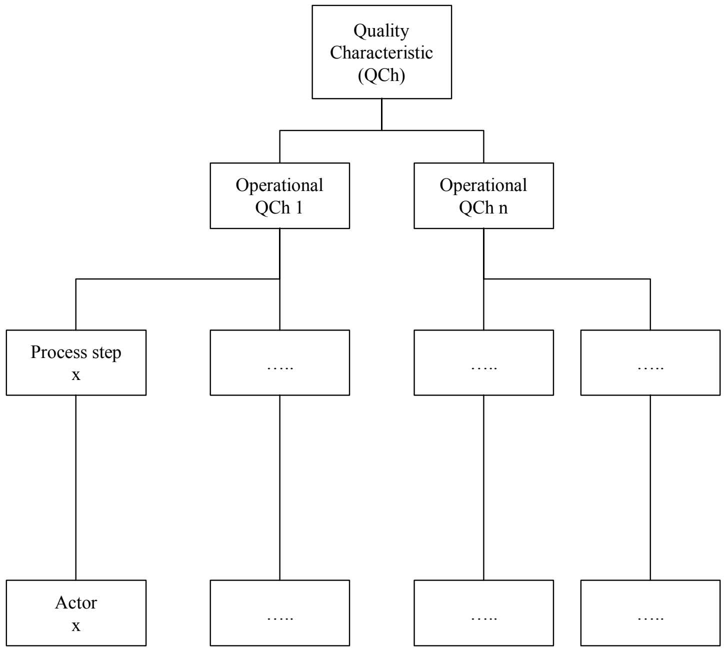

Figure 3.14 Generic Quality Dependence Diagram (QDD)

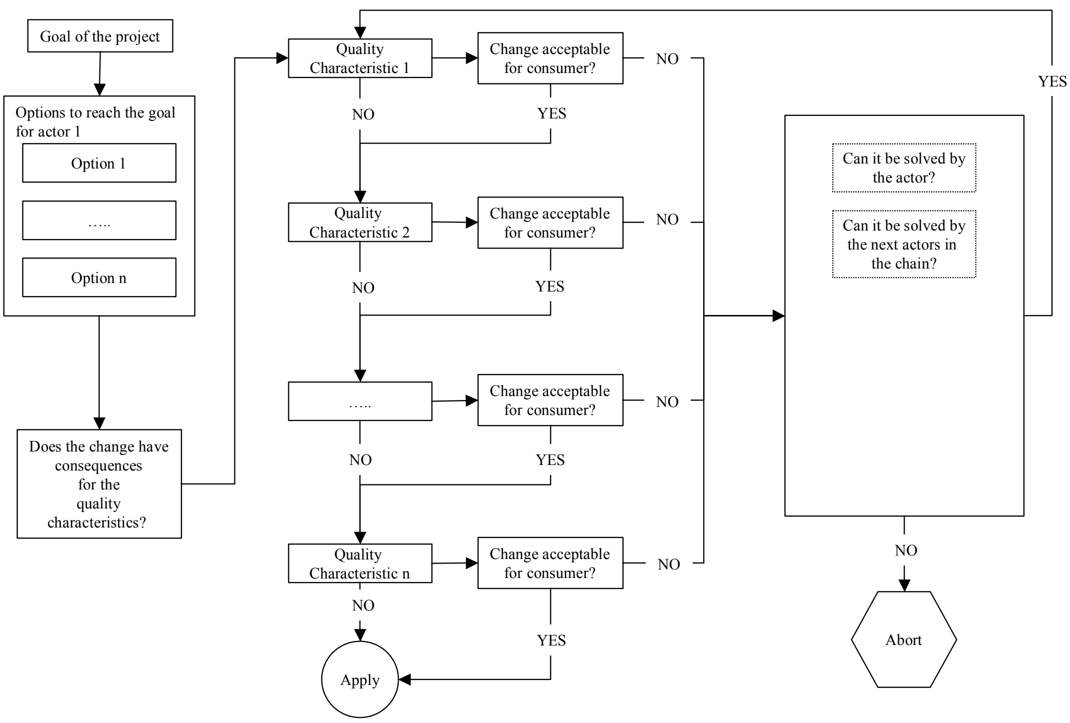

Figure 3.15 The decision tree generic

3.5 Conclusion

With the Chain Information Model (CIM) we have developed a tool for NPD teams to improve products in an efficient and effective way within production chains. In summary, the approach comprises three phases, namely the information-gathering phase, the information-processing phase and the information-dissemination phase: (1) *gather information concerning the quality characteristics*, the current production process of the concerned product and information regarding the new product feature that has to be built in; (2) *determine the influence of the production chain on the consumer wishes and on the new product feature.* Process this information into scenarios describing the options to realise the intended product. Tools to process this information are the Quality Dependence Diagrams (QDD) and the Information Matrix; (3) *establish the chain targets (selection criteria).* Determine the most preferable scenario, given the chain targets and distribute the necessary information among the actors of the production chain. In practice companies are not part of a production chain but form a production network. Therefore a distinction has to be made between tactical information and operational information. An actor only has to share operational information with the other actors. In our example the operational information is what an actor has to do to raise the total amount of glucosinolates and the tactical information is the specific glucosinolate that has the beneficial properties.

The conceptual tool provides participants of production chains with a systematic approach to map out the options for the chain to realise an intended product and to unravel the information flows necessary for its effective production. The strength of this approach is that it forces the expert teams to systematically review all the options and the results of changes in the production process in advance. It also provides feedback to the quality characteristics of the product from the consumers' point of view and in this way prevents the occurrence of unexpected product failure. Using this approach the development costs can be lowered and the chance of success improved. The approach also demonstrates that often much information is already available, either within the production chain or in scientific publications. The Chain Information Model can also prove to be valuable to capture knowledge that only exists as expert knowledge for the continuity of the organisation.

On the other hand, the implementation of this approach demands a change of current types of cooperation between the actors in the production chain. Actors have to be more open and willing to share information among each other and with the consumer.

4

The Chain Information Model (CIM) for a systematic product development process: an explorative study on the use of the model for the development of tomato ketchup with increased lycopene content

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4.1 Introduction

In the previous chapter the development of the conceptual Chain Information Model (CIM) has been presented, using the theoretical production of a ready-to-eat meal with a health benefit in the form of an increased amount of glucosinolates. To test the use and applicability of the CIM for efficient and effective product development (NPD) in a 'real-life' situation, an exploratory investigation has been conducted in an actual chain on another food with a health benefit, namely the production of tomato ketchup with increased lycopene content. Tomatoes are the main source of lycopene in the human diet (Shi and Le Maguer, 2000). Lycopene is beneficial for human health, and processing of tomatoes enhances the bioavailability of lycopene (Shi and Le Maguer, 2000). However, many factors in the production process can influence the final amount of lycopene in the product. The CIM was used to elaborate different options in the production chain to produce ketchup with increased lycopene content. As outlined in Chapter 3, the CIM consists of three phases: (Figure 3.13): (1) the information-gathering phase, (2) the information-processing phase, and (3) the information-dissemination phase. The options that were generated by the application of the CIM, were discussed with actors from the production chain. Also the general use of the CIM and the benefits of the model for use in a business situation were discussed.

4.2 Lycopene

In epidemiological studies, consumption of tomatoes, tomato sauce and pizza is associated with a reduced risk of developing digestive tract and prostate cancers (Rao *et al.*, 1998; Giovannucci, 1999; Bramley, 2000; Giovannucci *et al.*, 2002). Lycopene is assumed to be one of the major active agents of this protection, since tomatoes constitute the almost exclusive source of lycopene. Lycopene is a carotenoid, which provides the tomato with its red colour. Lycopene has the highest TEAC (Trolox-Equivalent Antioxidant Capacity) value of all carotenoids, although it lacks provitamin A activity (Bramley, 2000). Lycopene is an acrylic carotene with 11 conjugated double bonds, which can undergo isomerisation to produce cis-isomers. In most foods, lycopene occurs in the all-trans configuration, which is the most thermodynamically stable form. However, the double bonds are subject to isomerisation, and various cis isomers (mainly 5, 9, 13, or 15) are found in plants and plasma (Schierle *et al.*, 1997; Rao and Agarwal, 1999; Bramley, 2000).
Sources for lycopene are tomatoes and tomato products, watermelon, guava, rosehip, papaya, carrots and pink grapefruit (Table 4.1). Tomatoes and tomato products are considered the main sources of lycopene in the human diet, and are, for example, the second highest produced and consumed vegetable in the U.S.A. (Willcox *et al.*, 2003). Tomato products provide an estimated 80 % of dietary lycopene in the U.S.A., where the consumption of both fresh and processed tomatoes has increased nearly 30 % in the last two decades (Willcox *et al.*, 2003). In a survey that was conducted by the authors about 30 % of the consumers reported a daily use of fresh tomatoes, 60 % of processed tomato products, 30 % of tomato sauces, 7 % of paste and 15 % of the consumers reported a daily use of ketchup (Willcox *et*

al., 2003). Rao *et al.* (1998) have evaluated the lycopene content of different tomato products and estimated the daily intake levels in Canada. They observed that the average daily intake of lycopene was 25,2 mg, of which fresh tomatoes provided 50 % and processed tomato products provided the rest. Of the processed tomato products 2 % of the lycopene intake was provided by ketchup (Rao *et al.*, 1998). Precise figures about the required amount of lycopene intake to obtain health benefits are absent.

Literature reports that the amount of lycopene in processed tomatoes is generally higher than in raw tomatoes (Table 4.2). This is explained by the fact that processing tomatoes enhances the release of lycopene from the matrix, which is made more accessible for extraction (Dewanto *et al.*, 2002; Van het Hof *et al.*, 2000). Moreover, processing results in increased bioavailability. This has a direct influence on both sensory quality (the red colour of the tomato product) and on the health benefit. On the other hand, processing can result in some lycopene loss due to isomerisation and oxidation (Shi and Le Maguer, 2000).

Table 4.1 Lycopene content of fruits and vegetables (Sources: Rao and Agarwal, 1999; Shi and Le Maguer, 2000)

Product	**Lycopene content (mg/100 g)**
Watermelon	2.3 – 7.2
Guava	5.23 – 5.50
Rosehip	0.68 – 0.71
Papaya	0.11 – 5.3
Carrots	0.65 – 0.78
Pink grapefruit	0.35 – 3.36
Fresh tomatoes	0.72 – 20

Table 4.2 Lycopene content of processed tomatoes (Sources: Rao and Agarwal, 1999; Schierle *et al.*, 1997; Bramley, 2000; Shi and Le Maguer, 2000; Tonucci *et al.*, 1995; Hart and Scott, 1995)

Product	**Lycopene content (mg/100 g)**
Fresh tomatoes	0.72 – 20
Cooked tomatoes	3.7
Tomato sauce	6.2 – 17.98
Tomato paste	3.7 – 150
Tomato soup (condensed)	7.9
Tomato powder	112.6 – 126.6
Tomato juice	5.0 – 11.6
Tomato ketchup	3.0 – 17.23
Pizza sauce	6.51 – 19.45

Table 4.3 The quality characteristics for tomato ketchup

The best to eat	Easy to serve	Flows easily from the bottle
		Pours without scattering
	Healthy	Contains less salt
		Sweet but no sugar
		Amount of lycopene
		Bioavailability lycopene
		Contains no preservatives
		No artificial flavours
		No thickeners
		Contains no fat
	Appearance	Natural colour
	Tasty	Tomato aroma
		Sweet taste
		Not too acid
		Spicy
		Can feel the taste of vinegar
		Can feel the taste of tomatoes
		It is thick in the mouth
	No defects	Manufacturing waste is reduced
		Never spoils
	Others	Available in different tastes/varieties
Good packaging/ Label	Clear information	Proper storage indications
		Innovative usage suggestions
		Tomato content information
		Environmental-friendly practices information
	Best package	Can see the product inside
		Different sizes are available
		Can be squeezed
		Easy to handle and use
		Can be reduced or recycled
		No ketchup on the lid
		Possible to put bottle upside down

4.3 Application of the Chain Information Model (CIM)

The goal of this exploratory investigation is to produce tomato ketchup with a higher amount of lycopene as compared to the current product. To realise this product in an efficient and effective way the CIM was applied as discussed in Chapter 3 (Figure 3.13). This process has been conducted in close co-operation with professionals from industry.
The effects of processing on the amount of lycopene have to be known to guarantee a lycopene-rich ketchup at the moment of consumption. Although many processes in the production chain influence the amount of lycopene, and many of these effects are not quantified, general directions and orders of magnitude of the effects can be given. Moreover, the required amount of lycopene intake to obtain health benefits is not yet assessed by nutritionists. Therefore an assumption was made based on a literature review.

4.3.1 The information-gathering phase

In the information-gathering phase, phase 1 of the CIM, the information needed for the development of the new product is collected. Three kinds of information are required to complete this phase. First, the quality characteristics should be determined that are responsible for the success of the current product, of which the new product is an improvement. Therefore, consumer demands regarding this product need to be assessed. Second, the current production chain, including actors and production processes, is mapped out. Third, information on the influences of the entire production chain on the new product feature is gathered to determine possible changes to the quality characteristics.

Quality characteristics that make the current product successful. The quality characteristics of tomato ketchup, as formulated by consumers, were established in previous research by Costa *et al.* (2001a), the results are shown in Table 4.3. These quality characteristics were evaluated and up-dated by experts and then used as input for the CIM.

The current production chain. The production chain has been mapped in close cooperation with participants from the production chain (Figure 4.1). The tomatoes are grown in the south of Europe. The tomatoes are harvested in September/October and are subsequently transported to nearby paste factories. The tomatoes are processed into paste within one day from harvesting (Figure 4.2). At arrival at the paste plant, the tomatoes are washed and sorted. Only the red, ripe tomatoes are processed. Depending on the paste plant, the tomatoes are cut before further processing. Next, either a hot break (ca. 1 minute at 90 – 95 ºC) or a cold break (ca. 1 minute at 70 ºC) heat treatment is used. For the tomato ketchup production hot break paste is needed. Cold break paste is used for juices and vegetable cocktails. In cold break paste the pectolytic enzymes are activated, which subsequently destroy the cell walls. Cold break paste has a more natural colour and a fresher tomato taste. The product has a lower viscosity and is more susceptible to syneresis. Also more vitamin C is lost than in hot break paste (Gould, 1992; Hayes *et al*., 1998). Hot break paste has a higher viscosity, which is

caused by the inactivation of all enzymes. The hot break process results in a higher yield with a higher consistency. The product is also less susceptible to syneresis (Gould, 1992; Hayes *et al*., 1998). After the hot or cold break process the tomato pulp is passed through screens to separate seeds and peel and squeeze the juice out of the pulp. Next the juice is concentrated in an evaporator. Finally, the paste is packed in aseptic bags and transported to the production sites for tomato ketchup.
After arrival at the ketchup production plant, ingredients are added to the paste. The paste with ingredients is heated, deaerated, filled, packed and stored. The production process of tomato ketchup is shown in Figure 4.3.

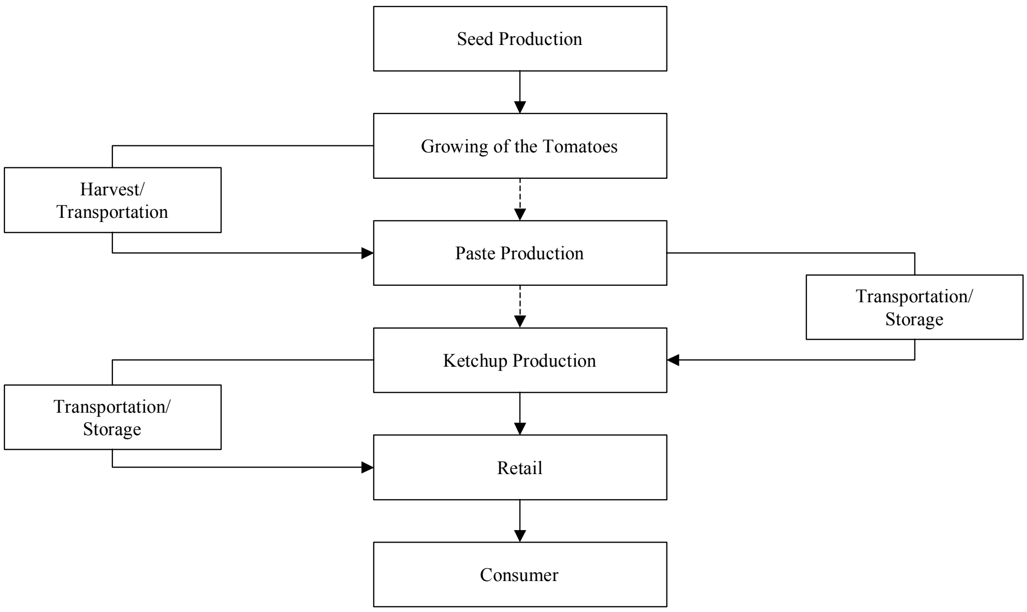

Figure 4.1 The complete production chain of tomato ketchup

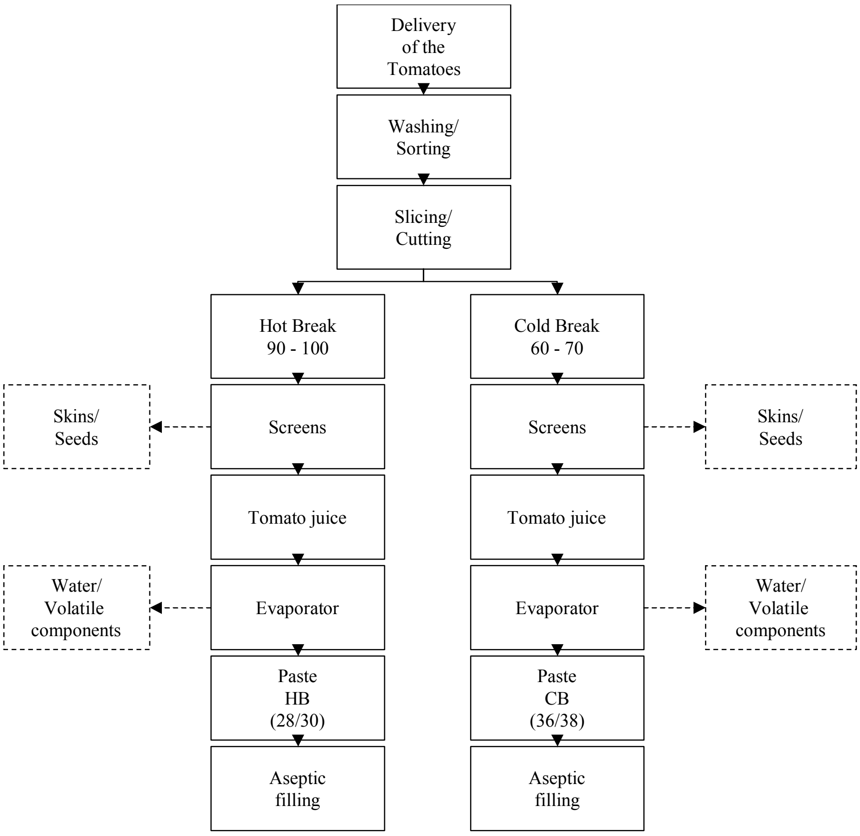

Figure 4.2 The production process of tomato paste

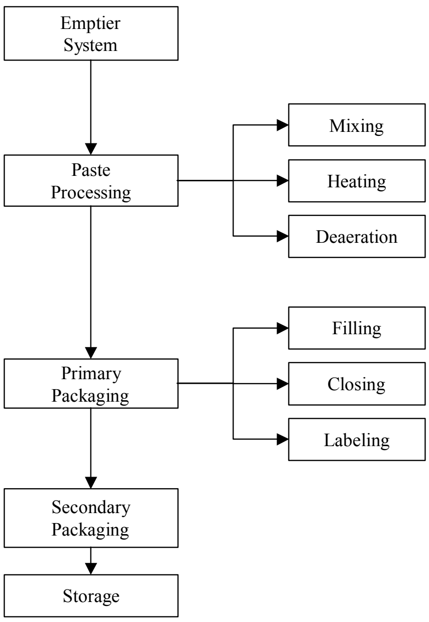

Figure 4.3 The production process of tomato ketchup

Table 4.4 (Possible) Influences of actors on the amount and bioavailability of lycopene

Actor	Amount of lycopene	Bioavailability
Breeder	Variety	-
Grower	Cultivation practices	-
Transport/ storage*	-	-
Paste producer	Oxidation Isomerisation Waste	Disruption food matrix Isomerisation
Transport/ storage	Oxidation Isomerisation	Isomerisation
Ketchup producer	Oxidation Isomerisation	Disruption food matrix Isomerisation
Transport/ storage	Oxidation Isomerisation	Isomerisation
Retailer	Oxidation Isomerisation	-
Consumer	Oxidation Isomerisation	Biological factors Lifestyle factors Diet

* this influence is assumed to be none, since the paste producer is located within close range of the farmers and tomatoes are immediately processed at arrival.

The influence of the actors and processes in the production chain on the lycopene content of the final product. This predominantly qualitative information was collected from literature (Table 4.4). The initial amount of lycopene in fresh tomatoes depends on variety, maturity, and the environmental conditions under which the tomato ripens. Literature is not conclusive about the amount of lycopene in tomatoes. On average, tomatoes contain 3 - 5 mg/100 g (Hart and Scott, 1995), but some authors report more than 9.3 mg/100 g (Tonucci *et al.*, 1995) and even more than 15 mg/100 g in tomatoes with a deep red colour (Hart and Scott, 1995). Lycopene concentration is higher in summer than in winter. Lycopene in tomatoes grown in greenhouses is lower than in fruits produced outdoors. Fruits picked green and ripened during storage are in general substantially lower in lycopene than vine-ripened fruits (Gould, 1992). However, a more recent study resulted in a lycopene concentration in post-harvest ripened tomatoes that was almost twice the value reached in vine-ripened tomatoes of the same colour (Giovanelli *et al.*, 1999). A relatively high temperature during cultivation (38 °C) inhibits lycopene production, while low temperatures inhibit both fruit ripening and lycopene production (Lurie *et al.*, 1996). The lycopene concentration was highest in the outer pericarp, about 3 times higher than in the rest of the fruit (Al-Wandawi *et al.*, 1985; D'Souza *et al.*, 1992; Sharma and Le Maguer, 1996).

In nature, lycopene exists in the all-trans form and isomerises to the mono- or poly-cis form under the influence of heat, light, or certain chemical reactions. Lycopene can also undergo trans-to-cis isomerisation during tomato processing and storage. In various tomato-based foods, the all-trans isomer comprises 35 to 96 % of total lycopene (Schierle *et al.*, 1997). The

5-cis, 9-cis and 15-cis isomers were found in various tomato-based foods and human tissues (Zumbrunn *et al.*, 1985). The cis-isomers contribute more than 50 % to total lycopene in human serum and tissue (Krinski *et al.*, 1990). Trans-cis isomerisation results in a higher bioavailability of lycopene. However, the cis-isomer is thermodynamically less stable, which can result in lycopene loss (Shi and Le Maguer, 2000).

Bioavailability of lycopene with respect to absorption in the human body can be affected by various dietary factors and food properties. The bound chemical form of lycopene is converted by temperature during processing, making the lycopene more easily absorbable by the body (Shi and Le Maguer, 2000). The lycopene bioavailability from foods containing tomatoes can be enhanced either by extraction of lycopene from the food matrix into the lipophilic phase or by thermal processing and mechanical disruption of the plant cells (Shi and Le Maguer, 2000). Studies indicate that the cis-form is more bioavailable than the trans-form because the cis-form is more soluble in bile acid micelles and may be preferentially incorporated into chylomicrons (Boileau *et al.*, 1999).

The structure of a food also influences the bioavailability of lycopene. Heating and chopping of tomatoes increases the bioavailability by breaking down cell wall structures, disrupting chromoplast membranes, and reducing cellular integrity, thus making lycopene more accessible (Shi and Le Maguer, 2000). Also homogenisation disrupts cell tissues and results in a higher bioavailability (Van het Hof *et al.*, 2000). Giovannucci *et al.* (1995) found that the lycopene serum concentration was greater after consuming heat-processed tomato-based foods than after consuming unprocessed tomatoes. Stahl and Sies (1992) found that 20 - 30 % of total lycopene consisted of cis-isomers when tomatoes had been heated at 100 ºC for 1 hour. The food matrix may contribute to the stability of the all-trans form of lycopene. This is supported by the observation that whole tomatoes still contained 90 % trans-isomers after being heated. The food matrix seems to prevent the occurrence of the isomeric equilibrium (Clinton *et al.*, 1996).

The presence of oil in the diet also enhances the bioavailability of lycopene. Cooking tomato juice in an oily medium resulted in a 2 - 3 times increase of lycopene serum concentrations after ingestion (Stahl and Sies, 1992). Heating in the presence of oil appeared to help convert lycopene from trans to the cis form (Stahl and Sies, 1996). In addition, the bioavailability of lycopene is enhanced by the presence of other carotenoids, such as β-carotene (Wilcox *et al.*, 2003; Rao and Agarwal, 1999; Shi and Le Maguer, 2000). Finally, several biological and lifestyle factors, such as menstrual cycle, smoking, and alcohol consumption influence the bioavailability of lycopene. These latter factors cannot be influenced in the production chain for tomato ketchup, and therefore are not considered in our study.

Consequently, the final amount of lycopene in the product largely depends on the amount of lycopene in the fresh tomato. The effect of processing is twofold. On one hand processing may result in a lycopene loss caused mainly by isomerisation (trans-lycopene is more thermodynamically stable than cis-lycopene), oxidation and in the case of ketchup by the fact that the major part of the lycopene content is located in the outer pericarp and tomato seeds, which are discarded in the process. Isomerisation and oxidation are influenced by process conditions, light, moist, temperature, presence of pro- or auto-oxidants, and lipids. On the other hand, the effect of processing is an enhanced amount of lycopene, mainly by an increase of bioavailability. This is caused by disruption of the food matrix, resulting in a release of lycopene but also by trans to cis-isomerisation, and presence of other dietary components such as dietary fat, β-carotene, vitamins and minerals. Therefore, to realise a higher beneficial effect of tomato ketchup on human health there are two possibilities. One, to produce ketchup with higher lycopene content and the other possibility is to raise the bio-availability of the lycopene in the ketchup.

Table 4.5 Quality characteristics for tomato ketchup

The best to eat	Easy to serve	Flows easily from the bottle
		Pours without scattering
	Healthy	Amount of lycopene
		Bioavailability lycopene
		Contains no preservatives
		No thickeners
		Contains no fat
	Appearance	Natural colour
	Tasty	It is thick in the mouth
	No defects	Never spoils
Good packaging/ Label	Clear information	Proper storage indications
	Best package	Can see the product inside

4.3.2 The information-processing phase

In phase 2 of the CIM, the information-processing phase, all information from phase 1 is processed into essential information for the actors in the production chain. In this phase, the influences of the processes in the entire chain, and hence the influences of the actors, on the new product feature and the quality characteristics of the product are analysed. The influences are placed in an information matrix, that shows if and to what extent the actors influence the various quality characteristics.

Quality Dependence Diagrams were constructed for each quality characteristic to determine systematically which actors influence the quality characteristics. Table 4.5 shows the relevant Quality Characteristics for tomato ketchup. The quality characteristics that have been removed from the initial table with quality characteristics (Table 4.3) are assumed to be constant and/or unaffected by any change in the process. For the quality characteristic 'healthy', i.e. the amount of lycopene and its bioavailability, the Quality Dependence Diagram is shown in Figures 4.4 and 4.5. Next, the information is placed in the Information Matrix to get a clear overview of the dependencies between the quality characteristics and the actors in the production chain (Figure 4.6). In the Information Matrix we have only indicated whether an actor influences a quality characteristic or not. The magnitude of the influence has not been determined. The Information Matrix indicates which actors are able to influence the amount of lycopene in the tomato ketchup and the bioavailability of lycopene. In the Information Matrix a distinction has been made between actors that can actively influence the quality characteristics, like breeder, grower, paste producer and ketchup producer, and actors who can not actively influence the quality characteristics but are supposed to follow instructions (transport, storage and retailer). The matrix also shows which other quality characteristics are possibly influenced by the actors. With the Information Matrix and the Quality Dependence Diagrams scenarios were formulated that describe the options for each actor to realise the intended product and what changes should be made in the entire production process to guarantee that the final product contains the intended amount of lycopene while the other quality characteristics do not change in a negative sense. The Information Matrix (Figure 4.6) shows that the breeder, grower, the paste producer and the ketchup producer can actively influence the amount of lycopene. For bioavailability, both the paste producer and the ketchup producer are the most important. From the information gathering phase, phase 1 of the CIM, it appears that the influence of the grower is limited. Therefore, we have used the breeder, the paste producer and the ketchup producer as a starting point to formulate scenarios in which the possibilities for the production of the improved ketchup are given. In these scenarios also the consequences and ‘best practices’ for the other actors are incorporated to prevent them from nullifying the desired improvement.

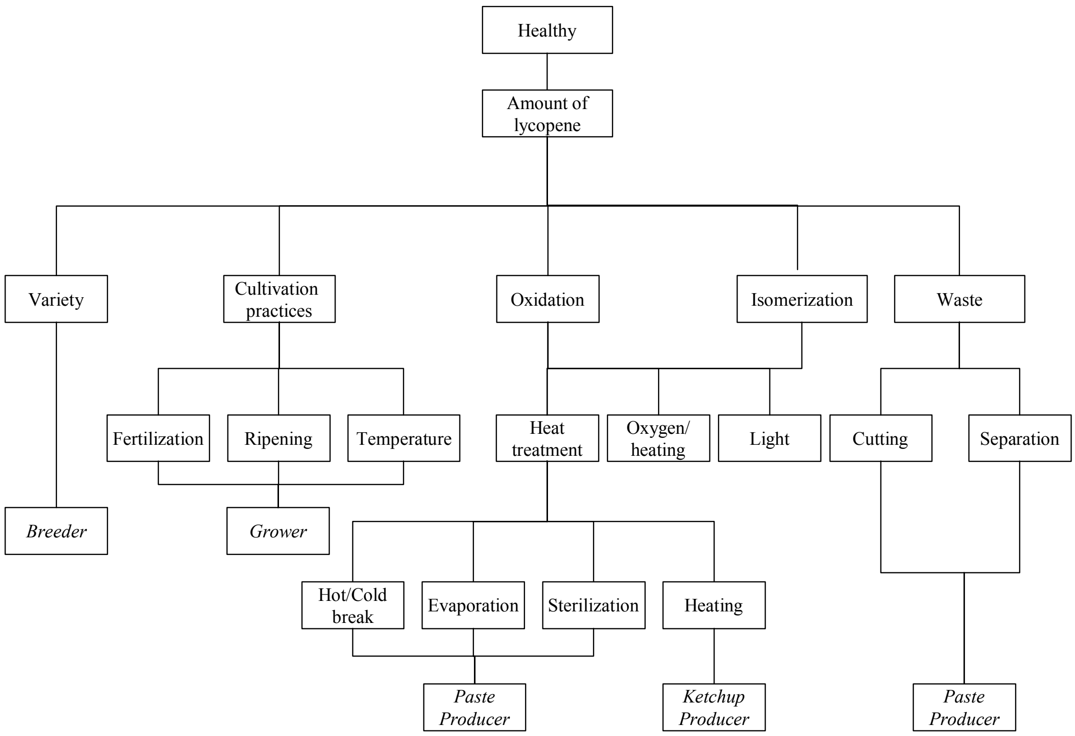

Figure 4.4 The Quality Dependence Diagram (QDD) for the quality characteristic ‘amount of lycopene’

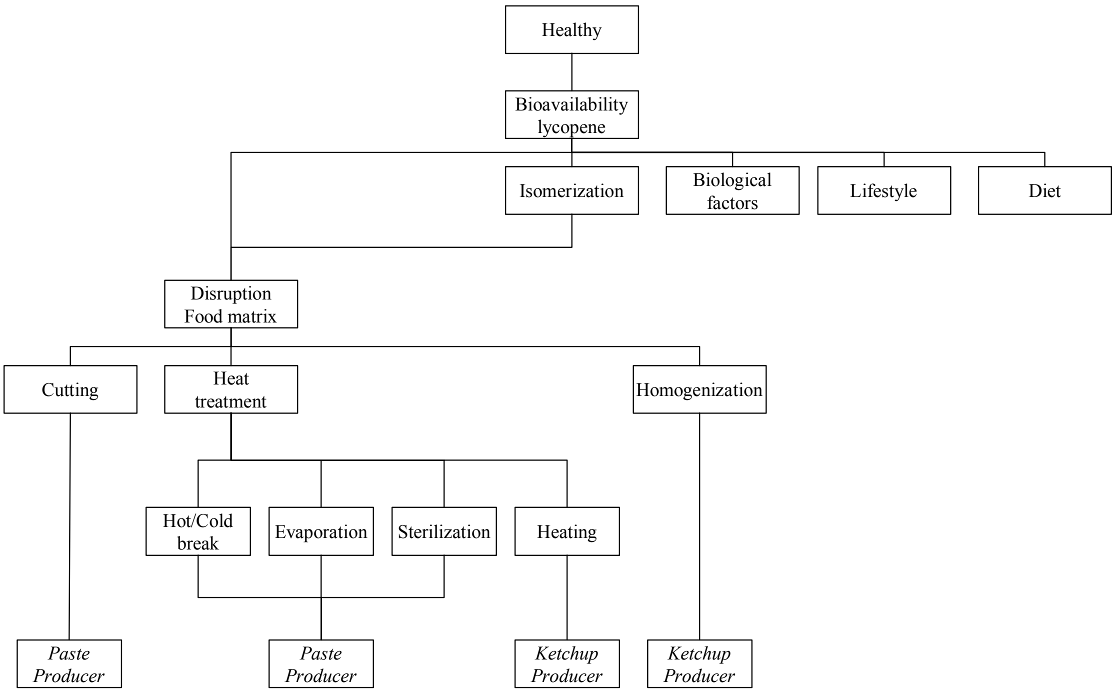

Figure 4.5 Quality Dependence Diagram (QDD) for the quality characteristic 'bioavailability lycopene'

Quality Characteristics \ Actors		Breeder	Grower	Transport*	Paste producer	Transport/ storage	Ketchup producer	Transport/ storage*	Retailer*
Easy to serve	Flows easily from the bottle	+	+		+	-	+		
	Pours without scattering	+	+		+	-	+		
Healthy	Amount of lycopene	+	+		+	+	+		
	Bio-availability lycopene	-	-		+	-	+		
	Contains no preservatives	-	-		+	-	+		
	No thickeners	+	+		+	-	+		
	Contains no fat	-	-		+	-	+		
Appearance	Natural colour	+	+		+	-	+		
Tasty	It is thick in the mouth	+	+		+	-	+		
No defects	Never spoils	-	-		+	-	+		
Clear information	Proper storage instructions	-	-		-	-	+		
Best package	Can see product inside	-	-		-	-	+		

Figure 4.6 The Information Matrix (- : no influence; + : influence; * : these actors can not influence the quality characteristics)

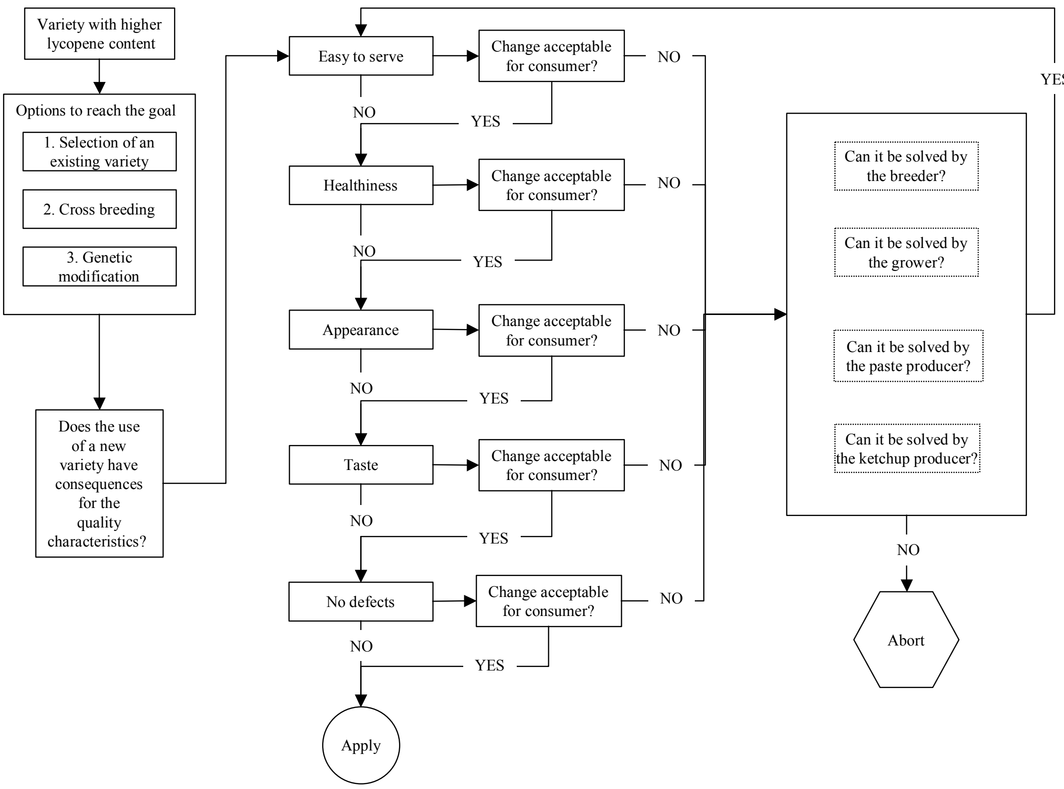

Figure 4.7 The decision tree for the breeder

The Breeder

The breeder can develop, or select if available, a variety with a higher lycopene content (scenario 1 - 3). The consequences of the first scenario, namely the selection of a different variety with a higher lycopene content, are elaborated in the decision tree in Figure 4.7. The first scenario is the fastest and easiest way for the breeder to obtain tomatoes with a higher lycopene content, but it is likely that a different variety will result in deviant quality characteristics of the tomato ketchup for the consumer. At this moment, the variety used is selected on the basis of its yield for the paste production.

With conventional breeding programmes (scenario 2) it is possible to raise the amount of lycopene without changing other characteristics of the tomato. A major drawback is that it takes several years before a new variety is developed. The third option is genetic modification; this method takes less time than conventional breeding but has a low acceptability among consumers (Schifferstein *et al.*, 2001).

For each scenario the next step is to verify whether the use of a different variety results in a change of other quality characteristics as the consumer expressed them. For this verification the acceptability intervals have to be known or established by means of consumer research by using, for instance, test panels. In this research these acceptability intervals were not established because the primary goal was to identify essential information flows for the development of the improved product, and therefore we used a more qualitative approach.

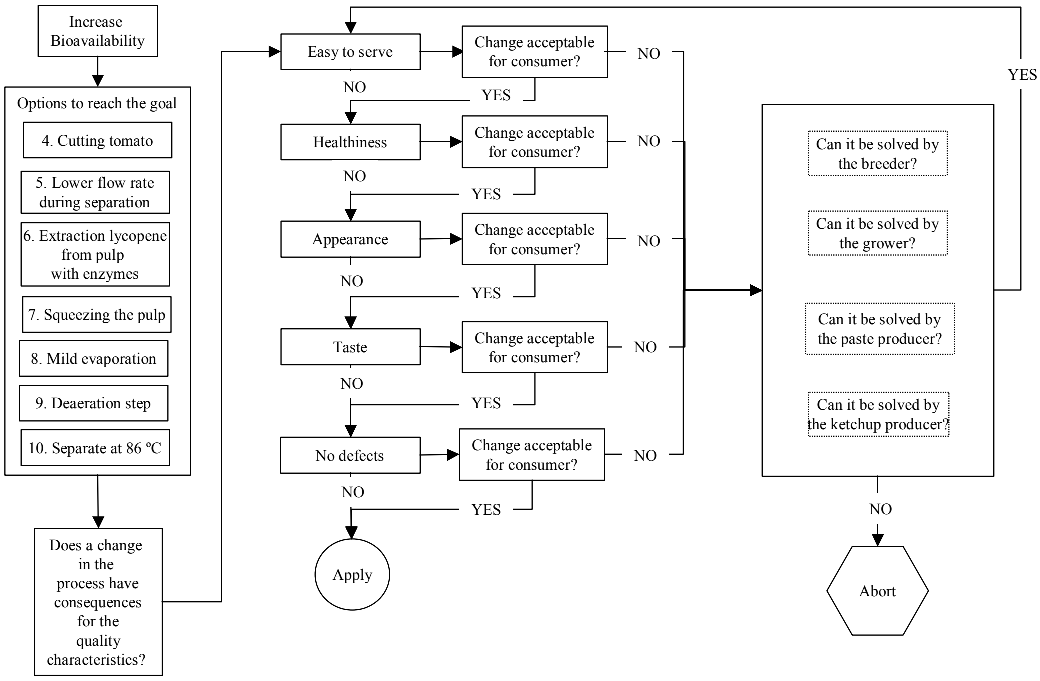

Figure 4.8 The decision tree for the paste producer

The paste producer

The next scenarios start with the paste producer. The paste producer has several possibilities to get a higher amount of lycopene in the paste and prevent oxidation and raise the bioavailability of the lycopene of the paste, namely: (1) Cutting the tomato before hot break; this results in a higher release of lycopene from the matrix because of tissue damage. However, during the hot break cis-lycopene is formed, which has a higher bio-availability but is less stable, therefore the processor has to be careful with what temperature to use otherwise the effect will be zero. Some paste producers already use this cutting procedure and therefore it is not likely that this change in the process will negatively influence other quality characteristics, since this ketchup is already at the market (Figure 4.6); (2) Application of a lower flow rate during separation. Lycopene is concentrated in the outer pericarp, which is separated from the paste. The speed and amount of tomato pulp that passes the extractor has an influence on the amount of lycopene in the paste. A lower flow rate will result in a higher amount of lycopene in the paste. However, this change in the process will also result in a higher viscosity of the paste, which might influence the quality characteristics 'flows easily from the bottle' and 'pours without scattering' from the end-product. (3) Extraction of lycopene from the pulp by using enzymes after the hot break. The enzymes are used to fluidise the peal of the tomato, which still contains lycopene; (4) Squeezing of the pulp (pericarp). The pulp, left over after the separation step, still contains lycopene. After squeezing the pulp, the obtained lycopene can be added to the paste; (5) Using mild evaporation. According to Brouwer (2003), the lycopene content lowers because of evaporation. A possible explanation is the shear force the product is subjected to. This causes a destruction of the network, resulting in a release of lycopene, which is subsequently oxidated and lost; (6) Adding a dearation step. The loss of lycopene is caused by oxidation with oxygen. In the current production process the paste is not deaerated. (7) Separation at 86 ºC. According to Rozzi *et al.* (2002), lycopene extraction is at maximum at 86 °C (Figure 4.8).

The ketchup producer

The ketchup producer has a relatively small influence on the amount of lycopene and the bioavailability of this compound (Figure 4.9). One improvement scenario is to use a non-transparent package, since light enhances the oxidation of lycopene. However, this does not comply with the quality characteristic 'Can see the product inside', as formulated by the consumer (Table 4.3). For this quality characteristic no acceptability interval exists, and the other actors do not have any options to solve this problem. Therefore this scenario cannot be used.

Another possible scenario is adding oil to the ketchup. Oil increases the bioavailability of lycopene. However, adding oil does not comply with the quality characteristic 'contains no fat'. Therefore this scenario is also not applicable. The heating steps can be optimised to minimise loss and maximise bioavailability of lycopene, while other quality characteristics do not exceed the acceptability intervals.

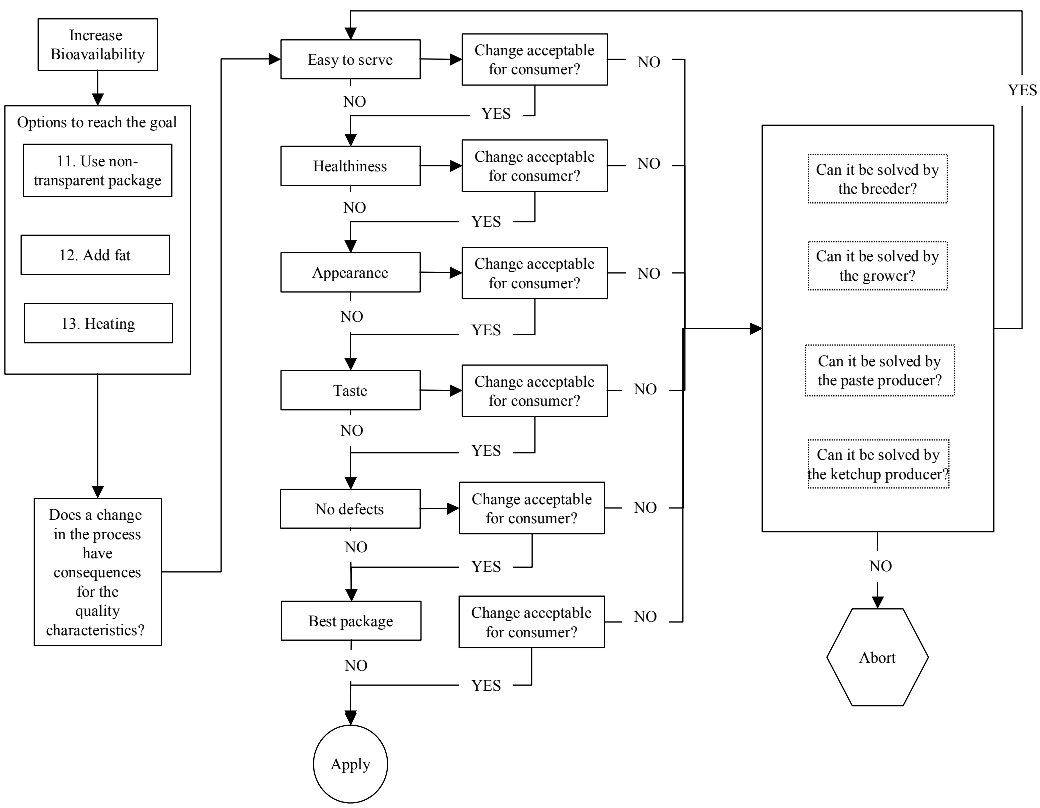

Figure 4.9 Decision tree ketchup producer

4.3.3 The information-dissemination phase

In the Information-Processing phase, the Information Matrix from phase 2 is used to select the actors with the largest potential influence on the desired new product feature and to generate scenarios to develop the intended product. Each scenario describes options available for each actor to produce the intended, improved product. From these scenarios the possible consequences of changes in the production process on the other quality characteristics can be derived. Also the consequences of these changes for the other actors in the production chain can be predicted. In the scenarios is also indicated how processes should be changed to optimise the production process for the intended product and which information should be shared for its realisation.

The scenarios generated in the second phase of the CIM were presented to a panel of experts with the question to select the best scenario to produce a lycopene-rich tomato ketchup. Confidentially with respect to technical details was requested by the experts to protect companies interests. This was granted to secure that the discussion would be as open and straightforward as possible. Opinions and suggestions concerning the possible use of the CIM in the food development process were gathered. The experts indicated that first of all the CIM was a useful tool to initiate a dialogue among the actors in the production chain as a starting point for cooperation in NPD projects. They highly appreciated the structured way in which the various options for the improvement of tomato ketchup were mapped out by the CIM. They also recognised that for their own part much of the company-specific information was not available on a single location, but distributed as fragments over various persons. Moreover, the discussion with the experts revealed that additional information is needed to confidently select a scenario. For this reason, the CIM was valued as an instrument that can help a company to draw up its research agenda.

The additional information, which the expert panel thought necessary, was:

- a quantification of all scenarios, to enable the selection of the scenario with the highest impact on the lycopene content;
- data on the dose-response relationship between lycopene and health, to know how much lycopene should be in the tomato ketchup;
- the current amount of lycopene in the tomato ketchup;
- the quality characteristics of the tomato ketchup. The data used to draw up the scenarios were not up-to-date and had to be tailored to the company's product.

The absence of this information precluded the selection of a particular scenario for the production of lycopene-rich tomato ketchup. The experts concluded that quantification of the relationship between the processing of the tomatoes and the lycopene content in the product is urgently required to be able to optimise tomato ketchup. Another research area they identified, concerned the beneficial amount of lycopene in the daily diet. The issue here is that the ideal lycopene content of tomato ketchup should be assessed in relation to the desired daily intake of lycopene.

The most realistic and promising scenario on the basis of the present state of knowledge appeared the selection of a tomato variety with a higher lycopene content. A change of variety can lead to a 28-fold increase in lycopene content if the extreme values are considered (Table 4.2). A higher lycopene content in the raw material is expected to result in an increased bioavailability of lycopene in the final product.

4.4 Discussion and conclusion

The application of the CIM to the development of a tomato ketchup rich in lycopene proved useful for structuring the information needed for various scenarios to achieve this goal. The CIM enables product developers to analyse the entire production process in an objective, structured and systematic way. By following such an approach, possible influences on the final product are mapped out before hand, and potential negative influences can be prevented. The strength of the tool is that it shows in which areas information gaps exist. The CIM indicates exactly which information is necessary to realise the intended product and in which areas more specific information is needed. In this case the relationship between tomato processing and lycopene content in the product should be quantified. Also, we do not know yet what amount of lycopene is beneficial for human health. This is also an indication that a quantitative approach is needed. As such the CIM enables actors in the production chain to start the dialogue and pinpoint areas for further research due to gaps in knowledge and information. We conclude that in its present form the strength of the CIM is that it assists actors in a production chain to set up a research agenda for future excellence in new products. During the NPD process the model enables the NPD team to make information explicit that is already present somewhere in the production chain. The systematic approach of the CIM enables to collect the information and apply it in the NPD process. By doing so the tool helps to gather information efficiently and prevents that a chain actor starts gathering information that has already been acquired by another actor. As such it aids to speed up the NPD process and to reduce costs. The CIM might also prove beneficial for producers in another way: this transparent approach can be utilised to guarantee the deliverance of levels of beneficial ingredients in a product to government and consumers.

5

Knowledge management for new product development in the food industry: the potential contribution of the Chain Information Model (CIM)

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5.1 Introduction

New product development (NPD) in the food industry continues to grow more complex and requires more knowledge than ever before. Much of this knowledge must be acquired outside the core project team (Mankin *et al*., 1996). To acquire all this knowledge much information is needed. As is argued in Chapter 1, a successful NPD process should be dealt with from a food production chain approach. Sharing information and knowledge is extremely important to manage the NPD process properly from such a perspective. From the foregoing chapters, it is clear that this is especially true for the food industry. The food industry is an industry where (technological) knowledge of effects of processing on ingredients is essential to reach the desired quality of the final product. This is caused by the many interactions between ingredients, which take place not only during processing but also during the storage and transportation of the final product. These interactions will influence the performance and the quality of the final product. In most food production processes the knowledge needed is very domain-specific and only kept and comprehended by experts who are directly involved in that part of the process (Goyache *et al*., 2001; Guillaume and Charnomordic, 2001). It is important for the continuity of food companies and to be innovative to capture this implicit knowledge and make it explicit for future use.

However, knowledge is not only important as a driving force behind innovation. Based on surveys in the life sciences-based industry, the following roles of knowledge for a company are clearly recognised (Folstar, 2001). Knowledge is a source of excellence, a cornerstone for a company culture, directed at being outstanding in benchmarking with competition and generating unique products and added value. Knowledge is also a basis for the reputation of a company: dedication to research brings the company in the top-league of outstanding businesses. Knowledge also enables a company to secure continuity in the portfolio of products. On a more practical level, it enables the company to effectively deal with claims: this is highly relevant in the food industry, where safety-related problems require immediate access to up-to-date knowledge. As mentioned before, knowledge also improves the market-value of a business. From a human resource point-of-view a knowledge-based company culture attracts high level professionals, which can be seen as key to management development and will help to secure senior positions for the future. On the basis of their knowledge, especially life sciences-based companies develop attractive portfolios of patents. Such patents are not just a way to solidify the future from a defensive point-of-view, but are also a source of licensing income in strategic partnerships. Finally, knowledge is seen as an asset to build internal and external new networks, one of the most important reasons behind success in innovation (Folstar, 2004).

A systematic system to collect and exchange information and knowledge is indispensable to deal with the complex information flows within food production chains. Literature reports the use of knowledge management systems to manage knowledge in companies. The objective of knowledge management is to support creation, transfer, and application of knowledge in organisations (Alavi and Leidner, 2001). However, knowledge management is a broad concept and implementing it within a company is often not easy. Many authors and professionals recognise the importance of knowledge and share the need for good knowledge

management (Folstar, 2004). Much literature has been published on theoretical approaches to knowledge management and its use in industry. However, not much has been published on the practical application of knowledge management for food NPD.
In this thesis we have developed the Chain Information Model (CIM) as a tool to structure the food NPD process. We believe that the CIM can also be of benefit for knowledge management by making knowledge management operational on an inter- as well as on an intra-organisational level. In this chapter we will demonstrate how the CIM can be used as a knowledge management tool and help practitioners to make knowledge management operational in the food NPD process.

5.2 Knowledge management

Knowledge management is a broad field of activities, which includes all the human and organisational aspects of collecting, combining and exchanging knowledge as a basis for the creation of added value in an organisation (Folstar, 2004). According to Shani *et al.* (2003), knowledge management is an integrating practice of meshing human and automated activities. According to Liu *et al.* (2005) knowledge management can be defined as a group of clearly defined processes or methods used to search important knowledge among different knowledge management operations. According to Wiig (1997), the objectives of knowledge management are: (1) To make the enterprise act as intelligently as possible to secure its viability and overall success and (2) To otherwise realise the best value of its knowledge assets. To reach these goals, advanced organisations build, transform, organise, deploy, and use knowledge assets effectively. In other words, the overall purpose of knowledge management is to maximise the enterprise's knowledge-related effectiveness and returns from its knowledge assets and to renew them constantly. Knowledge management is to understand, focus on, and manage systematic, explicit, and deliberate knowledge building, renewal, and application (Wiig, 1997). Knowledge is not just about facts and data from science and technology, but it encompasses all information, experiences and skills, either stored in peoples' heads (tacit knowledge) or stored in media external to people (explicit knowledge). Although explicit knowledge is most visible through specifications, recipes, procedures, reports and patents, tacit knowledge - once made explicit - probably offers more possibilities for competitive advantage. Tacit knowledge finds its basis in experience, expertise, skills and creativity, and is therefore also intangible and volatile, but if used well, can be of indispensable value to an organisation (Cook and Brown, 2002).
As mentioned in Chapter 1, knowledge and information are often used intermingled. However, there is a significant difference between knowledge and information that makes the difference between knowledge management and information management. According to Alavi and Leidner (2001) knowledge is information possessed in the mind of individuals. As such, it is personalised information related to facts, procedures, concepts, interpretations, ideas, observations, and judgments.
Knowledge management refers to identifying and leveraging the collective knowledge in an organisation to help the organisation compete (Von Krogh, 1998), and is important to increase

innovativeness and responsiveness (Hackbarth, 1998). A survey of European firms by KPMG found that almost half of the companies reported having suffered a significant setback from losing key staff with 43% experiencing impaired client or supplier relations and 13% facing a loss of income because of the departure of a single employee (Alavi and Leidner, 2001). In another survey, the majority of organisations believed that much of the knowledge they needed existed inside the organisation, but that identifying that it existed, finding it, and leveraging it, remained problematic (Alavi and Leidner, 2001). Such problems as maintaining, locating, and applying knowledge have led to systematic attempts to manage knowledge. According to Ruggles (1998) knowledge management creates value by actively leveraging know-how, experience and judgment resident within and outside an organisation. Ramesh and Tiwana (1999) posit that knowledge management encompasses the activities surrounding the integration of this knowledge from different sources, in different forms, and maintaining it. An important part of knowledge creation is thus the mobilisation and conversion of tacit knowledge into a form of explicit knowledge. Knowledge management is aimed at improving the innovative position of the company and should be able to recognise the potential of any piece of information, any innovation and any new skill that arises (Folstar, 2004).

According to Alavi and Leidner (2001) knowledge may be viewed from several perspectives, namely (1) a state of mind, (2) an object, (3) a process, (4) a condition of having access to information, or (5) a capability. Alternatively, knowledge can be viewed as a process of simultaneously knowing and acting (Carlsson *et al*., 1996; McQueen, 1998). In this thesis we approach knowledge from the process perspective, so the knowledge management focus is on knowledge flow and the processes of creation, sharing, and distribution of knowledge.

Since knowledge management is such a broad concept it is often hard for practitioners to implement it in a company. According to Alavi and Leidner (2001) knowledge management can be regarded as a process involving various activities. There exist slight differences in the identification of these processes. However, these differences are mainly in terms of number and labelling of these processes rather than in the underlying concepts. Minimally, four basic processes are distinguished (Alavi and Leidner, 2001): (1) creating knowledge; (2) storing/retrieving knowledge; (3) transferring knowledge; and (4) applying knowledge. These key steps are the technical elements of knowledge management, which an effective knowledge management system should deal with.

According to Davenport and Prusak (1998), most knowledge management projects have one of three aims: (1) to make knowledge visible and show the role of knowledge in an organisation, mainly through maps, yellow pages, and hypertext tools; (2) to develop a knowledge-intensive culture by encouraging and aggregating behaviours such as knowledge sharing (as opposed to hoarding) and proactively seeking and offering knowledge; (3) to build a knowledge infrastructure not only as a technical system, but as a web of connections among people giving space, time, tools, and encouragement to interact and collaborate. If we assess the CIM in this respect, we can state that use of the CIM is intended to build an inter-organisational knowledge infrastructure.

The most important conclusion that can be drawn from literature is that knowledge management is a broad concept that still has to be developed further. No univocal definition is presented, but it is clear that a good knowledge management process addresses several distinct key processes.

5.3 Making knowledge management operational in food NPD

The first step in demonstrating the benefits of the CIM for knowledge management is determining whether the CIM can be used for knowledge management in the first place. Based on the four basic processes mentioned in section 5.2, we will analyse if the CIM deals with all these elements. We will discuss the use of the CIM to make knowledge management operational in a production chain for food NPD. This will be done by a practical example of the development of a healthy apple juice. The development process is discussed briefly from the point of view of the apple juice producer.

> Example: The example used deals with the development of an apple juice with a health benefit. The health benefit is based on a higher content of flavonoids in the juice. Flavonoids are secondary plant metabolites present in fruits and vegetables. In epidemiological research some flavonoids are associated with protection against aging diseases, like the development of cancer and coronary heart disease (Van der Sluis *et al.*, 2001). Flavonoids are present in the apple, but most are lost in the production process. According to Van der Sluis *et al.* (2002), the following stages in the food production process influence the content of bioactive components in the juice: cultivation methods, choice of raw material, industrial processing, storage, distribution, and final processing by the consumer. Knowledge about these aspects is a prerequisite for the food processor to optimise the product with respect to the desired level of health-protecting compounds.

Before the NPD process starts a project leader has to be appointed, who will initiate the development project. The next step is the decision on what product to make. In this example the new product is a health-supporting apple juice. The new product feature is the increased amount of flavonoids in the apple juice. These flavonoids are present in the apple but no longer in the juice. According to Van der Sluis *et al.* (2002), most of the flavonoids are lost during the production process.

5.3.1 Knowledge creation

According to Alavi and Leidner (2001) the creation of organisational knowledge involves the development of new content or replacing existing content within the organisations tacit and explicit knowledge. They use the organisational knowledge creation model from Nonaka (1994). In this model organisational knowledge creation is viewed as a continuous interplay between the tacit and explicit dimensions of knowledge. Alavi and Leidner (2001) state that four modes of knowledge creation have been identified: (1) Socialisation: the conversion of tacit knowledge to new tacit knowledge through social interactions and shared experience among organisational members (e.g. apprenticeship); (2) Externalisation: the conversion of tacit knowledge to new explicit knowledge (e.g. articulation of best practices or lessons learned); (3) Internalisation: the creation of new tacit knowledge from explicit knowledge (e.g. the learning and understanding that results from reading or discussion); (4) Combination: the creation of new explicit knowledge by merging, categorisation, reclassifying, and synthesising explicit knowledge (e.g. literature survey reports).

The development process for the healthy apple juice starts with identifying and collecting all the required information (Phase 1 of CIM, Figure 3.13). According to the CIM, this phase encompasses information regarding the production process, the quality characteristics and information regarding the new product feature. With respect to the production process, information on the actors and all processes involved in the production process of the current product has to be gathered. To prevent the final product from not complying with the consumer wishes, the quality characteristics have to be gathered. Information regarding the quality characteristics of the current product is needed to predict whether changes in the production process will affect them. Also relevant information regarding the effects of processing and the complete production process on the new product feature has to be gathered. In this case we need information on the effects of all processes in the production chain on flavonoids.

Together, this information will lead to new knowledge with regard to an improved production process. The CIM identifies who has the necessary information and by formulating scenarios, knowledge is created with respect to the possible ways to develop the product. The scenarios also indicate what information and knowledge is missing. Compared to the four basic processes for knowledge management this is the knowledge creation process.

Before the identification and collection of the information, a team should be formed consisting of members representing the actors involved in the production process. In this example the lead will be taken by the producer of the apple juice, who is the initiator of the new product. The project leader identifies and contacts the relevant actors for the production process of the improved apple juice. As a starting point the production process of the current apple juice is taken.

In this example, the production chain of apple juice consists of the following actors: breeder, grower, processor (producer of apple juice), retailer, and consumer. In order for the NPD process to be effective and efficient these members of the production chain should be present in the NPD team.

In the first project meeting these actors have to be consulted in order to map out the production processes into more detail. In this example we will only deal with the basic steps of the production process. An apple variety is selected and planted. The apples are cultivated, harvested and stored. Next they go into the processing process consisting of the following steps: washing and inspection, crushing, milling, pressing, clarification/filtration, pasteurisation, and packaging (Van der Sluis *et al.*, 2002). The juice is stored, transported to the retailers, displayed on the shelves and finally purchased by the consumer.

Also, the quality characteristics of the current product have to be assessed. Since we are adding an extra feature to an existing product the quality characteristics of the current product can be used. If they are not known by the producer of the apple juice, they have to be generated using different tools, like for instance focus groups and sensory testing (Van Kleef *et al.*, 2005).

Finally, the information regarding the new product feature and the influences of the processes on the new product feature and the relations between the quality characteristics have to be gathered. Sources for this information can be scientific publications, internal knowledge, or knowledge from other actors in the production chain. In this example the basic information needed can be gathered from scientific publications by Van der Sluis *et al.* (2000, 2001, 2002, 2004). According to these publications the following aspects influence the amount of flavonoids in the juice: cultivation methods (cultivar, growing conditions, seasonal differences, and harvest and storage conditions), industrial processing (choice of raw material, specific extraction of the apple pulp or on the pomace), storage of the final product, and consumer processing. For more detailed information about exact influences more publications can be studied or scientists might be consulted or even contracted to conduct further research.

The information has to be processed using Quality Dependence Diagrams and the Information Matrix (Chapter 3), and scenarios with options to realise the intended product have to be formulated.

If we compare these actions with the four model of knowledge creation, we observe that the CIM mainly contributes to all modes. By discussing and exchanging knowledge with respect to the development of the new product in the project team, tacit knowledge from one actor is absorbed by other actors and hence for that actor new tacit knowledge is created (socialisation). By using the formats of the CIM (Quality Dependence Diagrams, Information Matrix, and written scenarios), this tacit knowledge is converted to explicit knowledge and hence made available for others (externalisation). For the new product feature, the actors retrieve new knowledge from external (explicit) sources like scientific publications and the internet (internalisation) and by writing this information down and combining it in the Information Matrix and in scenarios new explicit knowledge is created for the production chain (combination).

5.3.2 Knowledge storing/retrieving

During the knowledge creation, organisations also forget acquired knowledge. Therefore, the storage and retrieval of knowledge is an important process in effective knowledge management. This process of storing, organising, and retrieving knowledge is referred to as organisational memory, or collective memory (Alavi and Leidner, 2001; Nevo and Wand, 2005).
Once the project team has gathered all the information in phase 1 of the CIM, this information is processed into information understandable for each actor. For the processing of the information the CIM uses formats like the Quality Dependence Diagrams, Information Matrix and written scenarios to visualise the information and knowledge. The knowledge which has been created can be retrieved from the scenarios that have been constructed in phase 2 of the CIM. In phase 3 of the CIM, from the scenarios the information which is necessary for an actor to produce the product is identified and relayed to that actor. For instance in the example of the apple juice the scenarios identified that one way to produce the juice with a higher flavonoid content is to by using a different apple cultivar (Van der Sluis *et al.*, 2001). The project leader contacts the breeder that he should use a different cultivar. He uses the scenario to identify possible influences of the change in the production process on the other quality characteristics and other processes in the production chain. This knowledge is stored in the Information Matrix and can be easily retrieved to identify these influences.

5.3.3 Knowledge transfer

Transfer of knowledge occurs at various levels: transfer of knowledge between individuals, from individuals to explicit sources, from individuals to groups, between groups, across groups, and from the group to the organisation (Alavi and Leidner, 2001).
The CIM is developed to systematically identify and collect information and knowledge needed for the NPD process in the production chain. In all phases of the CIM the knowledge is transferred from members of the project team to Information Matrix and scenarios. Also knowledge is exchanged between members of the project team. The knowledge acquired from one project is very likely to be used for other projects; hence it is transferred within the companies.

5.3.4 Knowledge application

The value of knowledge is not so much in possessing the knowledge but in applying the knowledge. Therefore, knowledge application is an important process in knowledge management (Alavi and Leidner, 2001).
As is mentioned in this section, the knowledge that is created with the CIM is used for the successful development of the product. Also, the knowledge created in this development process can be applied for the development of future new products. In the example, the

knowledge on the production of apple juice and the influences of the actors on the quality characteristics can be used to produce variations to the existing product. Once the CIM has been used and the matrices and diagrams have been constructed, it is fairly easy for the production chain to develop other products based on the existing product and the knowledge gathered. The CIM can also be used to set priorities for a research agenda to create the knowledge needed for the successful development of the product.
Table 5.1 reflects the results of the analysis whether the CIM covers all key processes of knowledge management as they were formulated by Alavi and Leidner (2001). From Table 5.1 and the example on the production of apple juice it is clear that the CIM covers all these key processes. From the example it is clear that a lot of persons are involved in the whole knowledge management process, namely NPD employees from the different companies involved in the production process, management from the different companies to facilitate the process and to create commitment. All persons have a different role in the knowledge management processes. Table 5.2 shows a short protocol to illustrate how the CIM can be used to make knowledge management operational in a food NPD project.

Table 5.1 Key processes of knowledge management

Key process of knowledge management	**CIM**
Knowledge creation	Phase 1: - Identification and collection of information Phase 2: - Information processing - Formulation of scenarios
Knowledge storing/retrieving	Phase 1: - Use of Quality Dependence Diagrams Phase 2: - Use of Information Matrix - Use of scenarios
Knowledge transfer	Phase 3 - Information dissemination
Knowledge application	Phase 2: - Use of scenarios Phase 3: - Knowledge dissemination

Table 5.2 Protocol to make knowledge management operational using the CIM

Key process of knowledge management	Activities	Actor(s)
	- Management chooses new product feature to develop; - Project leader is appointed.	Management
Knowledge creation	- Project leader identifies chain actors.	Project leader
	- Management contacts other actors to guarantee cooperation.	Management
	- NPD team is formed consisting of representatives of each actor.	Project leader
	- Goals are set (what to develop, time path is defined, regular meetings are planned).	NPD team
Knowledge creation	- Each actor collects information on his production process for the product.	NPD team
Knowledge creation	- Project leader consults marketing department to identify quality characteristics.	Project leader
Knowledge creation	- Identifies and collects information on new product feature (scientific publications, consults experts).	Project leader
Knowledge creation Knowledge storing	- Information is brought together; - Quality Dependence Diagrams are constructed; - Information Matrix is constructed.	NPD team
Knowledge storing/ Knowledge retrieving	- Constructs scenarios.	Project leader
	- Formulate selection criteria.	Management + project leader
	- Selects best scenario.	NPD team
Knowledge retrieving Knowledge transfer	- Disseminates all relevant information.	Project leader
Knowledge application	- Implements scenario.	NPD team

5.4 CIM as a supportive knowledge management tool for food NPD

In section 5.3 we have discussed the possible contribution of the CIM to make knowledge management operational. We have demonstrated that the CIM covers all the different key processes for knowledge management (Alavi and Leidner, 2001). However, we have not yet evaluated the CIM as a knowledge management tool for food NPD.

Not much literature can be found on the use of knowledge management tools in food NPD. A problem is that tools are often developed for the use in other industries and are not easily transferred for use in the food industry, as is the case with the QFD method (Chapter 2). Nijssen and Frambach (1998) have observed that although most of these tools have been designed to exclusively facilitate a specific part of the NDP process, they are used in a rather unfocused way. This can be explained by the confusion concerning terminology used in literature and by the complexity of the application of NPD tools in practice (Nijssen and Lieshout, 1995; Araujo, 2001; Garcia and Calantone, 2002).

NPD is a field in which creation, sharing and applying of knowledge is crucial to success. Cooper (2003) states that knowledge management tools exist to create, manage and use resources that have encapsulated knowledge applicable to the given design domain. Each category of tools supports the acquisition and development of knowledge (e.g. through experimentation, interaction with team members or external experts, access to encoded knowledge). As such, they have the potential to reduce uncertainty and NPD risk, which is one of the main issues in NPD.

However, according to Cooper (2003), there are also multiple ways in which existing tools can do more harm than good: by diverting attention, adding work, negatively impacting team dynamics, disrupting cognitive processes, reducing contextual cues, eliminating valuable intermediate products, adding to information overload, and creating difficult-to-fill roles.

Based on the frustrations experienced by users of existing tools for knowledge management and collaborative tools, Cooper (2003) has defined a set of desired characteristics that these tools should have from a practitioners' point-of-view:

- Characteristics that reduce disruption of the work process;
- Characteristics of beneficially altered user roles;
- Characteristics to support contextualisation.

For a knowledge management system tool to contribute positively to the NPD process it should deal with these characteristics. In this section we will demonstrate whether the CIM deals with these characteristics and helps closing the gap between existing tools and desired tools.

5.4.1 Characteristics that reduce disruption of the work process

According to Cooper (2003) the integration of knowledge management into the work processes requires both an understanding of human factors issues relative to tools and systems use and a sensitivity as to what constitutes a 'disruption' in the NPD context. This can be translated into three separate requirements a knowledge management system should comply with: (1) the system should be able to integrate how knowledge management and collaboration in NPD work are done; (2) the system should enable users to work at multiple levels of abstraction; (3) the system should have a great sense of timing.

If we consider the CIM as a tool for knowledge management in NPD processes we can observe that the first two characteristics are met. One of the key points of the CIM is that it forces actors in the production chain to work together, identify which knowledge is needed by whom to develop the intended product and identify where this knowledge is located in the production chain. Members of the project team are encouraged to share information to complete the Information Matrix and construct the scenarios for the optimal development process. This knowledge used in the CIM varies from very abstract knowledge, like which concept to realise to very technological, specific knowledge (influences of production processes on the quality characteristics). With respect to the third characteristic, the timing, Cooper (2003) mentions three important issues: (a) determine what type of information would be relevant, (b) determine when it would be most relevant; and (c) be able to affectively match existing information to the target user. So such a system would be able to determine what to deliver, in what form, when and via what means.

The CIM determines via the use of the Information Matrix and scenarios which actor needs what information to produce the intended product. The CIM also delivers the needed information in the form of specific instructions for that actor once the scenarios are formulated and the information is disseminated among the actors.

5.4.2 Characteristics of beneficially altered user roles

In order to get less reluctance to a change it is important that the changes are of obvious benefit to the users. Therefore a knowledge management system should address the dull aspects instead of the creative, fun aspects (Cooper, 2003). According to Cooper (2003) knowledge management systems often generate tedious work instead of eliminating it.

In this respect the CIM in its current form also has the tendency to create a lot of tedious work for the users with respect to the completion of the Information Matrix. However, by transforming the current version of the CIM into a computerised model most of this work can be eliminated. The strong part of the CIM is that once it has been completed for one product it is fairly easy to apply it for future changes of the product.

5.4.3 Characteristics to support contextualisation

The importance of context in NPD is manifold; context is important to identify what is relevant; it helps to locate information or focus attention; and context is important as common ground to enable communication across thought worlds (Cooper, 2003). To overcome the lack of context, a knowledge management tool should be able to address context needs. The tool should be able to provide enough cues so that the users can apply and extend the results to different circumstances. In other words, users should be able to find required information easily and it should be prevented to access ‘confidential’ information.

If the CIM is handled by a project leader, this person can collect all information and once the CIM is computerised only the specific information needed by each member has to be relayed.

In this way one can easily protect strategic information, since only operational information is required. The facilitation of communication across 'thought-worlds' is done by the CIM by using graphical representations like the Quality Dependence Diagrams and the Information Matrix, in which consumer language is related to production processes and actors.

5.5 Discussion and conclusion

Although, there is only a small amount of literature available on the use of knowledge management in the food industry it is clear that knowledge management can be beneficial for food NPD to lower the risk in the development process. A major benefit of knowledge management in the food industry is that it helps transferring tacit knowledge into explicit knowledge, and thus making knowledge more easily available for the company. However, it is not easily understood how knowledge management should be put into practice. In this Chapter we have evaluated the CIM as a means to make knowledge management operational in food NPD and evaluated the CIM as a potential tool for knowledge management in food industry.

Based on a literature review, Alavi and Leidner (2001) have formulated four key processes that knowledge management should cover: (1) creating knowledge, (2) storing/retrieving knowledge, (3) transferring knowledge, and (4) applying knowledge. We have used these key processes for knowledge management as a framework to judge the CIM on its use to make knowledge management operational. An example has been used to demonstrate that the CIM is a suitable tool to make knowledge management operational. The example was the development of an apple juice with a health benefit. All the proposed steps are covered by the CIM and it provides the NPD practitioners with a useful tool to structure the knowledge needed and structure the steps that have to be taken to determine what knowledge is needed, what is available, and what still has to be developed. Moreover, it also provides the food industry with a means to make implicit knowledge explicit, store the knowledge and make it available for future projects. By adapting the CIM and carefully completing all the phases of the CIM, a production chain would be able to make knowledge management operational. The protocol (Table 5.2) can be used as a stepwise approach to complete the key processes of knowledge management.

From literature it appeared that existing knowledge management systems and tools failed to meet practitioners' demands and in many cases were counterproductive for NPD. Cooper (2003) has given several characteristics that a knowledge management tool intended for the use in NPD should be able to meet. We have investigated how the CIM complied with these characteristics. It seems that the CIM, although still in a preliminary stage, is able to meet with most of these characteristics. The strength of the CIM is that it is a tool intended for use across the complete production chain, thus enabling collaboration in NPD. By using the stepwise approach of the CIM the development process is divided into specific tasks for which specific tools should be used. By carefully gathering and processing this information, the integration of NPD tools and collaboration in NPD is achieved by the CIM. The CIM is also able to deal with multiple levels of abstraction; information of different levels of the

organisation is used to formulate and select the best scenario to produce a product. With respect to timing: information is not released until it is clear which actor needs which information, resulting in the fact that actors are not distracted by information they do not need at that time. Also, the CIM is perfectly capable of putting the information into context and when handled in the right manner by a project leader it will be able to provide only that information that is needed and prevents the dissemination of strategic information. However, to prevent the CIM from becoming time consuming the system should be automated.
The strength of the CIM as a tool for knowledge management in the food industry is based on several key elements. It helps food companies in the ongoing struggle to make tacit knowledge explicit by capturing the information in formats. Another key element is that the CIM puts information in a context and as a result makes it understandable and interpretable for all actors. By doing this the CIM can also help to overcome the ‘language barrier’, often reported as one of the main problems in NPD teams.

6

General discussion

6.1 Results of this thesis

Chapter 1 describes the current new product development (NPD) process for foods and elucidates the high failure rate of its outcome that occurs in spite of the many opportunities offered by the market and by technological developments. Several methodologies and tools have already been developed to address this problem. However, the food industry still has not been able to lower the failure rate of the NPD process. The objective of this thesis was to develop a tool that can be used to enhance the success rate of the NPD process in the food industry. The hypothesis was that a higher success rate could be realised by developing a tool for a systematic approach of the NPD process with two important characteristics, namely:
(1) A chain approach; for an effective NPD process a chain approach is essential. NPD efforts should be in accordance with all actors to prevent counter productivity during the production process.
(2) Information management; information and information exchange are needed to reduce the risk in decision-making in the NPD process. Information is also essential to structure the NPD process and to align development and production processes among actors.

The NPD process should be able to analyse all possibilities and come up with clear options to realise the intended product in a systematic way. Therefore, a NPD process has to efficiently and effectively match consumer wishes and new technological/scientific insights and translate those into successful new products. This requires a production chain point-of-view, instead of approaching the NPD process from a single actor perspective.

Much information and knowledge from the complete production chain are needed to realise such a process. This information has to be gathered, processed and disseminated along the actors in the production chain in a systematic way. A systematic inter-organisational tool for NPD is required to deal with such complex information. In this thesis we have developed such a tool.

Literature indicated that the Quality Function Deployment (QFD) method could be used for the purpose of systematic NPD. Therefore, in Chapter 2 the QFD method was studied for its use as a tool to link consumer wishes to processes and actors in the food production chain and to identify the necessary information flows. Several publications indicated that the QFD method is suitable for use in the food NPD process, but our analysis showed that:

- QFD in its present form is only suitable for product improvements and not for the development of truly innovative products;
- It is hard, or even impossible, to use the complete Four-Phase model for the improvement of food products. This is due to the complexity of food products, the many interactions between the ingredients and the influence of processes on functional properties of the product. Moreover, it is not possible to give precise target values (HOW MUCH) for the product requirements (HOWs);
- Many ingredients used in food products are still physiologically active, leading to changes in the quality of the ingredients during the production process. Food ingredients also show a natural variation in composition, making it necessary to work with bandwidths rather than with single target values;

- One is forced to select only the most important consumer demands and the demands new to the company, since there are too many consumer demands and design characteristics for each product. The risk is that interactions are overlooked and that, as a result, the final product is not what the consumer asked for.

In spite of these limitations, the first matrix of the QFD method, namely the House of Quality, is useful to get insight in the kind of information that is necessary to make trade-off decisions and to improve the product. A positive feature of using the House of Quality is that the matrix can provide a link between the quality characteristics as demanded by the consumer and the technical requirements of the product. From the analysis of the QFD method it was clear that in its present form QFD was not suited for our goal. This was mainly caused by the problems with setting target values and transferring data from the House of Quality to the next matrices, making it difficult to provide a relationship between the quality characteristics and the actors in the production chain. Since this link could not be established, the required information for the NPD process could not be identified. Therefore, we decided to develop a new tool to analyse, process and disseminate the essential information for a systematic food NPD process.

Chapter 3 deals with the construction of a conceptual tool for information supply in the food NPD process with some elements of the QFD method. The tool was built using a hypothetical example on the development of a ready-to-eat meal with a health benefit, namely the presence of glucosinolates in the vegetable component of the meal. This resulted in the Chain Information Model (CIM), intended for use in food production chains to improve existing products by adding a health supporting component to the product. The CIM consists of three phases: (1) the information gathering phase, in which all the information needed regarding the product is identified and collected (processes in the production chain, quality characteristics of the existing product, and influences of the processes on the quality characteristics and the health beneficial component); (2) the information processing phase, in which all the information is linked together to get insight into the effects of processing on the product, resulting in several scenarios; (3) the information dissemination phase, in which the best scenario is selected and the required information is spread among the actors. This conceptual tool provides actors in production chains with a systematic approach to map out the options for the chain to realise an intended product and to unravel the information flows necessary for its effective production. The strength of this approach is that it forces the expert teams to systematically consider all the options and judge the results of possible changes in the production process in advance. It also provides feedback on the quality characteristics of the product from the consumers' point of view and in this way prevents the occurrence of unexpected product failure. Using this approach, the development time and costs can be lowered and the chance of success improved. The approach also demonstrates that often much information is already available, either within the production chain or in scientific publications and the CIM can be used to collect and store this information. Another important benefit of the CIM is that by collecting and storing the information it is also usable to capture knowledge that only exists as expert knowledge (tacit knowledge) for the continuity of the organisation.

In Chapter 4, the CIM is tested in an exploratory study on the development of tomato ketchup with an increased amount and bioavailability of the anti-oxidant lycopene. The use and results of the CIM were discussed with a panel of experts. The discussion showed that the tool proved useful for structuring the information towards a clear scenario to improve tomato ketchup. The tool enables product developers to analyse the entire production chain in a systematic way. By following this approach, possible influences of process changes on the final product are mapped before the actual production is carried out. The strength of the tool is that it shows in which areas information gaps exist. The tool indicates exactly which information and knowledge are necessary to realise the intended product and in which areas more specific information is needed. As such, the CIM can be used to draw a research agenda for the production chain.

From the foregoing chapters it was clear that information and knowledge are key elements in the NPD process. This information and knowledge have to be properly managed for the NPD process to be effective and efficient. Therefore, we have evaluated the CIM as a tool for knowledge management (Chapter 5). We have used the key processes for knowledge management as a framework to judge the CIM on its use to make knowledge management operational. By using an example on the development of apple juice with a health benefit it was demonstrated that the CIM is a suitable tool to make knowledge management operational. All the key processes are covered by the CIM and it provides the NPD practitioners with a useful tool to structure the knowledge needed and structure the steps that have to be taken to determine what knowledge is needed, what is available, and what still has to be developed. Also, the CIM provides the food industry with a tool to make implicit knowledge explicit, store the knowledge and make it available for future development projects. By adapting the CIM and carefully completing all the phases of the CIM, a production chain will be able to make knowledge management operational. A protocol has been presented as a stepwise approach to complete the key processes of knowledge management.

We have demonstrated that the CIM can be used for knowledge management in general. To judge whether the CIM can specifically be used for knowledge management in NPD we have used the characteristics for a knowledge management tool as they are proposed by Cooper (2003). In Chapter 5 is demonstrated that the CIM can be used as a tool for knowledge management; it identifies the knowledge needed and encourages cooperation in the NPD process by its chain-orientated approach. It does not disrupt the NPD process and only supplies the NPD practitioners with the information they need. As such it does not distract them by supplying enormous amounts of irrelevant information. And by using the scenarios of the CIM the information is also put in a context.

We conclude that the CIM can be an effective tool to implement knowledge management in food NPD processes. However, the effectiveness of knowledge management is not only dependent of the use of a good tool. Effective knowledge management largely depends of top management support and the organisational structure. If top management does not acknowledge the importance of knowledge management and does not encourage and support the use of such a tool it will never be successfully implemented in the organisational structure of the company. The strength of the CIM as a tool for knowledge management in the food industry is based on several key elements. It helps food companies in the ongoing struggle to make tacit knowledge explicit by capturing the information in formats. The CIM puts information in a context and as a result makes it understandable and interpretable for all actors. By doing this the CIM can help to overcome the 'language barrier', often reported as one of the main problems between technologists and marketeers in NPD teams. Also, the CIM deals with the problem that exists with the enormous amount of NPD tools and the misuse of tools by structuring the information needed and identifying which tools should be used to collect or generate the knowledge required in each stage of the CIM.

6.2 Reflection on the results

As mentioned in Chapter 1, we have used a techno-managerial approach in this research project. This thesis shows that both technological aspects as well as managerial aspects are important for the realisation of a systematic approach for the food NPD process. Technological information and know-how are required to technically realise the intended product, while managerial aspects are needed to create the necessary infra-structure to exchange the technological information between actors. However, before information can be exchanged, agreements have to be reached with respect to cooperation.

The approach of the NPD process from a production chain point-of-view gave added value compared to current existing tools. Current processes, and possible changes in processes, could be tuned to each other by using a chain approach. In Chapter 3 and 4 is demonstrated that multiple processes in the complete production chain influence the quality characteristics of a product. These influences would have been overlooked when the NPD process would have been approached from the viewpoint of a single actor. Also, possible solutions for defects in quality characteristics could be more easily identified by interaction with other actors. For instance, if there is a defect in the mouth feel of a product, this can be solved by a more severe heat treatment, which can lead to other defects (lower nutritional value or taste differences) but the solution can also be found in choosing a different variety of ingredients.

In the NPD process many decisions have to made, like what product to make, trade-off decisions, what ingredients and technologies to use, etcetera. To make these decisions and to reduce the risk of making the wrong decisions, and hence improving the success rate of the new product, information is needed (Chapter 1). From the systematic analysis of the information needed for the development of products in Chapter 3 and 4 it is clear that much of this information is needed from other actors in the production chain. Detailed technological information on influences from processes on the quality characteristics is necessary to guarantee that the consumer's demands are met by the final product.

By exploring the complete production chain for influences of the processes on the new product and systematically gathering all the information needed for the development of new products the drawbacks can be identified at an early state of the process. In this way it can be prevented to a certain extent that the production chain delivers products to the market that would not completely fulfil the consumer's expectations. Chapter 3 and 4 demonstrated that much information is already available somewhere in the production chain, but is not used, simply because one does not realise that the information is needed or that the information already exists. By systematically analysing what information is necessary and what information is missing, future research programs can be constructed more efficiently.

The application of the CIM delivers several scenarios, each indicating options to develop and produce the intended product, and in this way it provides the production chain with a NPD tool to select the best scenario under the given circumstances. Often, actors in the production chain are reluctant to cooperate in strategic projects like NPD projects because they do not want to share strategic company information. The use of the CIM shows that it is often not necessary to share strategic information in chain NPD processes since the information required for the development process is mainly operational by nature (Chapter 3 and 4).

The information needed for NPD covers various fields. In this thesis the information supply is analysed and structured from a technological point of view. Other information, for instance marketing, logistic, legal, and financial information, was not directly taken into account, although these fields play an important role in the success of a product (Van Beek *et al.*, 1998). However, the actors of the production chain use this information when the best scenario is determined.

The CIM was developed for the improvement of existing products, more specifically for products with a health-benefit. We did not focus on true new products, as discussed in Chapter 1, i.e. the classically innovative and equity transfer (Anon., 1999). However, the CIM can be used to aid the development of true new products. It is possible to extend the CIM with other techniques, for instance with creative techniques, to make it suitable for use in the development process of complete new products. Once a new concept has been created and a prototype has been conceived, the CIM can be used to explore the production chain for the best scenario to further develop the product. Often new food products are still recognisable for the consumer and are new concepts in existing carriers. An example is Benecol or Becel pro-active, where a cholesterol-lowering component (the new concept) is put in a well-known existing product (margarine). So, the product is not radically new but the benefit that is put in the existing product is. In this way the CIM can be used to develop new products.

An important issue with food products with a health beneficial component is that producers have to be able to reliably deliver a predefined amount of this component to the consumer (Dekker and Verkerk, 2003). Chapter 3 and 4 illustrate that the complete production chain may influence the quantity of the beneficial component in the product. The CIM can be an important tool for producers to demonstrate the consumers how they make their promise to incorporate a certain quantity of a functional property come true. This adherence to specification is already day-to-day business in the pharmaceutical industry but relatively new in the food industry.

The CIM can also be useful in another way. In international food production chains, which are becoming more important due to the increasing globalisation, communication in NPD projects is often difficult because of the long (physical) distances between team members (Moenaert *et al.*, 2000). The CIM can be used as a communication tool between team members and can be used to transfer information and knowledge between all the members of the production chain all over the world.

The results of this thesis also demonstrate the importance of information and knowledge management for the food industry. Especially, storing information and transferring implicit (tacit) knowledge to explicit knowledge might prove necessary for future excellence. In Chapter 5 is shown that the use of knowledge management for food NPD is not yet common practice, or at least not much is published concerning this subject. Knowledge management for food NPD in a complete production chain is a new concept which offers possibilities to structure the NPD process and enhance the success rate of future products. In Chapter 5 it is demonstrated that the CIM can be used as a tool to make knowledge management operational in food production chains. The CIM not only helps the NPD team to get insight into what information the team needs to successfully develop a new product but also to locate that information. The strength of the CIM for knowledge management is that it helps companies to capture tacit knowledge, which is only kept in the heads of employees, and make it explicit. In this way the knowledge is easily available for future use and for the continuity of the business. The CIM also possesses most of the characteristics a knowledge management tool should possess in order not to be counterproductive (Cooper, 2003). The CIM enables NPD practitioners from different disciplines to communicate with each other and helps to translate different disciplines into understandable knowledge for each practitioner. However, a tool should be supportive for NPD and not be extra work for NPD team practitioners; therefore the CIM should be automated.

Concluding, the CIM provides the food industry with an effective tool to:

1. Exploit the full potential of the production chain;
2. Make NPD processes more efficient;
3. Assure adherence to specifications;
4. Make knowledge management operational in food production chains;
5. Aid product developers in their communication processes.

6.3 Future research

Thus far we have tested the CIM for the improvement of products with a health beneficial component. In order to improve the general use of CIM for the development of other products more case studies should be conducted in production chains in the food industry. The case studies should be done for different types of products to make the CIM more generic. Also, the type of chain organisation might prove important for the use of the CIM. In Chapter 4 we have tested the CIM in a production chain which was closely directed by one actor, which undoubtedly will facilitate the use and implementation of CIM. Many food production chains are actually more related to networks than to chains, so this area should also be tested. It might also prove interesting to test the use of the CIM in the Small and Medium sized Enterprises (SME) since this category compose an important sector in the overall economy

(Avermaete, 2004). It also more likely that larger advantage can be gained in SME's since they often lack the larger budget for R&D of multi-nationals and often do not have knowledge management systems.

In addition, different types of NPD projects should be selected to judge the applicability of the tool. For instance, not only product improvements but also the use of the CIM for true new products should be analysed.

Although the use of the CIM proved beneficial, the construction of the Quality Dependence Diagrams, the Information Matrix and the Decision Trees as part of the CIM (Chapter 3) is a time-consuming job. This might be a drawback for product developers in the food production chain to use the model. With the current ICT knowledge and the widespread use of the Internet and Intranets it should be possible to automate most of these processes parallel to information systems for supply chain management (Van Beek *et al.*, 1998; Wortmann, 2000). Thus far, the collection and processing of the information (phases 1 and 2) has been done manually. Two types of information are needed in these phases: implicit knowledge and explicit knowledge. The completion of the Information Matrix is mostly an expert job; in the Information Matrix the relationships between quality characteristics and processes in the production chain have to be mapped out. This is mainly caused by the nature of the knowledge and information used for completing the Information Matrix, which is often implicit knowledge. Most of this information is not yet made explicit and might prove difficult to gather in a different way than by involving the experts in the process. To collect and process the explicit knowledge it might prove useful to explore the possibilities of text mining (Yang and Lee, 2004; Yoon and Park, 2004).

In this thesis we have used consumer wishes as quality characteristics for the NPD process. However, in practice for actors in a production chain the consumer is not the only customer with certain product quality demands. For a producer of raw materials the buyer of these raw materials is also a customer, whose quality demands have to be taken into account and thus incorporated into the Information Matrix.

The CIM has been analysed for use for knowledge management in the entire production chain. However, from the discussion with the expert panel, as described in Chapter 4, it appeared that the information and knowledge within individual companies often is not properly managed. Therefore, knowledge management within the individual companies has to be taken care of before the CIM can be implemented as an inter-organisational tool.

The exploratory study in Chapter 4 indicated that the CIM was useful as a tool for food NPD. However, the CIM is a qualitative tool. The discussion with the expert panel indicated that a quantification of the output of the CIM would be highly desirable. The expert panel was especially interested in what change in the production chain had the largest influence on the final product. Also, to prioritise future research projects it would be useful if the influences of the processes on the quality characteristics could be quantified. For quantification it is necessary that for each element in the production process the exact (technological) influences on the quality characteristics are known and incorporated into the CIM. CIM is designed in such a way that once the quantified relationships between quality characteristics and processes in the production chain are known, they can be easily incorporated in the tool.

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Summary

Summary

New product development (NPD) is a necessary activity for food companies to survive in the market. However, the failure rate of the current NPD processes is high in spite of the numerous technological possibilities and opportunities offered by demands from the market. Earlier research and experiences of the last years indicate that successful products are the result of a combination of technology push and consumer pull. A systematic approach is needed to lower the failure rate of the food NPD process. Current NPD tools are not able to adequately fulfil this demand. Therefore, a new tool to structure the NPD process has to be developed. Two elements are crucial in realising this objective, namely:

1. A chain approach; for an effective NPD process a chain approach is essential. NPD efforts should be in accordance with all actors to prevent counter productivity during the production process and to fully exploit all possibilities for optimisation.
2. Information management; information and information exchange are needed to reduce the risk in decision-making in the NPD process. Information is also essential to structure the NPD process and to align development and production processes among actors.

The aim of this Ph.D. project has been to develop a NPD tool that is based on the two key elements mentioned above. The tool is based on an existing tool for systematic, consumer-orientated NPD: the Quality Function Deployment (QFD) method.

Chapter 2 presents a review of the QFD method for its use for food NPD. QFD is a planning tool to systematically translate consumer demands into technical (product) requirements. As such QFD could be used to provide the desired relationships between the consumer demands and the actors in the production chain. Publications on the QFD method state that it is potentially a useful tool for the development of food products. However, an evaluation of the literature on the use of QFD for food NPD reveals that the number of examples in which QFD is actually used for the development of food products is limited. From the available literature on the application of QFD on food NPD the following conclusions can be drawn:

- Not many (complete) examples are published;
- In most of the literature only the House of Quality, i.e. the first matrix of the QFD method, is discussed;
- In the House of Quality the HOWs, i.e. the product requirements, are sometimes divided into a sensory and a technical part;
- Some articles refer to the QFD Food Industry Roadmap as presented on a workshop of the American Supplier Institute, although an example of an application of the method is not published to our knowledge;
- QFD should be custom-designed to apply it in a company.

We have used the QFD method to develop a ready-to-eat meal with a health benefit. During this process numerous problems were encountered. The main problem was that is was not possible to give precise target values for the product requirements, which were needed to go to the next matrix. This was caused by the complexity of food products, the many interactions between the ingredients and the influence of processes on functional properties of the product.

Combined with the review of the literature on the use of QFD, we concluded that the application of QFD in the food industry is more complicated than current literature suggests and that at this moment QFD is not suited for our goal to relate consumer demands with actors in the production chain. However, the basic structure of QFD and the first matrix (the House of Quality) appeared to be useful.

In Chapter 3 we used the House of Quality to construct a conceptual tool to structure the information supply in the food NPD process. The conceptual tool was constructed using a hypothetical example on the development of a ready-to-eat meal with a health benefit. The health benefit was based on the presence of glucosinolates in the vegetable component of the meal. This resulted in the Chain Information Model (CIM), intended for use in food production chains to improve existing products by adding a health-supporting component to the product. The CIM consists of three phases: (1) the information gathering phase, in which all the information needed regarding the product is identified and collected (i.e., processes in the production chain, quality characteristics of the existing product, and influences of the processes on the quality characteristics and the health-beneficial component); (2) the information processing phase, in which all the information is linked together to get insight into the effects of processing on the product, resulting in several scenarios; (3) the information dissemination phase, in which the best scenario is selected and the required information is spread among the actors. The CIM provides actors in production chains with a systematic approach to map out all options for the production chain to realise the intended product and to unravel the information flows necessary for its effective production. The strength of this approach is that it forces the NPD team to systematically consider all the options to fully exploit the potential of the production chain and judge the results of possible changes in the production process in advance. It also provides feedback on the quality characteristics of the product from the consumers' point of view and in this way prevents the occurrence of unexpected product failure. Using this approach, the development time and costs can be lowered and the chance of success improved. The use of the CIM also demonstrates that often much information is already available, either within the production chain or in scientific publications and the CIM can be used to collect and store this information. Another important benefit of the CIM is that by collecting and storing the information it is also usable to capture knowledge that only exists as expert knowledge (tacit knowledge) for the continuity of the organization.

Chapter 4 presents an exploratory study to test the CIM in an actual production chain. The exploratory study dealt with the development of tomato ketchup with an increased amount and bioavailability of the anti-oxidant lycopene, a component considered to have health-protecting properties for its consumers. The use and results of the CIM were discussed with a panel of experts. This discussion showed that the CIM proved useful for structuring the information towards a clear scenario to improve tomato ketchup. The CIM enables product developers to analyse the entire production chain in a systematic way. By following such an approach, possible influences of process changes on the final product are mapped before the actual production is carried out. The strength of the tool is that it shows in which areas information gaps exist. The tool indicates exactly which information and knowledge are necessary to realise the intended product and in which areas more specific information is needed. As such, the CIM can be used to draw a research agenda for the production chain.

In Chapter 5 the CIM has been evaluated as a tool for knowledge management. The key processes for knowledge management have been used as a framework to judge the CIM on its use to make knowledge management operational in food production chains. By using an example on the development of apple juice with a health benefit, namely an increased amount and bioavailability of flavonoids, it was demonstrated that the CIM is a suitable tool to make knowledge management operational. All the key processes are covered by the CIM and it provides the NPD practitioners with a useful tool to structure the knowledge needed and structure the steps that have to be taken to determine what knowledge is needed, what is available, and what still has to be developed. Also, the CIM provides the food industry with a tool to make implicit knowledge explicit, store the knowledge and make it available for future development projects. The CIM puts information in a context and as a result makes it understandable and interpretable for all actors. By doing this, the CIM can help to overcome the 'language barrier', often reported as one of the main problems between technologists and marketers in NPD teams. Also, the CIM deals with the problem that exists with the enormous amount of NPD tools and the misuse of tools by structuring the information needed and identifying which tools should be used to collect or generate the knowledge required in each stage of the CIM.

In Chapter 6 the main findings of this thesis are summarised and it is concluded that the CIM provides the food industry with an effective tool to:
1. Exploit the full potential of the production chain;
2. Make NPD processes more efficient;
3. Assure adherence to specifications;
4. Make knowledge management operational in food production chains;
5. Aid product developers in their communication processes.

Furthermore, suggestions are given for future research. The CIM, as presented in this thesis is tested for product improvements. By extending the CIM with creative techniques it can be used for the development of new, creative products. Also, the CIM might prove useful as a communication tool to aid international product development teams, which are more and more becoming common practice because of the ongoing globalisation. Ultimately, the CIM should be completely automated for optimal use. Current ICT knowledge, use of inter- and intranet, and text-mining might be useful in this respect.

Samenvatting

Samenvatting

Het is voor levensmiddelenbedrijven noodzakelijk om nieuwe producten te ontwikkelen om in de markt te kunnen overleven. Echter, ondanks de vele technologische mogelijkheden en de mogelijkheden vanuit de markt is het aantal nieuwe producten dat faalt hoog. Uit eerder onderzoek en ervaringen van de laatste jaren blijkt dat succesvolle producten een combinatie zijn van 'technologie push' en 'markt pull'. Een verlaging van het faalpercentage vereist een meer systematische aanpak van het productontwikkelingsproces. De bestaande 'tools' voor productontwikkeling zijn ongeschikt voor dit doel, en daarom is een nieuwe aanpak nodig. Twee elementen zijn hierbij cruciaal:

1. Een ketenaanpak; voor een effectief productontwikkelingsproces is een ketenaanpak essentieel. Het productontwikkelingsproces moet gedaan worden in overleg met alle spelers in de keten om enerzijds 'counterproductiviteit' tijdens het productieproces te voorkomen en anderzijds het proces te optimaliseren.
2. Informatiemanagement; informatie en het uitwisselen van informatie zijn nodig om de risico's bij het nemen van beslissingen tijdens het productontwikkelingsproces te verminderen. Informatie is ook essentieel om het productontwikkelingsproces te structureren en om de ontwikkelings- en productieprocessen op elkaar af te stemmen.

Het doel van dit promotieproject is het ontwikkelen van een productontwikkelingstool dat gebaseerd is op de hierboven genoemde sleutelelementen. De tool is gebaseerd op een bestaande aanpak voor systematische, consumentgestuurde productontwikkeling: de Quality Function Deployment (QFD) methode.

In hoofdstuk 2 wordt een overzicht gegeven van de QFD methode en de toepasbaarheid voor het ontwikkelen van levensmiddelen. QFD is een tool voor het systematisch vertalen van consumentenwensen in technische (product) vereisten. QFD kan aldus gebruikt worden om de gewenste relaties tussen de consumentenwensen en de spelers in een productieketen in kaart te brengen. Publicaties over de QFD methode melden dat deze methode potentieel geschikt is voor het ontwikkelen van levensmiddelen. Uit een evaluatie van de literatuur over het gebruik van QFD voor levensmiddelen blijkt echter dat het aantal voorbeelden waarin QFD werkelijk voor het ontwikkelen van levensmiddelen wordt gebruikt, zeer beperkt is. Uit de beschikbare literatuur over de toepassing van QFD voor de ontwikkeling van levensmiddelen kunnen de volgende conclusies getrokken worden:

- Er zijn weinig (complete) voorbeelden gepubliceerd;
- De meeste publicaties beperken zich tot het bespreken van het 'Kwaliteitshuis', de eerste matrix van de QFD methode;
- In het 'Kwaliteitshuis' worden de 'HOWs' (de technische productvereisten) soms opgesplitst in een sensorisch en een technisch gedeelte;
- Sommige publicaties verwijzen naar de 'QFD Food Industry Roadmap' zoals deze is gepresenteerd in een workshop van het American Supplier Instituut. Echter, voor zover wij hebben kunnen nagaan is een voorbeeld van een toepassing van deze specifieke methode nooit gepubliceerd;

- QFD moet specifiek voor levensmiddelen aangepast worden om in de levensmiddelenindustrie te kunnen worden toegepast.

In dit proefschrift is de QFD methode gebruikt voor het ontwikkelen van een kant-en-klaar maaltijd met gezondheidsbevorderende eigenschappen. Tijdens dit proces hebben vele problemen de kop opgestoken. Het grootste probleem werd veroorzaakt doordat het niet mogelijk was om precieze doelwaardes te geven voor de producteigenschappen. Deze doelwaardes zijn noodzakelijk om naar de volgende matrix van de QFD methode te gaan. Het probleem werd veroorzaakt door de complexiteit van levensmiddelen, de vele interacties tussen de ingrediënten en de invloeden die processen in de levensmiddelenketen hebben op de functionele eigenschappen van het product. Op basis van deze bevindingen en de literatuurstudie van de QFD methode wordt geconcludeerd dat de toepassing van QFD in de levensmiddelenindustrie gecompliceerder is dan de huidige literatuur ons doet geloven en dat QFD op dit moment niet geschikt is om een relatie te leggen tussen de consumentenwensen en de spelers in de keten. Echter, de basisstructuur van QFD en de eerste matrix (het 'Kwaliteitshuis') lijken wel bruikbaar te zijn.

In hoofdstuk 3 is het 'Kwaliteitshuis' gebruikt om een conceptuele tool te ontwikkelen om de informatievoorziening in het productontwikkelingsproces in de levensmiddelenindustrie te structureren. De conceptuele tool is gemaakt aan de hand van een hypothetisch voorbeeld over de ontwikkeling van een kant-en-klaar maaltijd met een gezondheidsbevorderende eigenschap; de gezondheidsbevorderende eigenschap is het gevolg van de aanwezigheid van glucosinolaten in de groentecomponent van de maaltijd. Dit heeft geresulteerd in het keten-informatie-model (CIM), bedoeld voor gebruik in levensmiddelenproductieketens voor de verbetering van bestaande producten door een gezondheidsbevorderende component aan het product toe te voegen. Het CIM bestaat uit drie fases: (1) de fase van het verzamelen van informatie, waarin alle benodigde informatie voor het product wordt geïdentificeerd en verzameld (zoals processen in de productieketen, kwaliteitskarakteristieken van het bestaande product en invloeden van de productieprocessen op de kwaliteitskarakteristieken en de gezondheidsbevorderende component); (2) de fase van het verwerken van de informatie, waarin alle informatie aan elkaar gekoppeld wordt om inzicht te krijgen in de effecten van de verwerking op het product. Deze fase resulteert in een aantal scenario's; (3) de fase van het verspreiden van de informatie, waarin het beste scenario uitgekozen wordt en de benodigde informatie wordt verspreid over de spelers. Het CIM voorziet de spelers in productieketens van een systematische aanpak voor het in kaart brengen van alle mogelijkheden die in productieketen aanwezig zijn om het geplande product te realiseren en om alle benodigde informatiestromen voor een effectieve productie in kaart te brengen. De kracht van deze aanpak is dat door het gebruik hiervan het productontwikkelingsteam wordt gedwongen om heel systematisch alle mogelijkheden te overwegen en hierdoor het volle potentieel van de keten te benutten. Tevens stelt het het team in staat om vooraf de gevolgen van eventuele veranderingen in het productieproces te beoordelen. De methode geeft de productontwikkelaars ook feedback met betrekking tot kwaliteitseigenschappen van het product welke voor de consument belangrijk zijn en gebruik van de methode voorkomt dat het product hierdoor niet slaagt. Door deze methode te gebruiken kunnen de ontwikkeltijd en –

kosten verlaagd worden en de kans op succes vergroot. Het gebruik van CIM laat ook zien dat veel benodigde informatie vaak al beschikbaar is, ofwel in de productieketen ofwel in wetenschappelijke publicaties. Het CIM kan gebruikt worden om deze informatie te verzamelen en op te slaan. Een ander belangrijk voordeel van het CIM is dat het gebruik hiervan het mogelijk maakt om kennis en informatie die vaak alleen in de hoofden van experts zitten (de zogenaamde onuitgesproken kennis) expliciet te maken en op deze wijze de continuïteit van de organisatie te waarborgen.

In hoofdstuk 4 wordt een exploratief onderzoek beschreven waarin het CIM in een bestaande productieketen getest is. Dit onderzoek gaat over de ontwikkeling van tomatenketchup met een verhoogd gehalte aan lycopeen, dat tevens een hogere bio-beschikbaarheid heeft. Lycopeen is een anti-oxidant waarvan wordt aangenomen dat het voor de mens gezondheidsbeschermende eigenschappen heeft. Het gebruik en de resultaten van het CIM zijn voorgelegd besproken met experts. Uit deze discussie bleek dat het CIM zeer bruikbaar was voor het structureren van de informatie, resulterend in een duidelijk scenario om tomaten ketchup te verbeteren. Het CIM stelt productontwikkelaars in staat om de hele productieketen op een systematische manier te analyseren. Door het volgen van zo'n systematische aanpak kunnen mogelijke gevolgen van procesveranderingen op het eindproduct van te voren in kaart gebracht worden in plaats van achteraf. De kracht van de tool is dat het aangeeft op welke gebieden informatie ontbreekt. De tool laat precies zien welke informatie en kennis noodzakelijk zijn om het beoogde product te maken en waar nog meer informatie nodig is. In deze hoedanigheid kan het CIM gebruikt worden om een onderzoeksagenda op te stellen voor de productieketen.

In hoofdstuk 5 is het CIM als mogelijke tool voor kennismanagement beoordeeld. De sleutelprocessen voor kennismanagement zijn gebruikt als een raamwerk om kennismanagement in levensmiddelenproductieketens te operationaliseren op basis van het CIM. Hierbij is gebruik gemaakt van een voorbeeld over de ontwikkeling van een appelsap met een gezondheidsbevorderende eigenschap (een verhoogde hoeveelheid en bio-beschikbaarheid van flavonoïden). Daaruit bleek dat alle sleutelprocessen van kennismanagement door het CIM worden behandeld. Bovendien is het CIM voor productontwikkelaars nuttig om de benodigde informatie te structureren en om de stappen die nodig zijn om te bepalen welke informatie nodig is, welke beschikbaar is en welke nog ontwikkeld moet worden te ordenen. Tevens kan het CIM gebruikt worden in de levensmiddelenindustrie om impliciete kennis expliciet te maken en om de kennis op te slaan zodat deze gemakkelijk gebruikt kan worden in toekomstige ontwikkelingsprojecten. Het CIM plaats informatie in een context met als gevolg dat het beter begrijpbaar is en interpreteerbaar voor alle spelers in de keten. Hierdoor kan het CIM bijdragen aan het oplossen van de veelgenoemde taalbarrière tussen technologen en marketing in productontwikkelingsteams. Het CIM pakt ook de problemen aan die er zijn met betrekking tot de enorme hoeveelheid aan productontwikkelingstools en het fout gebruiken van tools door de informatie te structureren en te identificeren welke tools gebruikt moeten worden om de benodigde informatie te verzamelen of welke kennis verzameld of gegenereerd moet worden in elke stadium van het CIM.

In hoofdstuk 6 worden de belangrijkste resultaten van dit proefschrift besproken en wordt geconcludeerd dat het CIM een effectieve tool is voor de levensmiddelenindustrie om:

1. het volledige potentieel van de productie keten te benutten;
2. productontwikkelingsprocessen efficiënter te maken;
3. er zorg voor te dragen dat productspecificaties waargemaakt worden;
4. kennismanagement te operationaliseren in levensmiddelenproductieketens;
5. productontwikkelaars te helpen in het communicatieproces.

Ook worden in hoofdstuk 6 suggesties gegeven voor verder onderzoek. Het CIM, zoals dat in dit proefschrift gepresenteerd wordt, is getest voor het gebruik voor productverbetering. Door het CIM uit te breiden met creatieve technieken zou het gebruikt kunnen worden voor de ontwikkeling van nieuwe, zogenaamde creatieve producten. Het CIM zou ook gebruikt kunnen worden als communicatie middel in internationale productontwikkelingsteams; deze worden steeds belangrijker door de voortschrijdende globalisatie. Uiteindelijk zal het CIM voor optimaal gebruik volledig geautomatiseerd moeten worden. De huidige ICT kennis, het gebruik van inter- en intranet en 'text-mining' kunnen hierbij behulpzaam zijn.

Dankwoord

Dankwoord

Het is af! Eindelijk! Wat later dan gepland, maar uiteindelijk is dan toch het einde in zicht. Het was niet in mijzelf opgekomen om een promotieonderzoek te gaan doen, maar toen ik bezig was als toegevoegd docent bij de toenmalige vakgroep Geïntegreerde Levensmiddelentechnologie vroeg Wim Jongen mij ineens naar mijn toekomstplannen en zei dat het eigenlijk wel belangrijk voor mijn toekomst was om te promoveren. Toevallig had hij nog een voorstelletje liggen……. na het lezen van het voorstel begon het toch wel te kriebelen. En dus ben ik er toen maar mee begonnen, als desktop aio tussen de potjesroerders. Het was niet alleen een periode van veel denken en schrijven, maar ook een periode van veel verkassen. Ik ben begonnen bij Hugo in de zuurkast, daarna even met Ana achter het schot terwijl de practicumzaal werd omgetoverd tot kantoorruimte, vervolgens een tijdje in een voormalig weegkamertje gezeten om uiteindelijk te belanden in de gloednieuwe aio-kamer 211b. Aangezien ik als een van de eerste deze kamer betrok, kon ik een strategische plek bemachtigen met mijn rug naar de muur (zeer nuttig om ongestoord de vele attachjes te bekijken die toch wel zeer veelvuldig langs kwamen) en bij het raam (handig om even open te zetten als onze buitenlandse aio's de verwarming weer op 40 hadden gezet). De laatste 1 ½ jaar heb ik in de postdoc kamer vertoefd, eerst met Diane en de laatste periode met Marjolein.

Nu het boekje eindelijk af is, wordt het tijd om een aantal mensen te bedanken. Allereerst mijn promotor Wim Jongen. Wim, dankzij jou ben ik dit onderzoek gaan doen. Verder wil ik je bedanken voor de inhoudelijke discussies en de vele ideeën, al was het voor mij af en toe erg lastig om deze te relativeren waardoor ik soms de neiging had om compleet de andere kant op te willen.

Een belangrijke taak was er ook voor Anita Linnemann. Anita, als co-promotor en dagelijkse begeleidster was het vaak jouw taak om de vele ideeën van Wim iets te temperen en mij er van te proberen overtuigen dat ik toch mijn eigen ideeën moest volgen. Verder had je ook een belangrijke (dag)taak aan het uitvoeren van de taalkundige correcties en het regelmatig geven van een deadline en af en toe de schop onder mijn kont. Anita, bedankt!

Halverwege het project is Peter Folstar erbij gekomen, eerst als co-promotor en later als promotor. Peter, ik wil jou met name bedanken voor de praktische benadering. Jij vroeg mij altijd wat ik nu eigenlijk probeerde te zeggen. Met name voor het laatste stuk is jouw inbreng erg belangrijk geweest.

Dit project was niet alleen project van Wageningen, maar een samenwerkingsproject met TNO Voeding in Zeist alwaar ik officieel 1 dag in de week zou zitten maar waar ik uiteindelijk niet zo heel veel ben geweest. Hier wil ik ook een aantal mensen bedanken, allereerst Angelique Schwarz en vervolgens Hilde Cnossen die het stokje over nam.

Dan zijn er ook nog 'mijn' studenten die in meer of mindere mate hebben bijgedragen aan dit werk: Mari, Juha, Michiel, Geert, Ronald, Anouk en Maartje. Naast jullie bijdrage aan dit werk werd ik door jullie keer op keer gedwongen om zelf weer eens kritisch te kijken naar de dingen die ik aan het doen was.

Dan zijn er ook nog de kamergenoten van 211b, die allemaal in het zelfde schuitje zaten. En uiteraard mijn overige collega's van de leerstoelgroep. Allemaal bedankt voor de hulp, eventuele bijdragen en vooral de gezelligheid!
Alvast bedankt mijn paranimfen, Bas en Retze. Leuk dat jullie mij bij de verdediging terzijde willen staan. Bas, jij weet hoe het is om een promotieonderzoek te doen en de steun was altijd welkom! Retze, ik denk dat jij inmiddels wel een goed beeld hebt gekregen van Bas en mij wat het was om een boekje af te krijgen. Altijd prettig om met jullie en Wouter (die ook druk bezig is met zijn boekje) op donderdag de slachttanden en andere waren (die ik hier maar niet zal noemen) te verhandelen en even lekker je verstand op nul te kunnen zetten. We moeten snel de draad maar weer oppakken!
Mijn ouders bedankt, onder andere voor het geven van maar één voornaam, waardoor ik mij genoodzaakt zag om meerdere titels te halen omdat ik die enkele 'M' toch een beetje kaal vond. Maar toch ook vooral bedankt voor de steun en interesse in mijn werk.

En als laatste Sandra, die op het moment dat u dit leest inmiddels (hopelijk) mijn vrouw is. Hoewel het niet gelukt is om te promoveren voor ons huwelijk (helaas zat heel juni al vol), heb ik de indruk dat ook jij heel erg blij bent met de afronding van dit proefschrift. Ik heb de afgelopen jaren veel weekendjes weg en andere leuke dingen afgezegd omdat ik moest werken. En hoewel ik dat waarschijnlijk niet heb laten blijken was ik toch wel erg blij met je adviezen om toch maar eens een planning te maken……

Marco

Over de auteur

Over de auteur

Marco Benner werd geboren op 31 augustus 1971 in Rotterdam. In 1990 heeft hij zijn VWO diploma gehaald aan het Bisschoppelijk College Schöndeln in Roermond. Diezelfde zomer heeft hij een deelcertificaat Scheikunde behaald te Utrecht om in september 1990 te kunnen beginnen aan de studie levensmiddelentechnologie (specialisatie zuivelkunde) aan de toenmalige Landbouwuniversiteit Wageningen. Deze studie heeft hij afgerond in 1996 en vrij snel daarna is hij begonnen aan de toenmalige leerstoelgroep Geïntegreerde Levensmiddelentechnologie van Wageningen Universiteit, eerst als onderzoeker in het zuivellab en later als toegevoegd docent. In 1998 is hij begonnen als AIO bij diezelfde leerstoelgroep en TNO Voeding met het AKK project "Keteninformatievoorziening ten behoeve van gestructureerde productontwikkeling in voedingsmiddelenketens". Tijdens zijn aio project heeft hij nog enkele nevenwerkzaamheden gehad, zo is hij onder andere naar Nieuw Zeeland gegaan voor het project 'Internationalisering van het onderwijs voor productontwerpen' en was hij ook werkzaam als toegevoegd docent kwaliteitskunde. Momenteel is hij werkzaam als post-doctoraal onderderzoeker bij de leerstoelgroep Productontwerpen en Kwaliteitskunde van Wageningen Universiteit op het gebied van 'kennismanagement van innovatieprocessen'.

This research project was carried out at the Department of Agrotechnology and Food Sciences, Product Design and Quality Management group, Wageningen University and Research centre in cooperation with TNO Nutrition and Food Research, Zeist, the Netherlands.

Dit proefschrift is tot stand gekomen in het kader van de Task Force Ketenkunde.

stichting Agro Keten Kennis