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Viewpoint

A conceptual model of food quality management functions based on a techno-managerial approach

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In agribusiness and food industry quality management problems are commonly approached by applying control systems and procedures. However, assuming predictable food systems and people following procedures seems too straightforward. This paper introduces a model of food quality management functions to support a broader analysis of quality issues, using a techno-managerial approach. It shows essential technological and managerial functions contributing to food quality. Subsequently, it is argued how decision-making in the managerial functions affects food quality by deciding on variability and conditioning of food and human systems. Core decisions on variability and conditioning for all managerial functions are typified in a grid. Benefits of this broader approach are illustrated with a case.

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Introduction

Quality management attains much attention in agribusiness and food industry, in the last decade. Major causes for the increased concern for food quality are related to changes in food supply systems (e.g. more complex supply chains, booming food services), demographic situations (e.g. more elderly people), social situations, consumption behaviour and lifestyle (e.g. increased outdoor consumption, more travelling and exposure to unsafe foods, raised consumption of imported products, changes in food preparation habits). Also environmental conditions (e.g. increased pollution, climatic changes) and changes in food production systems (e.g. mild processing techniques) play a role (Grunert, 2005; Van der Spiegel, Luning, Ziggers, & Jongen, 2003). More specifically, increased consumer awareness (Lin, Jensen, & Yen, 2005), several serious food crises (e.g. Bovine Spongiform Encephalopathy [BSE]) in 1997, Belgian dioxin affair in 1999 (Crawford, 1999), outbreaks of Avian Influenza in Asia 2005–2006 (Center for disease control and prevention, Atlanta, 2006), and major changes in food law (Van der Meulen & Van der Velde, 2004) put more and more requirements on food quality. As a consequence, companies in agribusiness and food industry increasingly focus on quality management systems to deal with these changing requirements (Da Cruz, Cenci, & Maia, 2006; Efstratiadis, Karirti, & Arvanitoyannis, 2000; Luning, Marcelis, & Van der Spiegel, 2006; Ropkins & Beck, 2000; Van der Spiegel, 2004).

However, in practice the results of these systems are often unsatisfactory due to unexpected outcomes in food production and or in behaviour of people that have to work with these systems (Azanza & Zamora-Luna, 2005; Gerats, 1990; Motarjemi & Käferstein, 1999; Van der Spiegel, 2004). The systems are principally based on procedures and control circles as ways to control and assure quality, assuming predictable food systems and people following procedures. According to Luning and Marcelis (2006), food quality management is much more complicated due to the dynamic and complex character of perishable food products in combination with the dynamic and often unpredictable behaviour of people involved in food production. They proposed a techno-managerial (TM) research approach to support a more profound analysis of food quality management issues. The TM approach shows that food quality (FQ) is dependent on food and human behaviour (FQ-relationship) and involves an integrative use of theories from both technological and managerial disciplines to analyse both the food and human systems.

Food quality management deals with how to realise food quality. It consists of goal-oriented decisions resulting in activities which contribute to meeting or even exceeding quality requirements of customers and or consumers. In this paper, we introduce a conceptual model on food quality management functions. Firstly, we discuss which basic technological and managerial functions are relevant. Then, we discuss how decision-making plays a central role in the quality management functions, and how it affects food quality by directing food and human behaviour. Finally, we illustrate with a case the benefits of this analysis, using the food quality management functions model.

Food quality management functions model

In order to identify functions that contribute to the realisation of food quality, we analysed literature from both managerial sciences and food sciences, by using the techno-managerial research approach (Luning & Marcelis, 2006). The conceptual Food Quality Management (FQM) functions model (Fig. 1) shows the organisation

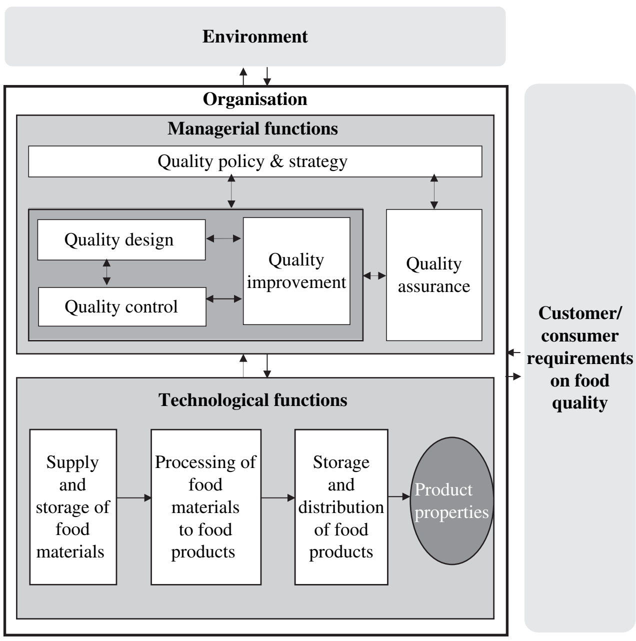

Fig. 1. Food quality management functions model (modified from Luning *et al.*, 2002).

in its environment, wherein technological and managerial functions interact, striving for food quality that meets or exceeds customer and consumer requirements. In our model, *technological functions* are described as technology dependent activities necessary to achieve a product with certain physical properties. Based on Schroeder (2000), technology is defined as a set of processes, tools, methods, and equipment used to produce goods. The technology dependent activities include the actual production activities (e.g. heating, storing, transporting) and the measuring activities (e.g. taking samples, analysing, measuring) to provide information about the status of products and processes. These activities are executed by (process) equipment, machines, and tools alone or in combination with people. In our model, *managerial functions* are described as necessary decision-making activities to activate the food production system as well as the management system, to give it the right direction, and to ensure that it meets consumer and customer requirements. The concepts and argumentations beyond the specific parts of the FQM functions model are discussed in more detail below.

Customer/consumer requirements on food quality

The primary objective of food quality management is to meet or exceed customer and consumer requirements on food quality (Luning, Marcelis, & Jongen, 2002). However, there is no unambiguous concept for food quality in literature (Da Cruz *et al*., 2006; Luning *et al*., 2002; Peri, 2006), so it is necessary to clarify a quality concept for our functions model (Fig. 1). From a techno-managerial perspective, food quality should be perceived broader than just physical product quality. Noori and Radford (1995) considered quality from a total quality perspective and identified six dimensions, that is, product quality, cost, time, flexibility, dependability, and service. We have selected this concept to define food quality, since it addresses both the physical product (first three dimensions) and the organisation (last three dimensions). We slightly modified the concept for food quality as described below:

- Product quality refers to intrinsic and extrinsic quality attributes of the food product. Intrinsic attributes are directly related to the physical product, like safety, health, sensory value, convenience, while extrinsic ones refer to other aspects like how it is produced (e.g. animal friendly) (Luning *et al*., 2002). A food product as such has no quality but consists of physical–chemical properties. Quality attributes are the result of (various) product properties, which are noticeable by sensory observation or via communication, and in this way they contribute to quality perception and experience of consumers and customers (Steenkamp, 1990; Van Trijp & Steenkamp, 2005).

- Cost is primarily considered in a (consumer) customer-oriented net value sense. It is the basis for quality/price perception.
- Availability concerns availability of products, ingredients and/or raw materials, at the right moment at the right place. For food this is important due to rapid decline in quality level of many food products, raw materials, and ingredients.
- Flexibility is the ability of the organisation to respond quickly to changing requirements on products, processes and resources, for example, due to new customer wishes, legislative demands.
- Dependability or reliability refers to the ability of the organisation to continuously meet requirements on quality, such as food safety level and other agreements, so providing confidence to customers and consumers.
- Service involves providing support for consumers (e.g. complaint support) and customers (e.g. service in application of ingredients or in product design).

Technological functions

In management sciences, technological processes are usually perceived as processes with a well-defined input and output, using the common input-process-output concept (Montgomery, 2001). However, due to the dynamic character of food products, being living materials, inputs and outputs are not well defined. Therefore, we distinguish three technological functions with different objectives (as shown in Fig. 1):

1) Physical supply and storage of incoming food materials (i.e. raw and semi-processed materials, ingredients). Technological activities are aimed at *obtaining* incoming food materials with required initial physical properties, which must be *maintained* by appropriate storage conditions. It requires profound understanding of sources of variation that influence variation in properties of incoming materials in relation to (history of) storage conditions (Tijskens, Konopacki, & Simčic, 2003).
2) Transformation of food materials into processed food products. Activities are aimed at *transforming* incoming materials into food products with desired physical properties by applying appropriate technological conditions (Boom, Dekker, & Esveld, 2005; Van Boekel, 1998), which require profound insight into how variation sources affect these transformation processes.
3) Physical storage and distribution of processed food products. Activities are aimed at *maintaining* the required food properties and preventing deterioration by applying appropriate storage and distribution conditions. It requires profound understanding of sources of variation affecting deterioration behaviour of (fresh and processed) products in relation to packaging, storage and distribution conditions (e.g. Galvis-Sánchez, Fonseca, Morais, & Malcata, 2004; Ozdemir & Floros, 2004).

Managerial functions

In agribusiness and food industry, quality control is commonly accepted as a basic function in realising food quality (Luning *et al.*, 2002). However, approaching food quality management only as control processes is reducing reality to cybernetic processes. This is too simple when we realise that the complexity of food quality management is determined by uncertainty due to lack of information, and by ambiguity due to lack of full understanding of the food and human systems (Luning & Marcelis, 2006). Therefore, more quality related activities are necessary, which are focused on understanding the systems (Evans & Lindsay, 2004).

From quality management literature, we have identified five managerial functions that contribute to the realisation of quality, that is, design, control, improvement, assurance, and policy and strategy of quality (Fig. 1), as will be discussed below.

Quality design is important because high quality in complex products can only be achieved by starting at the source of the production cycle (Evans & Lindsay, 2004; Juran, 1990; Luning *et al.*, 2002). Quality design aims at incorporating quality in food product and process design. It starts with specifying consumer and/or customer demands and translating them into product and process specifications. Then requirements on resources are specified, like suppliers, process and transport equipment, and people involved. Design activities reduce ambiguity due to the necessity to analyse and research underlying food and human systems, and they stimulate learning processes (Lessem, 1990; Luning & Marcelis, 2005; Prajogo & Sohal, 2000).

Quality control is a basic activity of food quality management and the objective is to keep product properties, production processes, and human processes between certain acceptable tolerances. Quality control is the ongoing process of evaluating performance of both technological and human processes and taking corrective actions when necessary (Evans & Lindsay, 2004). Control activities are basically focused on gathering information so reducing uncertainty but not ambiguity (Luning & Marcelis, 2006).

Quality improvement is advocated by most quality philosophers as a cornerstone of quality management (Crosby, 1979; Deming, 1986, 1993; Ishikawa, 1985; Juran, 1990). Quality improvement involves a systematic approach to improving a system by paying attention to structural causes and solutions. It is aimed at changing people, processes, and resources in order to bring them at a higher level of quality performance and into "new zones of control", which means working with lower tolerances (Juran, 1990). Improvement contributes to reducing ambiguity due to the necessity to better understand the systems.

Quality assurance is specifically important for food industry and agribusiness since the typical characteristics of agri-food production (like hidden safety risks, restricted shelf life, seasonal harvesting, heterogeneity of raw materials, complexity of supply chains) put high demands on assuring ultimate product quality, specifically on the intrinsic attribute safety (Luning *et al*., 2002; Van der Spiegel, 2004; Van der Spiegel *et al*., 2003). Quality assurance activities deal with setting requirements on the quality system, evaluating its performance and organising necessary changes. The objective is to control the quality system, which includes all activities and decisions to realise quality, and to provide confidence to customers and consumers that quality requirements will be met (ISO, 1998). As shown in Fig. 1, quality assurance is not only linked to quality control, but also to quality design and improvement. It evaluates these functions and influences them by means of the quality system.

Quality policy and strategy is an important function because it relates the quality objectives to the goals and strategy of the company by setting requirements on product quality levels and on the quality system. The importance of a quality policy and clearly establishing quality values in the company's strategy process is increasingly acknowledged (Bergman & Klefsjö, 1994; Hellsten & Klefsjö, 2000). The objective of the function quality policy and strategy is to determine long-term food quality goals and objectives, and how to achieve them by the quality system. It includes determining quality levels of both products, and technological and human resources, and the type of quality system.

Environment

The environment of the organisation has also an impact on food quality (Fig. 1). It refers to social, political, economical, and technological circumstances in the environment that affect decision-making on food quality by the organisation, via interests and power (Johnson & Scholes, 1997; Luning *et al*., 2002). Interests from society ethics provide a set of rules that define right or wrong behaviour (Grigorakis, 2006); interests from the firm's direct environment (e.g. stakeholders) have direct influence on decision-making. Typical examples of interests are related to human health, animal welfare (social, political), biotechnology (technological, political), and supplies from developing countries (social, economical, political). Depending on the power position these interests are contributing to the judgement of decision alternatives on food quality. Moreover, the government is quite dominant with a strong power position and clear interests in food safety (Van der Meulen & Van der Velde, 2004). The government influences food quality along two lines, via rules and procedures and via inspection.

Central role of decision-making in realising food quality

According to management literature, all outcomes of an organisation are the result of decision-making, because everyone takes decisions, both managers and people who are managed (Kampfraath & Marcelis, 1981; Schermerhorn, 2003; Teale, Dispenza, Flynn, & Currie, 2003).

In this section we discuss the central role of decision-making in food quality management, using the FQ-relationship (Luning & Marcelis, 2006). This relationship shows that both food and human systems contribute to food quality. The outcomes of these systems over time reflect their behaviour, that is, food and human behaviour, respectively. The relationship shows that food behaviour is dependent on food dynamics (i.e. variability in properties due to e.g. variable compositions, enzyme activities, or level of pathogens) and applied technological conditions (like process conditions, equipment and building circumstances). Likewise, human behaviour is dependent on human dynamics (i.e. variability in decisions due to e.g. variable perceptions, attitudes, or choice intentions) and administrative conditions (like information systems and procedures).

Fig. 2 schematically shows that human systems make decisions on, respectively, food (1a) and human dynamics (1b), and technological (2a) and administrative conditions (2b). Via these four factors decisions can influence food quality. More specifically, decisions on food dynamics determine the extent of variability in product properties by setting specifications. For example, more narrow specifications leave less room for variation in product property outcomes. Likewise, decisions on human dynamics determine the degree of variability in peoples' decisions, by specifying their actions. For example, by providing specific information, gaining commitment, and or by giving detailed instructions, people will take more similar decisions

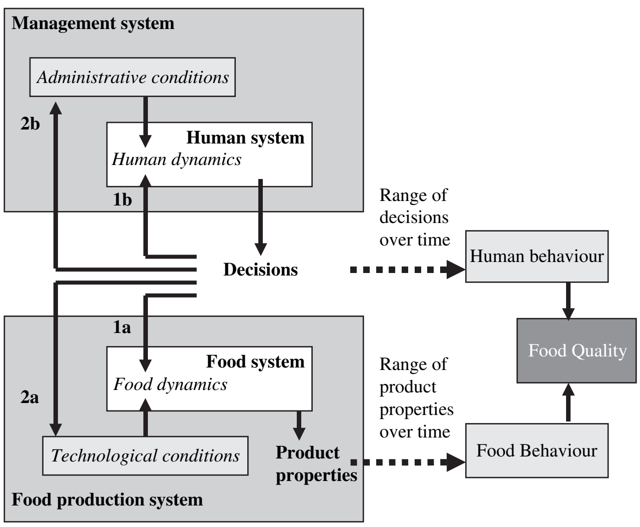

Fig. 2. Food quality decisions model.

resulting in less variation in decision outcomes (Anthony, 1986; Schermerhorn, 2003; Teale *et al*., 2003). In conclusion, decisions on dynamics are aimed at reducing variation by selecting preferred alternatives.

On the other hand, decisions on conditions create circumstances that prevent undesirable properties and/or actions. Decisions on technological conditions specify process parameters, equipment, and buildings. To illustrate, setting stricter requirements on hygienic design prevents contamination and therewith affects the level of microorganisms in the product. Decisions on administrative conditions specify people's competencies, procedures, and information systems, therewith restricting the room of decision-making (Kampfraath & Marcelis, 1981; Robbins, 2000).

Contribution of food quality management functions to food quality

The managerial functions design, control, improvement, assurance, and policy and strategy have different objectives and include different activities (Fig. 1). However, all managerial functions are decision-making activities that activate the food production system (and therein all technological functions) and the management system in a certain way. In this section, we typify decisions on dynamics and conditioning of the food and human systems, for each managerial function. Table 1 provides a grid of core decisions on those four factors.

For example, quality assurance deals with deciding on the design, implementation, and performance of the quality system. More specifically, decisions on food dynamics concern identifying, measuring and evaluating which compounds or agents, and where in the process, are critical towards quality (Luning *et al*., 2002; Peters, 1998). Requirements on the composition of quality system project team (Luning *et al*., 2006), and compliance behaviour towards rules and procedures related to critical quality points (Clayton, Griffith, Price, & Peters, 2002; Henson & Heasman, 1998) are typical decisions on human dynamics in quality assurance. Decisions on technological conditions deal with assessing and validating capability of equipment and processes related to critical points (Scott, 2005; Srikaeo and Hourigan, 2002), selection and validation of process control parameters (e.g. Gonzalez-Miret, Coello, Alonso, & Heredia, 2001), and choice of monitoring systems (e.g. Koutsoumanis, Taoukis, & Nychas, 2005; Tokatli, Cinar, & Schlesser, 2005). Decisions on administrative conditions concern the organisational position of the quality department (Luning et al., 2002), implementation of information systems for auditing purposes, and development of rules and procedures (Walker & Jones, 2002). All types of decisions affect the performance of the Q-system and therewith the actual level of assurance of food quality (Van der Spiegel, 2004; Van der Spiegel, Luning, Ziggers, & Jongen, 2005).

The grid can be used to systematically analyse problems in the realisation of food quality from a broader perspective; it concerns more functions than only control and it explicitly acknowledges the complex food and human systems.

Applying the FQM functions model

In this section a case situation is analysed using the decisions-grid to illustrate the benefits of this broader analysis. As an example, we take the problem situation of a company producing cacao products.

Table 1. Food quality management decisions grid

Functions	Decisions on			
	Food dynamics	**Technological conditions**	**Human dynamics**	**Administrative conditions**
Q-Design	Quality standards and tolerances on product properties	Requirements on process parameters, equipment and buildings	Quality standards and tolerances on actions of people	Requirements on people's competencies, procedures, and information systems
Q-Control	Out of tolerance of properties and corrective action	Deviation from requirements above and corrective action	Out of tolerance of actions and corrective action	Deviation from requirements above and corrective action
Q-improvement	Structural out of tolerance of properties and necessary modifications	Structural deviations from requirements above and necessary modifications	Structural out of tolerance of actions and necessary modifications	Structural deviations from requirements above and necessary modifications
Q-assurance	Critical properties, and critical points and parameters	Capability of processes, equipment and buildings at critical points, and related monitoring systems	Critical decision and action points	Responsibilities and procedures in quality systems, and auditing
Q-policy & strategy	Quality category of food products	Competence level of processes, equipment and buildings	Quality category of people's actions	Competence level of people, organisation and information system

Cacao products are very sensitive to microbial contamination and there are strict standards for acceptable numbers of micro-organisms in the final products. The number of micro-organisms in incoming cacao beans is reduced by sterilisation, but in the subsequent process steps recontamination by dust must be prevented (ICMS, 1980). The company faces many problems with contamination of the final products. The quality manager is a firm believer in quality assurance systems and their effect on product quality. Therefore, he intensifies the number of procedures and stresses on compliance, but without any positive result. Since the sterilisation process functions properly, he decides to analyse contamination via dust. This contamination is commonly prevented by filters, and dust reduction is highly dependent on the effectiveness of the filters (Heldman, 1974; Robinson & Quellet, 1999; Singh, Leela, Mohan, & Sankaran, 1986; Wolf, 2001). The analysis shows that almost two hundred filters are used, ranging from simple to very expensive absolute filters. In several production rooms the air is contaminated and two critical filters are not installed. So, new filters are installed and additional procedures are made. However, again contamination problems occur.

Then a new analysis started using the techno-managerial approach to identify more factors influencing dust levels. Typical technological shortcomings are found in poor separation of production rooms, melting of cacao butter in open air, and low pressure in the air system due to old air-treatment equipment, which was not removed from the air channels. Typical managerial shortcomings are workers not complying to procedures (e.g. operators leaving doors and windows open), poor cleaning during production, no filter replacement program, improper handling of new filters, and lack of in-house knowledge on use and maintenance of filters, because installation and replacement are executed by the filter supplier. Subsequently, the quality decision-grid (Table 1) is used to systematically analyse how the quality management functions may affect the problem situation, leading to following starting points for solutions:

Quality design: formulate standards for acceptable microbial levels at each production step (FD); redesign production rooms and set standards on acceptable number of specific micro-organisms in the air for each room (TC); provide clear instructions on proper filter handling to both operators and filter suppliers (HD); develop workable procedures and specific training for operators and technicians (AC).

Quality control: measure final product contamination (FD); measure pressure differences in the air system to detect unacceptable deviations (TC); control people on inspecting and replacing filters according to procedures (HD); check regularly if the procedures and information system are up-to-date (AC).

Quality improvement: combine data on air pressure with data on product contamination to find relationships as a basis for improvements (FD, TC); involve workers and quality managers in analysing data to improve quality and knowledge on contamination (HD, AC).

Quality assurance: determine which pathogens and where in production form an unacceptable risk due to recontamination (FD); verify process capability at critical production steps and air treatments with respect to recontamination (TC); determine how people should act on critical points (HD), include air treatment in the HACCP system (AC).

Quality policy and strategy: indicate acceptable risk (FD); invest in hygienic production technology (TC); involve own people instead of suppliers in filter control (HD); give responsibilities for filter control to production manager and operators, and allocate budget for training (AC).

The example shows that food quality management problems can be more complicated than expected before. Analysis in more detail reveals that all food quality management functions contribute the problem and possible solutions, and that the four types of decisions all play a role in determining final food quality.

Concluding remarks

Food quality management aims at realising food quality that complies or even exceeds customer and consumer requirements. The current approach in agribusiness and food industry is strongly focused on control mechanisms assuming predictable food and human systems. However, the complexity of food quality management requires that analysis and research should start with recognising the complexity and dynamic behaviour of the systems involved.

The Food Quality Management functions model supports in an in-depth analysis of factors that determine food quality. The model relates consumer/customer requirements with the complex food and human systems meeting these requirements, and the decisions grid explains how the food quality management functions affect the realisation of food quality by decision-making on dynamics as well as conditioning of both food and human systems.

For practitioners the model and grid can serve as a checklist, as is illustrated in the case analysis, to determine which factors have to be taken into account. It prevents a too straightforward diagnosis, and can support in developing more adequate solutions. When used in scientific research, the model and grid provide a consistent framework of factors and relationships that can be analysed to better understand the realisation of food quality. Moreover, the grid can place research outcomes on subsystems and detailed processes in a larger framework, and in this way the effect of different findings can be more easily judged.

When confronted with food quality problems, often more parts of the agri-food chain have to be involved in the analysis. Then the model can be used for the different parts of the chain, like farmers and growers, manufacturers, trading firms, retail companies, and households. The typical input–output way of thinking relates the physical flow of food product through the chain, wherein the output of one part is the input for the next. Analysis with the functions model will link the quality management functions of different parts in the chain, and raise questions like how to cooperate in decision-making, how to build up joint quality systems, and how to involve customers and or consumers in decision-making processes in the chain.

Management is for a large part making assumptions about the future and predicting future developments. In food quality management, prediction is focused on the dynamic behaviour of food and human systems. Future FQM research and analyses should therefore be focused on assessing, quantifying and modelling those technological and managerial factors that contribute to food quality, on the dynamic behaviour of these factors, and on how this behaviour can be conditioned.

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