Measuring effectiveness

of food quality management

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Measuring effectiveness of food quality management

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Abstract

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Keywords: effectiveness, food quality management, instrument, quality performance, contextual factors, agri-food production, conceptual model, performance measurement indicators, identification, validation, assessment, quality assurance systems, QA systems, HACCP, Hygiene code, ISO, BRC, GMP, bakery sector.

In the last decade several incidents have occurred in the agri-food sector, such as the affairs of dioxin and BSE, whereas also the incidence of food-borne diseases and the production of higher risk products are increasing. In order to build and maintain trust of consumers in food quality and food safety, quality management is of major importance in the food sector. Food manufacturers use several quality assurance systems, like HACCP, ISO and BRC, to assure food quality. However, their effectiveness cannot be assessed because an instrument did not yet exist for the food industry.

The aim of this thesis was to develop and validate an instrument that measures effectiveness of food quality management. This instrument enables the selection of appropriate QA systems and supports a proper application.

A reliable and valid instrument “IMAQE-Food” was obtained that measures effectiveness of food quality management. The development was based on a structured procedure including a comprehensive literature research, development of a conceptual model, qualitative research, delphi sessions, quantitative research, and validation. IMAQE-Food is generic for the bakery sector and is expected to be applicable in other food sectors as well after small modifications.

IMAQE-Food was used to investigate the effectiveness of food quality management in the bakery sector and to study the interdependency between the level of food quality management and the context of bakeries. Moreover, IMAQE-Food can also be used for assessment of quality performance and/or food quality management, obtaining insight in the interdependency between contextual factors and production quality, and analysing the appropriateness of QA systems in increasing the level of quality management to obtain a higher production quality.

The insights of this study support food manufacturers in deciding which quality management activities are most suitable for their situation and how their objectives have to be achieved. Policy makers can use information about effectiveness to improve established QA systems and to develop effective implementation methods. This can result in a more effective quality management and an increased production quality, which will lead to more confidence of consumers in food production quality and improving competitiveness of food manufacturers. The developed methodology will also support other researchers to develop similar instruments. For application in other food sectors, IMAQE-Food could be further tailored using the structured procedure as described in this thesis.

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General introduction

1.1 Importance of food quality management

Food quality management has become increasingly important in the agri-food sector. The perspective of quality management has been changed from quality inspection, quality control and quality assurance, to total quality management [1-6]. Quality has been more integrated in the organisation culture; quality policy is more integrated in the strategy, quality management is more found in all levels of the organisation, and quality is improved more continuously [5]. In the food industry, total quality management (TQM) is still not widely applied, however parts of this concept are used [7, 8].

Simultaneously, the perspective of quality has been changed from physical product quality to total quality like product quality, availability and costs. The perspective of production moves increasingly from a product approach towards process and supply chain approaches [5].

In the last decade several incidents have occurred in the agri-food sector, such as Bovine Spongiform Encephalopathy (BSE) and classical swine fever (CSF) in 1997, the dioxin affair in 1999, foot and mouth disease (FMD) in 2001, the nitrophen and medroxyprogesteron acetate (MPA) incidents in 2002, and the dioxin affair and Avian Influenza in 2003. These incidents had an effect on food safety and health of animals [9-20].

Besides these specific affairs, the incidence of food-borne diseases is still increasing world-wide [21], whereas the demography and lifestyle of consumers have also changed [21-24]. The proportion of elderly individuals in the population has grown, which increases the number of people as risk for food-borne illness. Moreover, food is increasingly consumed outdoors. Consumers prefer quick methods of food preparation. The consumption of convenience foods, fresh and fresh-like foods, minimally processed foods, and foods that meet specific health needs has increased. Due to an increased international trade and travel, consumers and manufacturers are in touch with new types of products and processing methods, which requires a more strict method of food control. To meet the consumer preferences and the needs of a changing population, new processing, preservation and packaging techniques have been incorporated into the manufacturing of food products and agriculture have been intensified [21-26].

Due to these incidents, more food-borne diseases and higher risk products, quality awareness of consumers has increased. Consequently, consumers have high demands on a broad range of quality aspects like food safety, production characteristics, sensory properties, shelf life, reliability, convenience, availability and quality/price ratio. Due to the consumer demands, the end linkages of the supply chain e.g. retailers require guarantees of an appropriate production quality. Therefore, also other linkages such as farmers and food manufacturers have to perform an appropriate food quality management, which is demonstrated by an increased number of customers in the supply chain that requires the application of QA systems by their suppliers.

1.2 Food quality management

What is food quality management? Food quality management consists of quality strategy and policy, quality design, quality control, quality improvement, and quality assurance. These activities are performed to produce and maintain a product with desired quality level against minimal costs [27].

Food quality management is complicated because it involves the complex characteristics of food and their raw materials due to variability, restricted shelf life, and the large range of (bio) chemical, physical, and microbial processes. The food supply chain is also complex and consists of a large number of linkages. Moreover, many people are involved in production operations along the food supply chain. Therefore, human behaviour plays a crucial role due to unpredictable and changeable handling.

Producing high quality food products requires a special approach due to the wide range of factors in the food supply chain that can affect quality. Luning *et al.* [27, 28] proposed the techno-managerial approach for food quality management as a way to analyse and solve the complex quality issues. Both the use of technology to understand behaviour of living materials and the use of managerial sciences to understand human behaviour are needed. Thus, both technological aspects (i.e. food characteristics and technological conditions) and managerial aspects (i.e. human behaviour and administrative conditions) should be managed.

1.2.1 Food characteristics and technological conditions

The quality of food products and raw materials change continuously and/or decrease rapidly due to their variability or perishability. Food characteristics and process conditions have to be analysed to know how these affect physical product properties. Examples of these aspects are composition of raw materials and products, product structure, time-temperature profile during processing, and composition of atmosphere within packaging. The relevant characteristics have to be translated to proper control measures like control of respectively time-temperature conditions, raw materials, and final products. Typical measures to reduce effects of the variation and perishability of food quality are selection of raw materials, processing and preservation techniques, packaging, storage and distribution [29].

1.2.2 Quality behaviour and administrative conditions

Behaviour of the people within the context of the organisation also plays a crucial role in food production. As a consequence, the result of agribusiness and food industry, as the combined action of individuals working with agri-food products and striving for quality, is much more uncertain than often is assumed [27].

Quality behaviour is dependent on the disposition and ability of employees [30]. Disposition is the employee's own disposition to behave in a certain direction. Factors that influence the disposition are e.g. knowledge of appropriate food production methods and standards, information about the results. Ability is the objective opportunity to behave in a certain direction. Factors that influence the ability are e.g. skills and competence, facilities and means, and the availability of time. Typical measures to manage human aspects of food production quality are e.g. providing suitable facilities, recruiting employees with required skills and competencies, training and education, communication, motivational programs and empowerment, and creating commitment.

The size of the organisation causes several problems for production quality. Many small and medium enterprises in the agricultural and manufacturing sector have problems to produce according to quality standards due to insufficient knowledge, time, resources, employees and financial possibilities. Large companies have more problems to obtain commitment in the total organisation, from workforce to top management. Besides, these companies often consist of temporary employees with insufficient knowledge, motivation or linguistic skills.

1.3 Quality assurance systems

Food quality management has become increasingly important in food companies, which is demonstrated in an increase of applied QA systems and higher requirements on these systems by customers. QA systems differ in their characteristics i.e. aim, method, perspective, location in supply chain, requirements, and composition (Table 1.1). These systems are distinguished in basic and derived QA systems.

Table 1.1 Differences between QA systems and TQM with respect to aim, method, perspective, location in supply chain, and composition.

Characteristics		**GMP**	**HACCP**	**ISO 9001-3:1994**	**ISO 9001:2000**	**EUREP-GAP**	**BRC**	**SQF**	**TQM**
Aim	Food safety	X	X			X	X	X	X
	Product quality	X	X	X	X	X	X	X	X
	Organisation quality			X	X		X		X
	Environment, and health and safety at work					X			X
	Total quality								X
Method	Plan of steps		X					X	
	Checklist			X	X	X	X		
	Guidelines	X				X			
	Awards / Self-assessment								X
Perspective	Technology	X	X			X	X	X	
	Management			X	X	X	X	X	X
Location in supply chain	Agricultural sector	X				X		X	
	Manufacturing sector	X	X	X	X		X	X	X
	Retail							X	
Composition	Combination of QA systems	-	-	-	-	-	GMP HACCP ISO	HACCP ISO	-

1.3.1 Basic quality assurance systems

The basic QA systems in the agri-food sector are GMP, HACCP and ISO.

GMP aims to combine procedures for manufacturing and quality control in such a way that products are manufactured consistently to a quality appropriate to their intended use [31]. GMP consists of fundamental principles, procedures and means needed to design a suitable environment for the production of food of acceptable quality. GMP-codes vary from general guidelines to procedures that can be applied in a horizontal or a vertical supply chain. GMP focuses on technology aspects [24]. It creates the basic environmental and operating conditions for food production. Therefore, the codes can be used as a basis for HACCP.

HACCP aims to assure the production of safe food products by identifying and controlling the critical production steps [32, 33]. It uses a systematic approach (i.e. a plan of steps) to the identification, evaluation, and control of those steps in food manufacturing that are critical to food safety. It is focused on technological aspects of the primary process. HACCP is included in the Hygiene of Foodstuffs Directive 93/43/EEC.

ISO aims to achieve uniformity in products and/or services, and to prevent technical barriers to trade throughout the world. It requires the establishment of all activities and handling in procedures, which must be followed by ensuring clear assignment of responsibilities and authority. The earlier ISO 9000:1994-series were focused on assuring customers that the products meet the required specifications [24, 34]. In the new standard ISO 9001:2000 a process approach is used. It aims to achieve customer satisfaction by meeting customer requirements, to improve the system continuously and to prevent nonconformity in products and/or services [35]. ISO is a checklist to assure managerial aspects [24].

1.3.2 Derived quality assurance systems

Nowadays, the basic QA systems are often combined to assure several quality aspects, e.g. the combination of HACCP and ISO 9000 [3, 5, 36-38]. Besides, directives are adjusted for integration e.g. the ISO 15161 Guidance on the application of ISO 9001:2000 in the food and drink industry [3, 5, 38, 39], and ISO will also develop a norm with requirements for food safety [40-42]. Moreover, QA systems are developed more specifically for an industry such as EUREP-GAP (Euro Retailer Produce - Good Agricultural Practice), and are integrated in new systems such as BRC (British Retail Consortium) [43-46] and SQF (Safe Quality Food) [47].

EUREP-GAP aims to maintain consumer confidence in food quality and safety, to minimise detrimental impact on the environment and to conserve nature and wildlife, to reduce the use of agrochemicals, to improve the efficiency of natural resources use, and to ensure a responsible attitude towards worker health and safety [48]. EUREP-GAP is a world-wide production standard for the production of agricultural products that are directly or indirectly delivered to supermarkets. It is a checklist that contains minimum standards to the leading retail groups in Europe with respect to food safety, welfare, environment, and health and safety at work [47, 48].

BRC aims to assure product quality and food safety [46, 49]. It is a technical standard for companies supplying retail branded food products. BRC is a checklist that combines HACCP with specific parts of GMP and parts of ISO [43-46]. It is focused on both technological and managerial aspects.

SQF aims to assure food quality and safety in the supply chain or successive linkages [47, 50, 51]. It consists of three standards based on the systematic of HACCP as described in the Codex Alimentarius [51]. SQF1000 is for the agricultural companies and low risk processing companies, SQF2000 is for large supplying and processing industry (high-risk companies), and SQF3000 is for the retail. It combines ISO and HACCP, although it also includes tracking and tracing [47]. It is focused on both technological and managerial aspects.

1.4 Measuring effectiveness of food quality management

Over the last few years, a large number of companies have implemented QA systems and total quality management programmes in order to be able to achieve quality systems and to manage food quality. Nevertheless, the implementation did not always result in the desired performance due to aspects like company characteristics, insufficient quality behaviour and inappropriate implementation methods [52].

Food manufacturers have to decide which quality management activities and QA systems are most suitable for their specific situation, and how these activities and systems should be implemented. Inappropriate management of food production operations can cause several problems like product failures, safety problems, and loss of materials leading to customer complaints and failure costs.

To make the right selection of appropriate quality management activities and QA systems, and to obtain a proper application, the effectiveness has to be investigated. Effectiveness of food quality management can be defined as the actual contribution of these activities to produce and maintain a product with desired quality level against minimal costs. For example, HACCP is effective if it actually contributes to assurance of food safety.

The evaluation methods of QA systems and TQM consider the extent of implementation and compliance with norms and requirements [53]. Nevertheless, their effectiveness in assuring food production quality is not measured.

For other industries, a broad range of instruments has been developed to measure performance of quality management, for example Malcolm Baldrige National Quality Award, EFQM Excellence Model, and the instrument by Saraph *et al.* [54]. These instruments are not directly applicable in agri-food production systems [55]. Moreover, they do not analyse all relations between production quality, quality management, and contextual factors, which is important to measure effectiveness.

Therefore, the food industry requires an instrument that assesses effectiveness of food quality management. Other authors have supported the need for such an instrument [35, 56].

1.5 Thesis

1.5.1 Aim of thesis and research method

The aim of this thesis is to develop and validate an instrument that measures effectiveness of food quality management. This instrument is called IMAQE-Food [I make food], which is an abbreviation for Instrument for Management Assessment and Quality Effectiveness in the Food sector. IMAQE-Food has been designed and used to investigate the effectiveness of food quality management and the effect of context of companies.

For the development of a reliable, valid and generic measurement instrument, literature research, qualitative research (case studies), delphi sessions and quantitative research were performed (Figure 1.1). For the quantitative research a food sector was selected that complies with the following requirements:

- Size of the food sector should be large enough for the selection of an appropriate sample size to apply statistic methods.
- The companies should vary in their contextual factors like QA systems, organisational size, degree of automation, and product characteristics.
- The companies should be representative for the studied sector to use the results in practice.

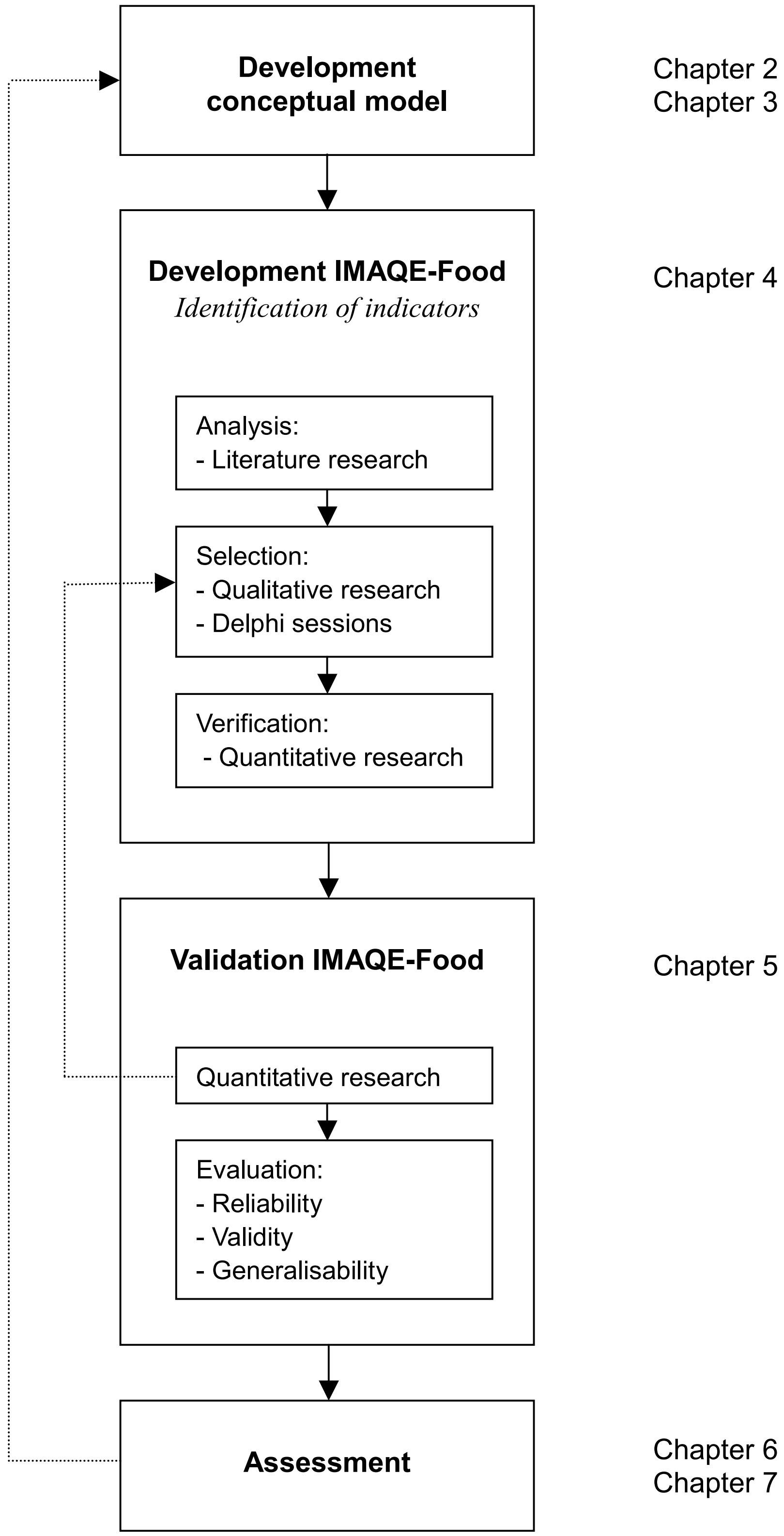

Figure 1.1 Procedure of development and validation of IMAQE-Food.

For these reasons the bakery sector was selected. The procedure of development and validation of IMAQE-Food is shown in Figure 1.1.

1.5.2 Outline of thesis

In **Chapter 2** of this thesis, current performance measurement instruments are evaluated on their use for food quality systems. In reviewing the literature, a broad range of instruments has been developed in other industries to measure performance of quality management. However, they cannot be used for measuring effectiveness of food quality systems. Three instruments and an integrated approach were selected for the development of a conceptual model. In **Chapter 3** the development of the conceptual model that aims at developing an objective diagnostic instrument is described. The purpose of **Chapter 4** was to identify performance measurement indicators of the instrument that measures effectiveness of food quality systems. The development of the instrument IMAQE-Food is described. In **Chapter 5** this instrument is evaluated on generalisability, reliability and validity among a sample of 48 bakeries. This evaluation resulted in a validated instrument that measures the effectiveness of food quality management. **Chapter 6** reports a study on the effectiveness of food quality management in the bakery industry. The interdependency between the context of bakeries and the level of food quality management was studied in **Chapter 7**. Quality management has to be simple and explainable for its application in practice. In **Chapter 8** the significance of this thesis for food production systems will be discussed in a general discussion.

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2

Evaluation of performance measurement instruments on their use for food quality systems

Abstract

This chapter describes the evaluation of instruments on their suitability for the development of an instrument that measures the effectiveness of food quality systems. For this evaluation, perspectives of quality, typical characteristics of agri-food production, quantification, and performance measurement of quality management were studied.

Instruments that measure the performance of both quality management and production quality were identified and evaluated on the basis of defined criteria. Criteria for performance of production quality were six quality dimensions, i.e. product quality, availability, costs, flexibility, reliability, and service. Criteria for performance of quality management were analysis of relationships between quality management, context of the organisation, and production quality; a normative procedure; validation; applicability; classification; and a process approach. Finally, for the final instrument the evaluation resulted in an integrated approach i.e. a techno-managerial approach, and three suitable instruments i.e. Wageningen Management Approach, Extended Quality Triangle, and the quality concept of Noori and Radford.

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2.1 Introduction

The general definition of a quality system is the organisational structure, responsibilities, processes, procedures, and resources that facilitate the achievement of quality management [1]. Within the quality system, manufacturers of agri-food have to realise total quality to comply with high demands of consumers. In the food industry often QA systems such as GMP, HACCP, ISO and BRC are applied voluntary or obliged by legislation to ensure food quality and food safety, to prevent liability claims, and to build and maintain trust of consumers. Total quality can partly be realised by using these QA systems, because they only cover a part of a complete quality system. Moreover, each QA system covers different quality aspects of this complete quality system: e.g. some focus on management aspects (ISO) whereas others focus on technology aspects (GMP, HACCP) [2, 3]. This is shown in Figure 2.1.

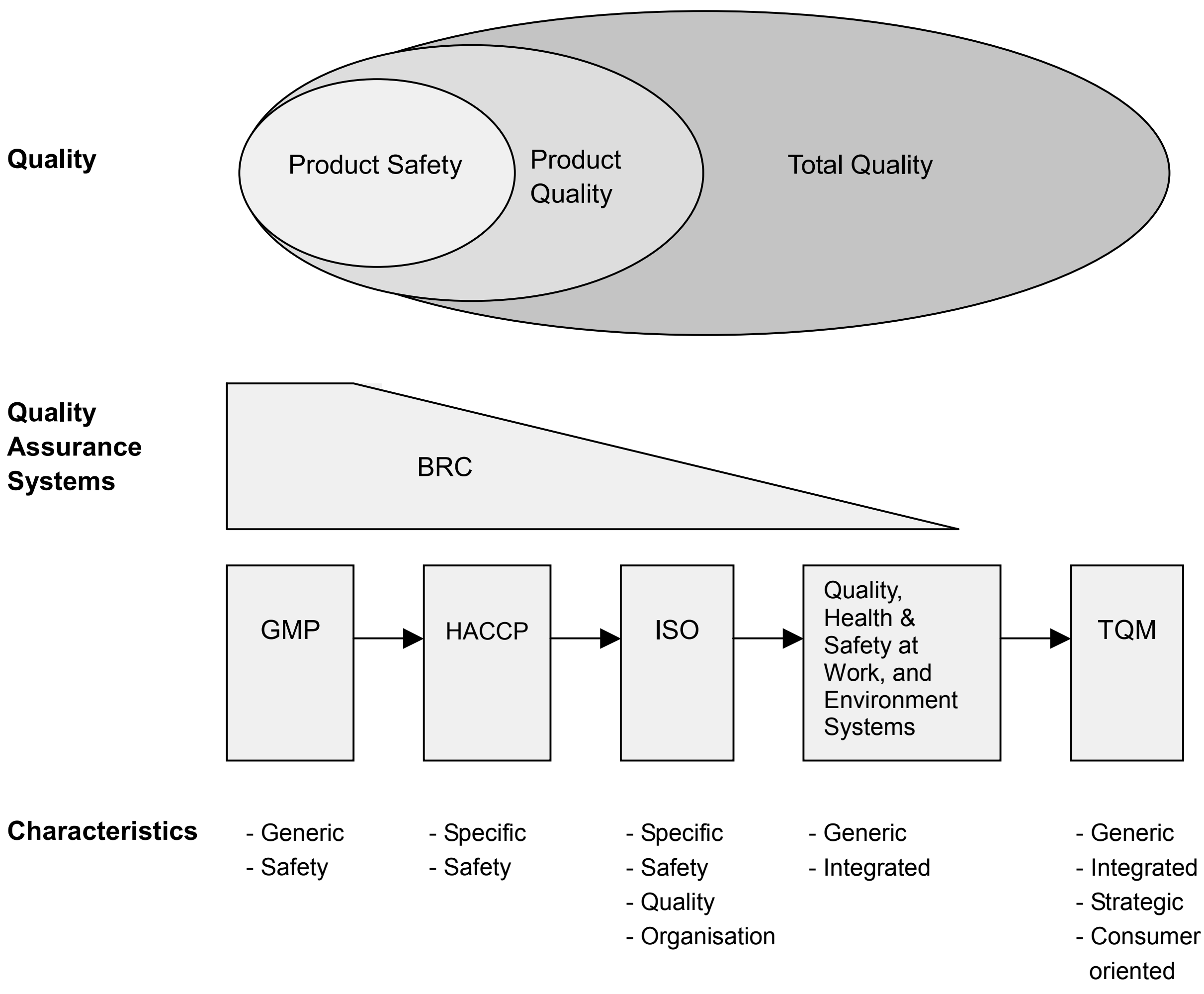


Figure 2.1 Position of QA systems in the food industry in relation to quality aspects (Modified from Hoogland *et al.* [2])

Due to many available QA systems a transparent and unambiguous policymaking is complicated. The QA systems are often combined or integrated to assure several quality aspects (Chapter 1). They can also be extended to the whole supply chain and networks [4, 5]. However, the performance of a stand-alone or a combined QA system might not guarantee total quality.

Additionally, it is still unknown to what extent these systems actually contribute to the total quality, since this depends on the level that an organisation has developed e.g. the size of the organisation, the automation degree of a production process, or the composition of a product. Moreover, an instrument that measures the effectiveness of quality systems for agri-food applications is lacking.

Little is known about which aspects of food production systems should be measured to determine the effectiveness of food quality systems in realising total quality. A broad range of instruments has been developed in other industries to measure performance of quality management and total quality. However, these instruments have a generic perspective and are not directly applicable in agri-food production systems.

This paper proposes that the following information is required for the development of an instrument for measuring the effectiveness of food quality systems:

- From which points of view can quality of production systems be considered and how can this be measured?
- What are the specific characteristics of the agri-food production compared with non-food production?
- How can performance of quality management be measured as related to agri-food production?

The objective of this study was to identify criteria to analyse, evaluate, and select instruments and elements suitable for the development of an instrument applicable in agri-food production systems.

2.2 Effectiveness of food quality systems

2.2.1 Quality concepts and performance

For the development of an instrument that measures the effectiveness of food quality systems, quality concepts have been identified, evaluated, and selected.

Identification

A quality concept should comply with three aims. The first aim is that quality must be evaluated from a broad perspective to account for the expectations of customers. Secondly, the quality concept must consider specific characteristics of agri-food production. Finally, quality must be quantifiable in order to measure the effectiveness of the agri-food production system.

Broad perspective

Quality must be evaluated from a broad perspective in order to account for the expectations of customers.

In the literature, there are many definitions of quality. In this study, these have been classified according to management and production based descriptions (see Table 2.1). Considering this classification, it appears that many authors in quality management use a management based quality description such as complying and/or exceeding customer expectations or satisfaction: Crosby [6, 7], Feigenbaum [8], ISO [1], Zuurbier *et al.* [9], Juran [10], Deming [11]. Some authors describe quality as the difference between customer's perceptions and customer's expectations [12, 13]. Quality can also be subdivided according to specific viewpoints, e.g. Evans and Lindsay [15] who identify judgmental, product based, user based, value based, and manufacturing based quality.

Other authors use a more production based description, which facilitates the quantification of quality. Some of them focus on one quality aspect such as costs or loss (e.g. Crosby [6, 7], Taguchi [17]). Others include more quality aspects like product quality, price, availability, and productivity (e.g. Ishikawa [18], Sloof *et al.* [19]). These quality aspects can be specified and measured using indicators. For example, physical product quality can be expressed as the product composition, which can be measured by e.g. content of water and number of *Bacillus cereus* per ml.

Some authors characterise quality in both management and technological aspects, e.g. Barendz and De Groote [20] distinguish functional, professional, relational, and operational aspects.

Because several descriptions of quality exists from different points of view, a suitable description of quality has to be selected that can be used for measuring effectiveness of food quality systems. Agri-food production exhibits specific characteristics [23-25], and therefore these features have to be taken into account before selecting an appropriate definition.

Table 2.1 Classification of descriptions of quality, on the basis of management based and/or organisation based descriptions.

Author	**Description of quality**
Management based descriptions	
Crosby [6, 7]; Feigenbaum [8]; ISO [1]; Zuurbier *et al.* [9]	To meet customer expectations
Juran [10]	To meet customer satisfaction; fitness for use
Deming [11]	To exceed customer satisfaction
Parasuraman *et al.* [12]; Rowley [13]	Difference between customer's perception and customer's expectations
Cramwinckel [14]	Analytical and emotional quality
Evans and Lindsay [15]	Judgmental, product based, user based, value based, manufacturing based quality
Mulder [16]	Goal quality, program quality, design quality, manufacturing quality, user value
Production based descriptions	
Taguchi [17]	Loss (e.g. failure to reach ideal performance, failure to meet the customer's requirements, breakdowns, harmful side-effects by products) imparted to the society from the time a product is shipped.
Ishikawa [18]	Development, design, production and service of a product that is most economical, most useful, and always satisfactory to the consumer.
Sloof *et al.* [19]	Product, preferences of user (intended use, socio-physiological factors), market situation (price, availability). Assigned quality and the acceptability of a product.
Management and production based descriptions	
Barendz and de Groote [20]	Functional, professional, related and operational quality characteristics
Steenkamp [21]; van Trijp and Steenkamp [22]	Quality cues (intrinsic and extrinsic) and quality attributes

Specific characteristics of agri-food production

The following features have been identified as characteristics of food production [23-25]:

1. *Restricted shelf life*:

   Food products are perishable; product properties can change very fast by physiological processes and microbiological contamination, which can result in deterioration. This requires both management and production aspects. High delivery frequencies are necessary in order to supply the desired product quality, which calls for planning and controlling. Besides, production methods like heating and conservation can prolong shelf life.

2. *Temporary availability*:

   Plant foods are produced and harvested seasonally. As a consequence, products are obtained from other countries or stored under specific conditions, which can affect the product composition. Therefore, temporary availability requires both management and production aspects. For example, variability of products can be prevented by special demands on specifications or by mixing several batches of products.

3. *Consumer awareness*:

   Consumers are aware of the relationship between diet and health, including undesired components (e.g. pathogens and toxicants) as well as components that are desired (e.g. vitamins). However, consumers cannot observe these components and require reliable information about levels and effects on food safety and healthiness. Therefore, consumer awareness requires both management and production aspects like informing consumers, controlling the product composition, and using and developing production methods to produce the desired product composition.

4. *Heterogeneous products*:

   Food products are heterogeneous due to, amongst others, small-scale production, cultivar and breeding differences, seasonal variables and harvesting time. This requires both management and production aspects, although this kind of variation in quality can hardly be controlled. However, effects can be minimised by special demands on specifications or by mixing several batches of products.

5. *High supply chain complexity*:

   The number of linkages in the food supply chain is large and complex: e.g. buyers, suppliers, retail outlets, and wholesalers. The origin and treatment of products is hardly traceable, which can have effects on the certainty on delivery of safe products. Therefore, a high supply chain complexity requires both management and production aspects. Monitoring and information systems can be used to trace the production system characteristics, whereas packaging methods can be used for giving information about the origin, treatment, and shelf life of the product.

6. *Low added value*:

   Food products have a low added value which requires both management and production aspects. If a product does not comply with the expectations, unsatisfied customers will not complain and/or buy the product another time. Consequently, marketing efforts are required to obtain information about customer satisfaction and to influence the quality experience of customers. Besides, the profit margins of the production are low which calls for scaling-up.

Since these characteristics are specific for the agri-food production, an integrated approach of management and technology is required for the development of the instrument. Therefore, both a management and a production based description for quality have been selected. The following management based description has been used: ‘to comply with the expectations of the user or consumer, while the production process is optimally organised, utilised, and controlled’. This description includes expectations of customers as well as parts of quality management. Nevertheless, a more production based description is needed to quantify effectiveness of food quality systems. The following description has been used for the development of the instrument: ‘the match between product specifications and actual performance’. Also the attributes of the specifications have to be made concrete for agri-food production and quantification.

In conclusion, quality is considered from a broad perspective by selecting both a management and a production based description. However, these descriptions have to be made quantifiable in order to measure the effectiveness of food quality systems.

<u>Quantification</u>

Quality must be quantifiable in order to measure the effectiveness of the production system. Therefore, besides the quality description, a quality concept has to be selected in order to measure the total quality performance.

For years, performance of production systems has commonly been evaluated by measuring costs or by measuring the intrinsic product quality such as product safety and sensory properties (taste, colour, texture) [9, 26]. However, nowadays consumers are more aware of additional quality dimensions of agri-food production, such as production system characteristics, variation in product assortment and available information. Therefore, for development of the instrument, a quality concept has to be selected which includes elements for total quality performance, i.e. production quality.

Criteria

In order to quantify this production quality, several concepts are available in literature (Table 2.2). These concepts are based on the measurement of several quality aspects. As mentioned, consumers not only have concerns about physical product features but also on quality aspects related to for example the production system. Therefore, all these aspects should be incorporated in one concept that integrates management and product based aspects [25, 27, 28]. Therefore, the following quality dimensions have been selected to evaluate the quality concepts:

1. *Product quality:*

   Product quality concerns the physical product attributes (taste, shelf life, etc.). It is the difference between the expected product quality according to the product specifications and the realised product quality.

2. *Availability*:

   Availability is the presence of the right quantity of products in the right place at the right time.

3. *Costs*:

   The costs incurred during the primary process including purchase, production and sales.

4. *Flexibility*:

   Flexibility is the ability of an organisation to respond to new situations. Different forms of flexibility exist, such as product flexibility (e.g. volume, innovation), process flexibility (e.g. machine, routing, product range), and infrastructure flexibility (adaptation of company or organisational structure to changes).

5. *Reliability:*

   Reliability or dependability is the ability of an organisation to fulfil its commitments (e.g. contracts with suppliers and customers).

6. *Service:*

   The degree of services which are provided to customers besides the delivery of the ordered product. This includes e.g. offering a variation in product assortment, making a commitment to each customer as an industry entity, helping customers install their products, and providing after-sales support.

Above-mentioned six quality dimensions are used for the evaluation of quality concepts in order to quantify quality performance (Table 2.2).

Evaluation and selection

As shown in Table 2.2, most concepts that describe performance related to production quality use product quality, availability and/or costs as parameter. In fact, these dimensions are related to the quality of the product. The quality aspects that are important for the quality of the organisation involve service, reliability and flexibility. Service is sometimes used in the concepts referred to in Table 2.2. Nevertheless, reliability and flexibility are not commonly used as quality dimensions. A reason might be that quality aspects of the organisation are enclosed in the performance of quality management.

Table 2.2 Classification of quality concepts to measure performance of production quality, on the basis of quality dimensions.

Concepts	Product quality	Availa-bility	Costs	Flexi-bility	Relia-bility	Service	Other dimensions
Garvin [29]	X	-	-	-	X	X	-
Evans and Lindsay [15]	X	X	-	-	-	X	-
De Toni *et al.* [30]	X	-	X	-	-	-	Total quality offered: a. In-bound quality b. Internal quality c. Out-bound quality
Isaksson and Wiklund [31]	X	-	X	-	-	X	Capacity Environment
Challik and Waszink [32]	-	X	X	-	-	-	Scope
Sloof *et al.* [19]	X	X	X	-	-	-	-
de Waal and Bulthuis [33]	X	X	X	-	-	X	Added value
de Groote *et al.* [34]	X	X	X	X	-	-	Improvement rate: a. Quality b. Past improvement c. Future ambition
Jayaram *et al.* [35]	X	X	X	X	-	-	-
Extended Quality Triangle [25]	X	X	X	X	X	X	-
Noori and Radford [36]	X	X	X	X	X	X	-

In addition, some authors use other dimensions, like scope, added value (quality/price ratio), total quality offered, capacity and environment. De Groote *et al.* [34] mention improvement rate across outcome performance dimensions including quality dimensions and indicators of management (past improvement achievements and future ambition). These other quality aspects have been identified and also used for evaluation and selection of the dimensions. Since only a few authors identify these aspects, these dimensions have not been selected.

Furthermore, the emphasis on dimensions and level of detail differ between the concepts. For example, Garvin [29] emphasises on product quality by using several aspects such as performance, features, conformance, durability, aesthetics, and perceived quality. In contrast, for example, Jayaram *et al*. [35] use only the term product quality in general.

It can be concluded that only two concepts, the Extended Quality Triangle [25] and the model of Noori and Radford [36], include quality dimensions of both product and organisation (i.e.

production quality). Therefore, these are considered as the most suitable concepts for performance measurement of production quality in agri-food.

2.2.2 Performance instruments of quality management

For the development of an instrument that measures the effectiveness of food quality systems, performance instruments of quality management have been identified, evaluated by defined criteria, and selected.

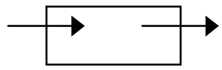
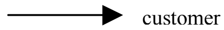
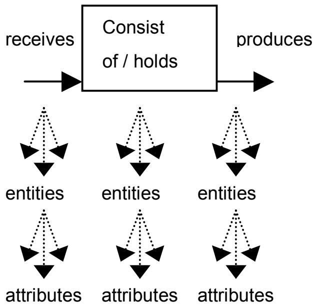
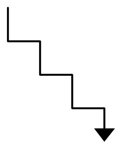
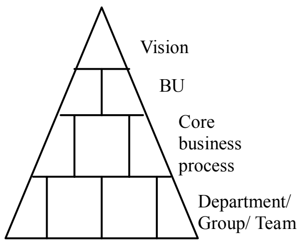
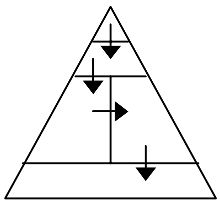
Identification

Performance of quality management can be measured 1) from different perspectives, and 2) by several approaches and instruments.

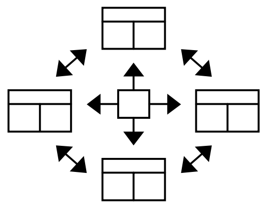
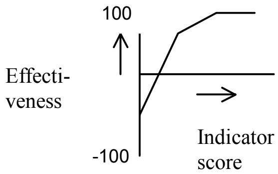
Firstly, quality management can be approached from disciplinary or multidisciplinary perspectives [25, 37]. Disciplinary perspectives can be: a technological approach (e.g. process or product approaches) or a management approach (e.g. process, contingency, decision-making process, cybernetics, integral management approaches [9, 38]). Multidisciplinary perspectives are combinations of disciplinary perspectives. However, they have not been applied in many studies. Since food characteristics can affect the food production quality to a large extent, a techno-managerial approach [25] is proposed to determine the effectiveness of food quality systems. The core element of this approach is the contemporary use of technological and managerial theories and models in order to depict food systems behaviour and to generate adequate improvements of the system (Chapter 1).

Secondly, several instruments have been proposed in literature that may be used for the development of performance measurement systems. The main principles of those instruments have been summarised by Kerssens-van Drongelen [39]. In this study, these performance measurement instruments have been classified from a techno-managerial perspective. These classes are distinguished according to the focus on processes (e.g. process model approach, horizontal approach), on organisation levels (e.g. performance pyramid), on predetermined subject clusters (e.g. Balanced Scorecard) or on indicator formats (e.g. ProMES), as shown in Table 2.3.

Table 2.3 Classification of instruments to develop performance measurement systems, from a techno-managerial perspective (Modified from Kerssens-van Drongelen [39])

Approach	Basic concept	Measurement system format
Process		
1. System / process models approach		Indicators derived from four clusters of identified information needs essential to control a (sub) process: input information, process information, output information and effect information.
2. Horizontal approach		All indicators have a causal relationship with customer requirements.
3. Goal / Question / Metric approach		Process indicators derived from general business goals.
Organisation level		
4. Vertical Approach		Set of indicators for each business level derived via deployment of quantified organisation goals.
5. Performance Pyramid		▪ Nine clusters of indicators derived from corporate vision and spread over three levels; ▪ Business unit level: market and financial clusters; ▪ Core business process level: customer satisfaction, flexibility and productivity clusters ▪ Department / group / team level: quality, delivery, cycle time and waste clusters (these four clusters have to be shown together).
6. Critical Success Factor		Mission and (contingent) strategy are translated into approximately five strategic and functional Critical Success Factors; At the bottom level approximately ten generic optional Critical Success Factors are identified in each functional area; For each Critical Success Factor one or more indicators have to be defined.

Continue Table 2.3

Approach	**Basic concept**	**Measurement system format**
Predetermined subject clusters		
7. Balanced Scorecard		Four clusters with 4-5 indicators reflecting the company strategy: the financial, customer, internal business and learning & growth perspectives.
Indicator formats		
8. ProMES		Indicators derived from responsibilities ('products') of unit subjected to measurement. Performance on each indicator is expressed in an effectiveness impact score using 'contingency diagrams' that allow for non-linearity. Effectiveness scores on each indicator sum up to one effectiveness indicator, with a positive score indicating that the unit is exceeding expectations.

Criteria

Several measurement instruments have been used in literature to measure specifically performance of (quality) management. In this study, six criteria have been developed to evaluate measurement instruments of quality management. These criteria were assessed based on factors to achieve a reliable tool as proposed by De Leeuw [40, 41] and Lichtenstein [42]. De Leeuw [40, 41] describes three criteria to evaluate the quality of instruments, i.e. (1) relevance, (2) reliability and (3) efficacy. Lichtenstein [42] describes also factors that are relevant for the application of instruments, whereas the description of the organisation is also mentioned (external influences, agreement, organisational structure and size, level of risk of the organisation, organisational size and philosophy, and automation). Besides, the criteria were also evaluated on typical aspects necessary to study quality management and effectiveness like approach, suggestions for implementation, and aspects that should be assessed to measure effectiveness [20, 27, 43-45].

In this study the following criteria have been identified to evaluate the measurement instruments on their usefulness to measure the effectiveness of food quality systems:

1. *The instrument must analyse the relationships between quality management, production quality and context of the organisation*:

   Analysis of quality management and its production quality can be a measure of the effectiveness of a quality system. However, quality management and production quality can be affected by the context of the organisation such as the size of the organisation, the automation degree of a production process, or the composition of a product [34, 46-48]. Differences in the context of organisations might explain why performance of quality systems differs. Therefore, determination of the relationship between quality management, production quality and context of the organisation is required.

2. *The instrument must use a process approach*:

   Product quality is related to characteristics of delivered products, which result first from processes. Studying these processes can result in assurance and improvement. Consequently, a process approach is essential to study quality management [43]. Moreover, nowadays companies become aware that effectiveness and efficiency are served by a process approach [27]. Also Van der Bij and Broekhuis [46] observed this orientation on processes and systems. A process approach is also used by the new ISO 9001:2000 series to consider quality management [49]. Therefore, quality management requires a process approach.

3. *The instrument must be normative*:

   A normative instrument is focused on *how* quality management should be performed. Most publications about QA systems described *what* should be done (descriptive), but not how to execute the quality management activities [20, 44, 45]. It is expected that knowledge about performance will facilitate the implementation of QA systems. Therefore, the instrument must be normative.

4. *The instrument must be validated and reliable*:

   An instrument is valid when it measures what it is intended to measure. An instrument is reliable when it consistently yields the same results. This can be achieved by tests and improvements before application or during usage in practice. The validity and reliability can be determined by statistical analysis methods. A valid and reliable instrument is a basis for a high validity and dependability of an instrument. Therefore, the instrument must be validated and reliable.

5. *The instrument must be applicable*:

   An applicable instrument has been developed in such a way that it is concrete, specific and can be used without too many adjustments. Moreover, an applied instrument is more accessible for use. Therefore, the instrument must be applicable.

6. *The instrument must contain a classification system*:

   An instrument must be able to classify different performances of food quality systems. Therefore, the instrument must contain a classification system.

For the evaluation of instruments on their use for measuring the effectiveness of food quality systems, the instruments have to comply with all six criteria. These criteria have not been weighted for the evaluation, since they are considered to have all the same relevancy. The identified criteria represent major requirements for the measurement of the effectiveness of food quality systems and are shown in Table 2.4.

Evaluation and selection

The different instruments have been evaluated on the selected criteria. As shown in Table 2.4, only one instrument complies with the six criteria i.e. Wageningen Management Approach (WMA) [47, 61]. It is described below how this instrument complies with the six criterions and how it differs from other instruments.

WMA is an instrument that studies the relationships between management, performance and the context of the organisation. It assumes that management and the context of the organisation have to be fine-tuned to obtain performance. Table 2.4 shows that most instruments measured quality management and its quality performance, or quality management and context of the organisation, but do not evaluate the relationships between all these elements. However, De Groote *et al.* [34] and Novak and Eppinger [60] also evaluate these relationships.

WMA states that the decisions made by management result in the activities carried out in the primary process, and it uses therefore a process approach. Table 2.4 shows that also three other instruments use a process approach, i.e. instruments by Flynn *et al.* [57], Zhang [50], and De Groote *et al.* [34].

Only WMA appears to be normative; it studies *how* quality management should be performed. Although the Malcolm Baldrige National Quality Award [51] and the Dutch Quality Award [53] apply how-questions, these questions are descriptive. Table 2.4 also shows that most of the instruments were validated or applied.

WMA uses a rating classification system to classify different performances of companies. Table 2.4 shows that the quality awards include a classification method, but other measurement instruments do not classify. The classification methods differ from each other; they use a rating or a score classification or a combination of both.

Because WMA is the only instrument that complies with all six criteria, this instrument can be used for measuring the effectiveness of food quality systems.

Table 2.4 Classification of instruments to measure performance of (quality) management, on the basis of six criteria

Concepts	**1. Subjects / Relations**					**2**	**3**	**4**		**5**	**6**
	Performance	**Contextual Factors**	**Relation between Quality Management and Performance**	**Relation between Quality Management and Contextual Factors**	**Relation between Contextual Factors and Performance**	**Process Approach**	**Normative**	**Evaluation model**		**Applied**	**Classification Method**
								Validity	**Reliability**		
Deming Prize [50]	X	-	-	-	-	-	-	X	-	X	Score
Malcolm Baldrige National Quality Award [51]	X	X	-	-	-	-	-	X	-	X	Score
EFQM Excellence Model [52]	X	-	-	-	-	-	-	X	-	X	Score
Dutch Quality Award [53]	X	-	-	-	-	-	-	X	-	X	Score + rating
ICM-model [54]	X	-	-	-	-	-	-	X	-	-	Rating
Shingo Prize for Excellence in Manufacturing [55]	X	X	-	-	-	-	-	X	-	X	Rating
Crosby [50]	X	-	-	-	-	-	-	X	-	X	Rating
Saraph *et al.* [56]	-	-	-	-	-	-	-	X	X	X	-
Benson *et al.* [46]	-	X	-	X	-	-	-	X	X	-	-
Flynn *et al.* [57]	-	X	-	-	-	X	-	X	X	-	-
Ahire *et al.* [58]	X	-	X	-	-	-	-	X	X	-	-
Black and Porter [59]	-	-	-	-	-	-	-	X	X	-	-
de Groote *et al.* [34]	X	X	X	X	X	X	-	X	-	X	-
Zhang [50]	-	X	-	-	-	X	-	-	-	-	-
Novak and Eppinger [60]	X	X	X	X	X	-	-	X	-	X	-
Wageningen Management Approach (WMA) [61, 47]	X	X	X	X	X	X	X	X	X	X	Rating
Balanced Scorecard [62, 63]	X	-	-	-	-	-	-	-	-	X	-
Productivity Measurement and Enhancement System (ProMES) [64]	X	-	-	-	-	-	-	-	-	X	-

2.3 Conclusions

Although many QA systems have been implemented to realise total quality, it is still unknown to what extent these systems contribute to the design, control, improvement and assurance of total quality. Insight in this contribution can be used for the implementation and development of QA systems. Moreover, the performance of different quality systems can be compared and the value of each individual quality system can be assessed. Therefore, an instrument is needed that measures the effectiveness of quality systems. The need for such an instrument is also emphasised by ISO [65] that stated: 'a significant new effort will be required to identify objective indicators and develop appropriate procedures to monitor them as the basis for any evaluation of strategy implementation'.

For the development of the instrument, information is required about the perspective of quality, the typical characteristics of the agri-food production, quantification, and about performance measurement of quality management.

In this study, instruments to measure performance of both production quality and quality management were selected; quality concepts and performance instruments were identified and evaluated on the basis of defined criteria. Firstly, criteria for the performance of production quality included six quality dimensions, i.e. product quality, availability, costs, flexibility, reliability, and service. Secondly, criteria for evaluation of instruments to measure the performance of quality management were identified. The first criteria in order to evaluate performance of quality management referred to the relationship between quality management, context of the organisation and production quality. Besides, the instrument must be normative, validated, and applicable. Finally, it must contain a classification system and must use a process approach.

Considering the agri-food production, an integrated approach was selected i.e. a techno-managerial approach. Based on the evaluation of instruments, the final instrument to measure effectiveness of food quality systems combines the Wageningen Management Approach with the Extended Quality Triangle and the quality concept of Noori and Radford [36].

In future research, a conceptual model will be developed that involves the relationship between quality management, production quality and context of the organisation. On the basis of this model, an instrument will be developed that can be used to assess the effectiveness of food quality systems.

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3

Towards a conceptual model
to measure effectiveness of food quality systems

Abstract

This chapter analyses several QA systems, and discusses the development of a conceptual model that aims at developing an objective instrument. Successive research can use this instrument to assess performance of food quality systems.

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3.1 Introduction

Food manufacturers have to decide which QA system is most suitable to their specific situation, and how this system should be implemented. Especially specific characteristics of agri-food production [1] require the correct application of the appropriate QA system. However, it is still unknown to what extent these QA systems contribute to the actual assurance of food quality, because the performance of these systems cannot yet be measured. Although a broad range of instruments has been developed in other industries to measure performance of quality management and total quality, in specific they are neither normative nor do analyse effectiveness [2]. Therefore, the food industry requires an instrument that assesses effectiveness of food quality systems in order to make a better selection of appropriate QA systems and to obtain a better application. Improved QA systems should be developed that are adjusted to the specific situation of an organisation. The need for an instrument is also emphasised by ISO [3] that stated that 'a significant new effort will be required to identify objective indicators and develop appropriate procedures to monitor them as the basis for any evaluation of strategy implementation'. As a result, a higher assurance of food quality can be obtained, which in turn results in trust of consumers.

This chapter discusses the analysis of QA systems in the food industry. Additionally, a conceptual model is represented that reflects the interrelationship between quality management, contextual factors and total quality. In future research, this model will be used to develop an objective diagnostic instrument to assess performance of quality systems in agri-food production.

3.2 Analysis of QA systems in the food industry

3.2.1 Quality Assurance systems

The general definition of a quality system is the organisational structure, responsibilities, processes, procedures and resources that facilitate the achievement of quality management [4]. The organisational structure is the formal pattern of functions and tasks, the relations between them and the order of the processes within the organisation [5]; it clarifies the arrangement of an organisation. Within this organisational structure, the responsibilities, tasks and competencies of the employees have to be determined in order to know who is accountable for a specific activity. This activity is part of processes in the organisation, e.g. the production process, purchase, and product development. What has to be done, by whom and how is written in procedures. The execution of tasks requires resources including employees, raw materials and equipment.

QA systems cover only different aspects of the complete quality system [1, 2, 6, 7]. This is shown in Table 3.1. In comparison with GMP, HACCP, ISO and BRC, TQM is not a QA system but a concept to improve organisations continuously, to satisfy both the external and internal customer, to achieve quality of products, and to save costs by doing things right the first time [8-10]. TQM is a management view that covers the complete quality system.

As shown in Table 3.1, other differences between above-mentioned systems exist. GMP and HACCP are especially developed to assure food safety. BRC deals like HACCP with food safety and product quality but evaluates also on management aspects (ISO) and facility conditions (GMP). TQM aims to improve total quality. Additionally, ISO and TQM focus more on management aspects, whereas GMP and HACCP focus on technology aspects [6]. GMP, HACCP and ISO are more detailed than BRC and TQM. Furthermore, food manufacturers are obliged by legislation to apply HACCP, while the other systems are applied voluntary in the food industry. Whereas quality control and quality assurance are central issues in HACCP, the ISO 9000:1994-series and BRC, continuous quality improvement is aimed by ISO 9001:2000 and the philosophy of total quality management. HACCP is the only QA system that consists of a plan of steps, in contrast to the checklists of ISO and BRC. GMP includes guidelines, and TQM uses awards or self-assessments. Thus, HACCP has a normative approach, while the other systems are descriptive.

Because QA systems differ in several aspects, they are combined or integrated to assure more aspects of food quality. For example, HACCP and ISO are combined to take technological and management measures for assuring food safety and food quality [11-15]. Especially the new ISO norm with requirements for food safety could be helpful for the application of HACCP [16-18]. Although food manufacturers use several QA systems and concepts, the application still fails.

Table 3.1 Differences between QA systems and TQM with respect to quality system characteristics, result, perspective, extensiveness, requirements, quality management, method, and suggestions for implementation.

Tools	GMP	HACCP	ISO 9001-3:1994	BRC	ISO 9001:2000	TQM
Quality system characteristics						
Organisational structure			X	X	X	X
Responsibilities			X	X	X	X
Processes		X		X	X	X
Procedures	X		X	X	X	X
Resources	X			X		X
Result						
Food safety	X	X		X		X
Product quality	X	X	X	X	X	X
Organisation quality			X	X	X	X
Total quality						X
Perspective						
Technology	X	X		X		
Management			X	X	X	X
Extensiveness						
More detailed	X	X	X		X	
Requirements						
Legislation		X				
Voluntary	X		X	X	X	X
Quality management						
Quality control	X	X	X	X	X	X
Quality assurance		X	X	X	X	X
Quality improvement					X	X
Method						
Plan of steps		X				
Checklist			X	X	X	
Guidelines	X					
Awards / Self-assessment						X
Suggestions for implementation						
Descriptive	X		X	X	X	X
Normative		X				

3.2.2 Implementation

Food manufacturers have to decide which QA system is most suitable to their specific situation, and how this system should be implemented.

Over the last few years, a large number of companies have implemented QA systems and total quality management programmes in order to introduce effective quality systems and to achieve high-quality products. Nevertheless, the introduction did not always result in the desired performance. Several studies investigated the causes of failures. Some mentioned company characteristics as major cause, whereas others suggested that improper implementation was the reason. Noci and Toletti [19] mentioned that distinctive features of small companies and general problems affecting all companies in the assessment of quality-based programmes are responsible for these failures. Other authors also suggested that some pitfalls are caused by implementation failures, such as a fixed organisation culture, lack of commitment or knowledge, and no clear goals [10, 20-31]. Moreover, several authors suggested that the uniform method is not suitable due to the different business environment (the context) of the organisation. They mentioned the complexity of the organisation [5, 23, 32-37], the complexity of the production process [29, 35, 38, 39], the complexity of the product [29, 35, 40, 41], and human resource management practices [42]. These implementation failures and the context of the organisation require continuous adjustments of quality management activities, which should be based on assessment of quality performance.

3.2.3 What and how

Most publications about QA systems described *what* should be done, but not *how* the activities should be accomplished to manage quality [2, 7, 24, 43-45]. QA systems are often too generic in nature in order to be applicable for each company. Consequently, they only describe what level of quality system a company must achieve and not the necessary steps to arrive at this level. Therefore, failures are made due to an inappropriate implementation method. Moreover, since agri-food production differs from non-food production [1], it is expected that this sector also requires a specific approach to achieve the expected quality level. To know to what extent the systems contribute to total quality, an instrument is required that measures performance of quality systems. The development of such an instrument necessitates information about which factors affect the realisation of the production quality. The relationships of these factors and the production quality are represented in a conceptual model.

3.3 The conceptual model

Figure 3.1 shows the conceptual model, which reflects the interrelationship between factors influencing quality performance, quality management and production quality. The selection of a relevant instrument for the development of the conceptual model was based on a comprehensive literature research. Several performance measurement instruments were compared and selected upon a set of criteria [2]. Two instruments were selected as a basis for the model, i.e. the Wageningen Management Approach [33, 46] and the Extended Quality Triangle [1].

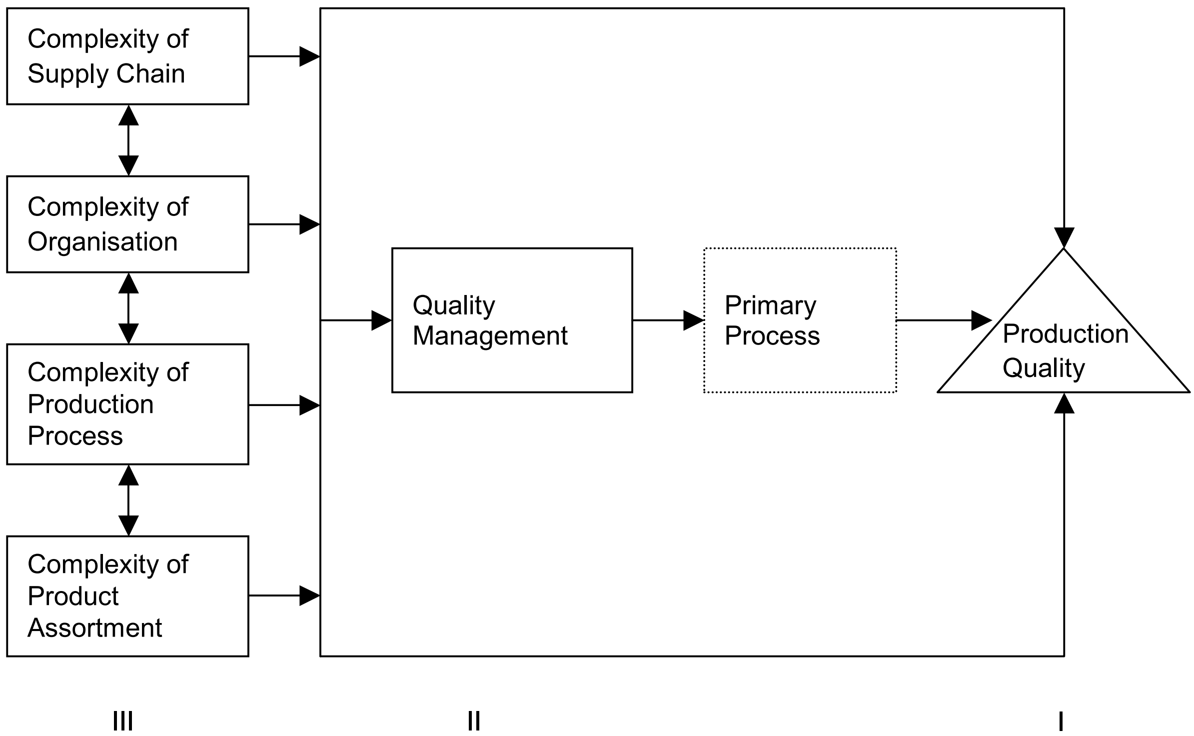

Figure 3.1 The conceptual model to measure effectiveness of food quality systems (adapted from van der Spiegel *et al.* [45])

This integrated conceptual model consists of three elements: I. production quality, II. quality management, and III. contextual factors. Arrows reflect the relationship between these elements. According to the model the primary process is managed by quality management (II) to obtain an appropriate production quality (I). In fact, the decisions made by employees on

each organisation level result in activities carried out in the primary process. The contextual factors (III) can affect the production quality directly [32, 33]. Proper quality management (II) is assumed to obtain an appropriate food production quality by adjusting quality management activities to these contextual factors.
It is hypothesised that a higher production quality is obtained by a higher level of quality management. A higher complexity of contextual factors is expected to relate to a lower production quality; a higher level of quality management is assumed to reduce the influence of the contextual factors on production quality. These hypotheses will be explained below.

3.3.1 Quality management and production quality

Production quality is the end result of quality management and the primary process (Figure 3.1). For defining production quality in the model, the Extended Quality Triangle [1] (Figure 3.2) was selected by evaluating quality concepts on a set of criteria [2].

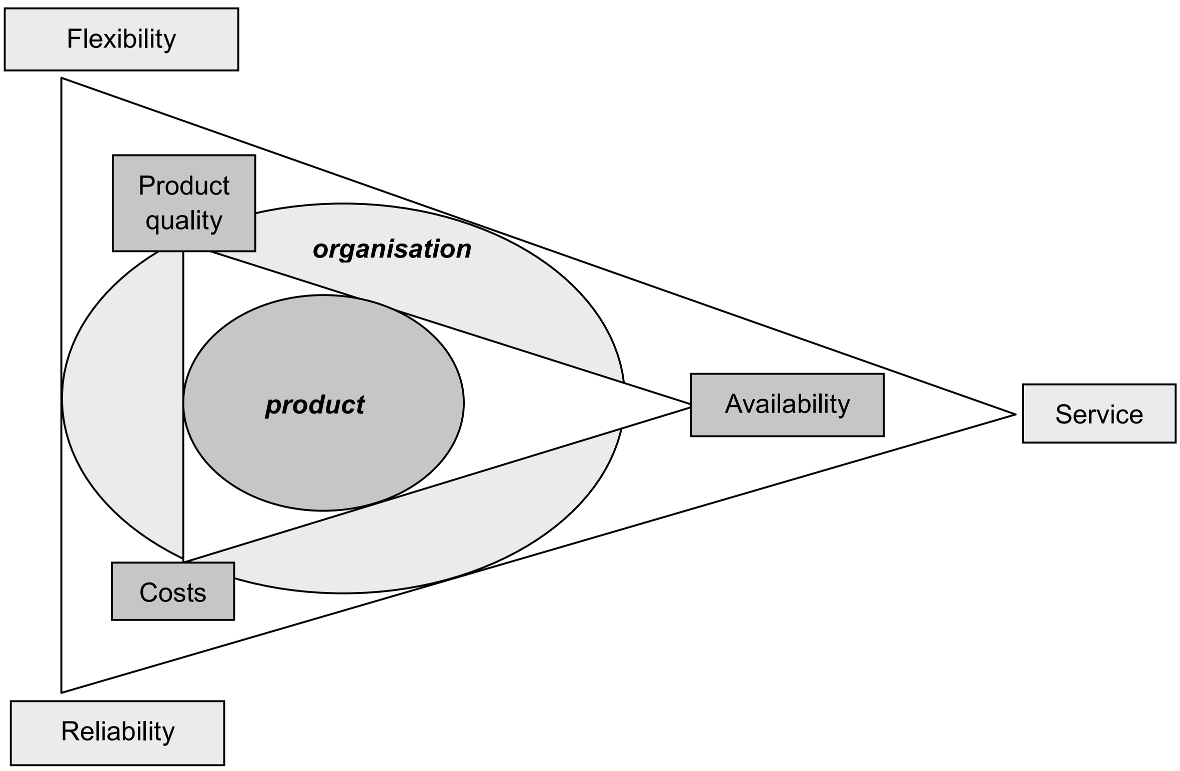

Figure 3.2 The Extended Quality Triangle [1].

For years, performance of production systems has commonly been evaluated by measuring costs or the intrinsic product quality [47]. However, the quality perception of consumers is not only affected by physical product attributes (taste, shelf life, etc.) or costs, but also by additional dimensions such as availability of the product, and flexibility, service and reliability offered by the organisation [1, 39, 42, 48-50]. Therefore, quality has to be considered in a broad perspective including technological and managerial aspects. The Extended Quality Triangle distinguishes production quality between quality dimensions of the product (product quality, availability and costs) as well as those of the organisation (flexibility, reliability and service). Production quality can be measured by the extent to which quality dimensions are achieved. These quality dimensions must comply with the expectations of the customers [4], and therefore with the agreed specifications.

Production quality can be controlled by quality management. In our view, quality management of primary production consists of activities that control, improve and assure the primary process, which in turn results in a certain production quality. It is focused on obtaining and controlling the expected production quality against minimal costs and efforts.

In literature, several relations between quality management and production quality are described: e.g. selection of suppliers or mixing several batches of raw materials improves product quality [1, 51, 52], quality management activities improve financial results or reduce quality costs [32, 33, 48], selection of suppliers improves availability of products [51].

3.3.2 Contextual factors, quality management and production quality

The contextual factors are part of the environment in which a company operates that affect the production quality. Some factors cannot be controlled (e.g. regulations of the government) in contrast to other factors such as type of the process. The last mentioned factors have to be controlled to realise the desired quality performance. This control requires a certain level of quality management. The diversity in contextual factors might explain why the performance of quality systems differs.

In literature, several contextual factors are described which affect both quality management and production quality, such as size of the company, type of the product, technology, type of the process, human resource management practices, networks of relationships, and organisational culture [5, 22, 23, 32, 34, 35, 38, 39, 42, 53-55]. For example, if the variety of raw materials is large, the number of aspects that has to be considered during decision-making will also be large in order to obtain the desired production quality. These aspects are controlled by activities like mixing several batches of raw materials, investing in systems in order to obtain information of preceding production systems, or co-operation between linkages in the supply chain [1, 2, 52, 56].

Although all above-mentioned contextual factors affect the quality management tasks, four variables were selected that are related to food production quality and quality management by analysing food production characteristics. These variables include complexity of the supply chain, complexity of the organisation, complexity of the production process, and complexity of the product assortment.

Complexity of the supply chain

Food supply chains are special forms of networks in which food companies are the actors [57]. A supply chain consists of at least three sequential companies in a vertical relationship, including multiple partnerships [54]. In general, food supply chains are characterised by a large number of linkages, a lot of suppliers and customers, a small-scale production in the primary sector, and seasonal supply of raw materials [1, 58]. However, differences between individual food supply chains also exist, e.g. the number of linkages, location of a linkage in the supply chain, relationships and co-ordination between linkages, and characteristics of food production (like organic production, genetic modification, and origin of raw materials). The diversity of these aspects is called complexity of the supply chain.

The complexity of the supply chain requires co-operation and trust between linkages in order to ensure quality, such as agreements of production specifications and exchange of information. This can result in a synergistic effect on quality performance. However, which partner takes advantage of the co-operation is dependent on the way individual companies operate, the degree of dependency and the extent to which the co-operation dominates. Thus, interdependencies, behaviour of co-operating companies and their context affect performance of a supply chain [53-55, 57, 59, 60]. Therefore, performance of the company is also influenced by supply chain complexity [57]. Consequently, differences in the supply chain can affect performance of quality management activities in a company.

It is expected that the diversity of the food supply chain will affect performance of quality management and/or production quality of an individual food company. The diversity of food supply chains may explain why food quality systems of several supply chains differ in the realisation of the production quality.

Complexity of the organisation

Food-producing companies differ in several aspects, e.g. the origin of raw materials and resources, the number of suppliers, the number of employees, the number of products produced, and type of outlets. The diversity of these aspects is called complexity of the organisation [32, 33].

Several researchers have observed an effect of some organisation aspects on quality management, e.g. the origin of raw materials and resources or the company size [33, 35, 38]. Due to the complexity of the organisation, a food-producing company performs different activities. For example, a company distributes or sells products by itself, or leaves these activities to other organisations such as a distribution company or a supermarket. Additionally, the production occurs at one or several affiliates. Besides, the extent of differentiation and specialisation affect quality management. A diverse and specialised organisation structure (e.g. a large number of departments and hierarchical levels) hinders obtaining insight in processes. Therefore, control of goals and requirements are complicated and a larger amount of control measures might be necessary. Thus, complexity will complicate the effective application of quality management considerably [34, 61].

It is expected that the diversity of the food organisation will affect performance of quality management and/or production quality. The diversity of the food organisation may explain why food quality systems differ in the realisation of the production quality. In our study, complexity of the organisation is focused on merely management aspects.

Complexity of the production process

Food production processes differ in e.g. the number of process steps, specificity of production processes, and the heterogeneity of raw materials due to seasonal harvesting and natural variation. This diversity is called complexity of the production process [62]. The complexity causes variation during manufacturing, which makes demands on quality management to control food production quality.

Additionally, operation and design of the production processes differ. For example, the ratio between batch and continuous processes affect quality management activities [39, 63-65]. Besides, the number of closed and open processes differ which affect risks and actions during production. Automatic and manual operations also influence risks, speed and actions of the production process. Therefore, complexity of the production process is expected to affect performance of quality management and/or production quality. The diversity of food production processes may explain why food quality systems differ in the realised production quality. In our study, the complexity of the production process contains merely technological aspects, whereas management aspects are classified in the complexity of the organisation.

Complexity of the product assortment

The product assortment of food-producing companies consists mostly of a variety of products that have diverse product compositions. This diversity is called complexity of the product assortment. The complexity requires diverse production techniques, manufacturing processes or highly specialised knowledge to ensure acceptability and asks for diverse controls and checks to ensure quality [40].

As an example, in a study in the automobile industry the impact of different product varieties on performance varied but was in general less than expected. Nevertheless, a large number of parts affected the productivity negatively [66]. Benson *et al.* [35] also revealed that product or process contextual factors have little effect on quality management. Nevertheless, product complexity affected service companies, probably due to more diverse industries and different type of product environment. Because of the diverse and specific characteristics of food production [1, 58], it is expected that the complexity of the food product assortment cause the same or even a larger effect on production quality.

Food characteristics are affected by the composition of individual raw materials, the recipe of the product, and the processing conditions. Especially manufactured food products may consist of a large number of raw materials, often present in complex matrices. The characteristics of these ingredients are modified by several reactions that affect the food shelf life in different manners. Control of these reactions requires quality management activities e.g. selection of raw materials or production methods. Therefore, it is expected that the complexity of the product assortment affects the performance of the quality management and/or the production quality. Also, the diversity in production assortment may explain why food quality systems differ in the realisation of the production quality.

3.4 Conclusion

Quality assurance is of major importance in the food sector. Food manufacturers have to decide which QA system is most suitable to their specific situation and how this system should be implemented. However, effectiveness of food quality systems cannot be assessed because an instrument does not exist. In this study, a conceptual model was developed as a basis for an instrument.

On the basis of a comprehensive literature research and model development it is assumed that a relationship exists between production quality, quality management, and contextual factors. Four contextual factors are relevant for food production. These factors include complexity of the supply chain, complexity of the organisation, complexity of the production process, and complexity of the product assortment. The diversity of these factors between companies may explain why quality systems differ in the realisation of the production quality, and can be used for implementing and developing QA systems. The different situations of food companies and the specific characteristics of food production ask for a specific approach consisting of technological and managerial aspects, which should be included into a normative QA system in order to achieve the objectives of the system.

Successive research can use this model for the development of an instrument to measure effectiveness of food quality systems. This instrument can be developed by identifying performance measurement indicators for production quality, quality management, and contextual factors. Examples of indicators are: results of analyses, market share, number of complaints, selection of raw materials, type of product groups. Quantitative research and statistical tests should be used to test assumed relationships of the conceptual model, which will indicate how quality systems are related to production quality.

Knowledge about this effectiveness supports food manufacturers to decide which system is most suitable and how to achieve their objectives. This can result in a higher production quality, compliance with expectations of consumers, maintenance and building trust of consumers in food production quality, and maintenance and improvement of competitiveness of food manufacturers. Additionally, method development in performance measurement of food quality systems obtains insight in relations between technological and managerial aspects, and in factors that influence production quality to determine the desired level of quality management.

3.5 References

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4

Development of the instrument IMAQE-Food to measure effectiveness of food quality management

Abstract

This chapter is based on a study that was set up to identify performance measurement indicators of an instrument that measures effectiveness of food quality systems, called IMAQE-Food. This instrument has been developed by translating a conceptual model in quantifiable performance measurement indicators. Literature research, qualitative research, delphi sessions, and quantitative research resulted in 28 relevant and comprehensible indicators that measure performance of quality management, production quality and their influencing factors in the bakery sector. IMAQE-Food is useful to obtain information and knowledge about effectiveness of food quality systems, which support manufacturers in deciding which system is most suitable to achieve their objectives. The developed procedure can be used for providing insight in determining the desired level of quality management, and for extending the instrument for other applications.

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4.1 Introduction

The food manufacturing industry uses in particular three internationally acknowledged QA systems, i.e. HACCP, ISO, and BRC, and less frequently the concept of TQM. Based on HACCP principles, Hygiene codes have been developed which aim to assure the production of safe food products for non-industrial companies.

Table 4.1 shows that these QA systems and the TQM concept differ in aim, procedure, evaluation, and assessment. HACCP, Hygiene code, and ISO 9001:2000 use more detailed evaluation methods than BRC and TQM. The evaluation methods of the QA systems and TQM consider the extent of implementation and compliance with norms and requirements. Nevertheless, their effectiveness in assuring food production quality is not measured.

Moreover, a broad range of instruments has been developed to measure performance of quality management and/or total quality, however they do also not measure effectiveness of QA systems. Therefore, the food sector needs an instrument to measure effectiveness of food quality systems.

This chapter discusses the development of an instrument that measures effectiveness of quality systems in the bakery sector. For this purpose, an identification procedure to identify performance measurement indicators has been developed, which is described in detail in this paper. We discuss comprehensibility, availability, and relevancy of indicators to measure effectiveness of quality systems in the bakery sector. Moreover, we compare our instrument with other instruments and discuss the application in other sectors.

This study will make a contribution to the body of knowledge in the field of food quality management by developing an instrument to measure effectiveness in stead of compliance of norms and requirements or only performance. This will support food manufacturers to select suitable quality management activities, and the research method will support researchers to develop similar instruments.

4.2 Development of IMAQE-Food

The conceptual model (Figure 3.1) has been used to develop IMAQE-Food i.e. Instrument for Management Assessment and Quality Effectiveness in the Food sector: our instrument that aims at measuring effectiveness of food quality systems.

Table 4.1 Characteristics of HACCP, Hygiene code, ISO 9001:2000, BRC, and TQM.

QA system	Aim	Procedure	Evaluation	Assessment
HACCP	Assurance of production of safe food products by prevention [1, 2]	Systematic approach to the identification, evaluation and control of those steps in food manufacturing that are critical to food safety	Criteria to test reliability and implementation [3-6]. Aspects: • Information about the organisation • Requirements of the HACCP system [7]	Use of HACCP principles and execution of control and instructions, e.g.: • Verification procedures and their implementation • Number of times that critical control points exceed norms and frequency of taking corrective actions • Completeness of registrations • Results of audits, analyses, and hygiene controls • Number of complaints about food safety • Extent of quality attitude [8]
Hygiene code	Assurance of production of safe food products for non-industrial companies consisting of processes similar to those of Hygiene code	Description of production processes and guidelines to assure food safety, based on HACCP principles	Requirements prescribed, e.g.: • Flow diagrams • Temperature control • Pest control • GMP (Good Manufacturing Practice) requirements	Use of Hygiene code requirements and implementation, e.g.: • Receiving inspection • Temperature control • Prevention of cross contamination • Cleaning and disinfecting • Pest control [9]
ISO 9001:2000	1. Customer satisfaction by meeting customer requirements 2. Continuous improvement of the system 3. Prevention of nonconformity [10, 11]	Checklist on: • Management responsibility • Resource management • Product and/or service realisation • Measurement, analysis, and improvement	Establishment of all activities and handling in procedures, and implementation of the written procedures [11, 12]	• Description of the elements of ISO in a quality manual complying with the ISO norms [11, 12]. • Record keeping and audits must reveal if procedures have been followed [13]. • Check of the actual implementation of the written procedures [11, 12].

Continue Table 4.1

QA system	Aim	Procedure	Evaluation	Assessment
BRC	Assurance of product quality and food safety for companies supplying retail branded food products [5, 6].	Checklist on: • HACCP • parts of GMP • parts of ISO [3-5, 14]	• Presence of management systems • Implementation [15]	Classification (foundation level/higher level) on performance of six parts: • HACCP system • Quality management system • Factory environment standards • Product control • Process control • Personnel [18]
TQM	1. Continuous improvement of organisations 2. Satisfaction of both the external and internal customer 3. Achievement of quality of products 4. Saving costs by doing things right the first time [17-19].	• Quality awards (e.g. Deming Prize, Malcolm Baldrige National Quality Award, European Quality Award)	1. Quality awards: • Identification of companies utilising the best practices [20] • Evaluation of quality management methods and their deployment, and end results of organisations [21] • Self-assessment 2. Quantitatively based instruments [22-24]	Classification (degree of excellence) on extent to which some quality management activities are executed: • Leadership • People • Policy and strategy • Partnerships and resources • Processes • People results • Customer results • Society results • Key performance results [25] • Customer and market focus [26]

The conceptual model has been translated in performance measurement indicators. The indicators have been identified based on selected concepts [27]. An identification procedure has been developed that comprises an analysis, a selection, and a verification phase (Figure 1.1). This procedure is described in detail below.

4.2.1 Analysis

The aim of the analysis phase was to obtain a list of generic performance measurement indicators that could be used as pool for selection of relevant indicators for the food industry. A broad range of indicators was compiled and analysed by a comprehensive literature research and a screening on relevancy.

Table 4.2 provides an overview of the variety of indicators in literature: types of indicators, lists of examples, and types of utilisation.

Table 4.2 Type of indicators, lists of examples, and utilisation of performance measurement indicators used in the analysis phase

Type of indicators	• Financial and non-financial • Qualitative and quantitative • Tangible and intangible • Long term and short term • Strategic and operational • Individual and integrated • Direct and indirect • Feedback and predictive • Internal and external Mann and Kehoe [28], Wingren [29], Fortuin [30], Jorissen[31], Bonnet and Krens [32], Kerssens-van Drongelen [33], Roozen [34], ten Have *et al.* [35], Newall and Dale [36], Kerklaan *et al.* [37], McNair *et al.* [38]
List of examples of indicators	• Strategic and operational indicators [28, 30] • Process and customer related indicators [39, 40] • Vendor rating indicators [41, 42] • Research and development related indicators [33] • Indicators related to types of processes [37] • Indicators related to quality management [23, 24, 43, 44] • Indicators related to quality performance [24, 44] • Indicators related to contextual factors [23, 43, 44]
Utilisation	• Application • Subjectivity • Measurement units Fortuin [30], Jorissen [31], Kerssens-van Drongelen [33], Hilverdink [39]

Our indicators were mentioned by several authors and were chosen on their application (e.g. type of process, organisation, and results), subjectivity (dependent on number and involvement of the interviewer), and measurement units (Table 4.2). To measure all relevant aspects optimally, indicators were identified that belong to each type of indicators (Table 4.2). All indicators were screened on relevancy by assessing how meaningful it was to apply the indicators for measuring performance of quality systems in the food situation in general.

4.2.2 Selection

The aim of the selection phase was to identify indicators relevant for the bakery sector and to modify generic indicators into specific ones for this sector. Only indicators dealing with the primary process (purchase, production, sales) were studied, meaning that processes like quality design and customer service were not considered.

The selection phase consisted of two parts: a qualitative research and delphi sessions. For the qualitative research, eight (quality) managers of bakeries were selected on their knowledge about quality management and production quality. Bakeries were chosen that differed in organisational size, degree of automation and type of bakery. A questionnaire was used including indicators for production quality, activities to realise and improve production quality, bottlenecks in realising production quality. For the delphi sessions, six experts on quality management and the bakery sector were selected on their expertise in quality management, food safety, product quality, financial aspects, production process, characteristics of bakeries. Selected indicators of the qualitative research were discussed to add information and to optimise the selection.

During the selection phase indicators were screened next to relevancy on two additional requirements i.e. comprehensibility and availability. Comprehensibility is defined as the extent to which indicators are understandable for all respondents. Availability means that data should be obtained in the same way for all respondents.

4.2.3 Verification

The aim of the verification phase was to check if the selected indicators were relevant, comprehensible, and available at all bakeries in practice. For this purpose, a quantitative research among 48 bakeries was performed using a questionnaire that consists of the translated indicators.

4.3 Performance measurement indicators

As a result of the developed procedure, 28 performance measurement indicators were identified for respectively production quality, quality management, and contextual factors in the bakery sector. Table 4.3, 4.4 and 4.5 show the indicators that were chosen or eliminated in each identification phase, resulting in the finally identified indicators.

4.3.1 Production Quality (I)

Production quality is the first element of the model presented (Figure 3.1). In our study, production quality is defined as the match between production specifications and actual performance. This means that every time that a product will be produced, performance of production should comply with production specifications as established with customers. This reproduction quality is especially important in the bakery industry because bakeries use batch processes [45].

In a previous study, the Extended Quality Triangle was selected to measure performance of production quality [27]. In this concept, quality of the product (i.e. physical product quality, availability and costs) and quality of the organisation (i.e. flexibility, reliability and service) are distinguished [46].

In our study, actual performance was related to quality of the product, whereas quality of the organisation was reflected in the quality management element. Relevant dimensions of production quality for the bakery industry were physical product quality, availability, and costs.

Physical product quality

Physical product quality concerns product attributes like taste, shelf life, etc.. It is the match between the expected product quality according to product specifications and actual product quality.

Table 4.3 shows that the identified indicators for physical product quality were: percentage of rejected products; results of legislative evaluation; results of technical evaluation; and percentage of complaints about product quality. These indicators are measured by the company itself (internal) and inspection agencies (external).

Table 4.3 Identified performance measurement indicators of the analysis phase, selection (qualitative research and delphi sessions) and verification phase resulting in the identified indicators for production quality.

* = identified indicators; x = indicator not identified for the instrument, - = indicator removed after quantitative research

Indicators	**Analysis**	**Selection**		**Verification (Identified indicators)**
		Qualitative research	**Delphi sessions**	
Product Quality				
1. Percentage of rejected products	*	*	*	*
2. Results of legislative evaluation		*	*	*
3. Results of technical evaluation	*	*	*	*
4. Results of external audits	*	*		-
5. Results of evaluation by consumer panels / customer satisfaction survey		*	*	-
6. Percentage of complaints about product quality	*	*	*	*
7. Level of complaints	*			-
8. Results of internal audits		x	x	
9. Results of analyses		x	x	
10. Quality/price ratio	x	x		
11. Variability of quality		x		
12. Percentage of returns	x			
13. Number of recalls	x			
14. Supplier product quality	x			
15. Results of competitions	x		x	
16. Number of repeated purchase				
17. Quality reputation	x			
18. Percentage of scrap at customers	x			
19. Percentage of products classified as a lower quality product	x			
20. Percentage of products exceeding legislative norms	x			
Availability				
1. Percentage of complaints about availability	*			*
2. Percentage of products complying with specifications of delivery	*	*		-
3. Size of product assortment		x		
4. Percentage of non deliverable products			x	
5. Percentage of overproduced products			x	
6. Percentage of replacements	x		x	
7. Percentage of sold out products			x	
8. Percentage of products in stock	x		x	
9. Throughput time	x			
10. Timeliness	x			
11. Percentage of rejected products	x	x		
12. Percentage of returns	x	x		
13. Number of additional deliveries	x	x		

Continue Table 4.3

Indicators	Analysis	Selection		Verification (Identified indicators)
		Qualitative research	Delphi sessions	
Costs				
1. Quality costs	x			
2. Failure costs	*		*	-
3. Prevention costs	x		x	
4. Total costs	*	*		*
5. Return on investment	*	*		-
6. Cost price	x	x		
7. Scrap	x	x	x	
8. Time of non production	x	x		
9. Economical ratios (e.g. liquidity)	x			
10. Rework	x		x	
11. Number of additional deliveries		x	x	
12. Productivity	x		x	
13. Efficiency	x			
14. Reduction in costs	x			
15. Cost/benefit performance	x			
16. Activity Based Costing	x			
17. Percentage of costs complying with budgeting	x			
Flexibility				
1. Delivery time		x		
2. Size of batches		x		
3. Storage capacity		x		
4. Response time	x	x		
5. Possibility to order special products		x		
6. Possibility to rush orders		x		
7. Extra time in planning		x		
8. Possibility to change product line for another product(ion)	x			
9. Margins of tolerances	x			
10. Number of new products introduced	x	x		
Reliability				
1. Usage of QA system		x		
2. Certification of QA system	x	x		
3. Results of audits	x	x		
4. Results of monitoring		x		
5. Results customer satisfaction survey	x	x		
6. Possibility to submit complaints		x		
7. Number of times informing customers in time		x		
8. Percentage of complaints	x			
9. Percentage of products complying with specifications	x			
10. Results of analyses				
11. Number of repeating buying	x			
12. Response time	x			

Continue Table 4.3

Indicators	Analysis	Selection		Verification (Identified indicators)
		Qualitative research	Delphi sessions	
Service				
1. Degree of customer service	x	x		
2. Possibility to submit complaints		x		
3. Informing customers		x		
4. Response time	x	x	x	
5. Accessibility	x	x		
6. Number of bonuses and actions		x		
7. Flexibility		x		
8. Reliability	x	x		
9. Variability of product assortment		x		
Total number of indicators	**54**	**45**	**20**	**6**
Number of new identified indicators	**10**	**2**	**0**	**0**
Total number of identified indicators	**10**	**9**	**6**	**6**

Several other authors mentioned “number of rejected products” as indicator of performance of quality [28, 33, 41, 45]. It indicates how the production process is controlled and how internal standards are established. “Legislative evaluations” and “technical evaluations”, as proposed by Diepstraten [45] and Kerssens-van Drongelen [33], measure physical product quality against standards of safety and quality. “Percentage of complaints” was selected because it indicates the extent to which products comply with expectations of customers [28, 33, 45].

Availability

Availability is the presence of the right quantity of products at the right place in the right time. The identified indicator for availability was percentage of complaints about availability (Table 4.3). This indicator proposed by Diepstraten [45] and Mann and Kehoe [28] measures the extent to which availability complies with delivery requirements of customers.

Costs

Costs are the costs made during the primary process. The identified indicator was total costs corrected for payments, interest, and income of the owner (Table 4.3). Total costs measures the financial result of the organisation [28, 47], including quality costs.

4.3.2 Quality management (II)

Quality management is the second element of the model presented (Figure 3.1). For measuring performance of quality management the Wageningen Management Approach (WMA) was selected [27]. This concept assumes that management should result in right decisions, resulting in proper execution of the primary process and an optimal quality. It distinguishes strategic and operational management, and evaluates decision-making on the basis of four criteria [48]:

1. *Systematics:* extent to which a planning is developed in the same way.
2. *Feed forward:* extent to which decision-making is anticipated on aspects that will influence production quality in future.
3. *Feedback:* extent to which aspects of the past are used.
4. *Integration:* extent to which aspects of other decisions or activities are used.

In our study, quality management consists of activities that control, improve, and assure the primary process, which in turn results in a certain production quality.

Performance of quality management was evaluated on *how* decisions about quality management activities are made. Most publications about QA systems described *what* should be done, but not *how* activities should be accomplished to manage quality [27, 49-54]. This evaluation was based on the four criteria of WMA.

Table 4.4 shows that five indicators for performance of quality management in the bakery sector were identified i.e. strategy, supply control, production control, distribution control, and execution of production tasks. All indicators were composed of more elements, called sub indicators. These sub indicators consisted of both *what* and *how* aspects (not shown).

Strategy

In the strategy is formulated how the organisation's mission and objectives have to be accomplished. Identified sub indicators of strategy were policy and operational strategy, and development and evaluation of a long term planning (not shown).

Several authors emphasised that it is important for a good strategy to focus on quality policy as a part of the business strategy establishing how to achieve quality goals [18, 20, 22-25, 46, 55, 56]. To achieve these goals, resources have to be acquired and allocated [23, 45, 46]. Therefore, "policy and operational strategy" was identified as sub indicator.

"Development and evaluation of a long term planning" was also identified as sub indicator, because long term planning is important to make appropriate decisions with regard to the primary process [18, 20, 26]. Realisation of this planning has also to be monitored to know if objectives are accomplished or have to be adjusted or improved [18, 20, 22, 24, 25, 55].

Table 4.4 Identified performance measurement indicators of the analysis phase, selection (qualitative research and delphi sessions) and verification phase resulting in the identified indicators for quality management.

* = identified indicators; x = indicator not identified for the instrument

Indicators	**Analysis**	**Selection**		**Verification (Identified indicators)**
		Qualitative research	**Delphi sessions**	
1. Strategy	*		*	*
2. Supply control	*	*	*	*
3. Production control	*	*	*	*
4. Distribution control	*	*	*	*
5. Execution of production tasks	*	*	*	*
6. Quality design	x	x	x	
7. Customer service	x	x	x	
Total number of indicators	**7**	**6**	**7**	**5**
Number of new identified indicators	**5**	**0**	**0**	**0**
Total number of identified indicators	**5**	**4**	**5**	**5**

Supply control

Supply control is that part of quality control that focuses on the purchase process. It is an ongoing process of evaluating performance of suppliers and raw materials, and taking corrective actions when necessary. Identified sub indicators for supply control were: purchase and selection of raw materials; selection and evaluation of suppliers; and co-operation with suppliers (not shown).

"Purchase and selection of raw materials" was identified as sub indicator because especially in the food sector quality performance of raw materials has a major influence on production quality of final products [24, 42, 46]. Quality performance of raw materials is controlled by selection on e.g. specifications and conditions, and is evaluated by receiving inspections and audits [20, 22, 24, 45, 46].

"Selection and evaluation of suppliers" was identified because selecting suppliers on criteria (like quality, price, flexibility, and reliability) and auditing their QA systems have an influence on performance of suppliers, and therefore on performance of production quality of final products [18, 20, 22-24, 41, 42, 45, 46, 57].

The level of production quality is also influenced by agreements and co-operation between manufacturers and suppliers [20, 22-24, 45]. Therefore, "co-operation with suppliers" was identified as indicator as well.

Production control

Production control is that part of quality control that is focused on the production process. Identified sub indicators for production control were: development of a short term production planning; standardisation of production methods; and product and process control (not shown).

Several authors emphasised that the production planning is important in order to control production quality by e.g. order of products, production time, and selection of production lines, operators and equipment [18, 20, 22, 26, 45, 46, 56]. Therefore, "development of production planning" was identified as sub indicator.

"Standardisation of production methods" was identified because documentation of production methods and execution of these methods by employees control production quality [20, 23, 45, 55].

Several authors mentioned that "product and process control" is also important for control of production [18, 20, 22, 23, 25, 46, 55]. Process parameters and product specifications should be monitored, recorded, and used for improvement.

Distribution control

Distribution control deals with the process of transporting final products from manufacturers to customers. Identified sub indicators for distribution control were divided in two groups i.e. agreements and physical distribution (not shown).

Identified sub indicators of agreements were: making agreements with customers; analysis, acceptation and processing of orders; and communication (not shown). "Making agreements with customers" was identified because agreements made before production (e.g. customer orders) facilitate compliance with requirements of customers and development of the planning [20, 58].

"Analysis, acceptation and processing of orders" and "communication" are identified as sub indicators, because Diepstraten [45], Flynn *et al.* [23] and Zuurbier *et al.* [59] described that manufacturers analyse orders to comply with requirements of customers. Accepted orders are communicated to all departments involved and are processed into the production planning. Customers are informed if orders can not be produced according to the requirements.

Identified sub indicators of physical distribution were: development and evaluation of distribution planning and distribution conditions. "Development and evaluation of distribution planning" was identified because distribution planning controls production quality by anticipating on delivery times and delivery places [45, 59]. Some manufacturers always use the same distribution routes or contract out their delivery orders, whereas others make a new planning every time [45].

Luning *et al.* [46] and TLN [60] emphasised that "distribution conditions" are also important. Cooled or frozen products ask for other conditions than fresh products, as unpacked and packed products. Distribution equipment may also only be used for food. These conditions are monitored by inspections of equipment and products.

Execution of production tasks

The planned production tasks should be performed in such a way that production quality is obtained. Identified sub indicators for execution of production tasks were: training and education; communication; assignment of tasks; and adjustments of procedures (not shown).

Many authors described that "training and education of employees" and "communication" control performance of execution [18, 20, 22-26, 46, 55, 56, 61]. Evaluation of assigned tasks and established procedures also control performance of production tasks and consequently production quality [45]. Therefore, these aspects controlling performance of production tasks were identified as appropriate sub indicators.

4.3.3 Contextual factors (III)

Contextual factors are the third element of the model presented (Figure 3.1). These factors are part of the environment in which a company operates, which affect production quality. The diversity of these factors is called complexity. For the conceptual model, four variables were assessed i.e. complexity of the supply chain, complexity of the organisation, complexity of the production process, and complexity of the product assortment [49]. However, complexity of the supply chain was assumed not to be relevant for the current instrument for the bakery sector, because no comparison was possible with other types of supply chains.

Complexity of the organisation

Food-producing companies differ in several aspects, e.g. origin of raw materials, number of suppliers, number of employees, and type of outlets. The diversity of these aspects is called complexity of the organisation.

Table 4.5 shows that identified indicators for complexity of the organisation were: number and composition of employees; percentage of not-producing affiliates; number of suppliers; percentage of produced products; number of customers and delivery points; percentage of products sold to third parties; and number of relationships. “Number and composition of employees” consists of the sub indicators: number of employees, percentage of part timers, percentage of temporary contracts, and number of production shifts.

Several authors described “number and composition of employees” as an indicator to characterise organisations [43, 47, 62]. “Number of suppliers” and “percentage of products sold to third parties” were also used as indicators by Ziggers [47]. NBC [63] mentioned that bakeries differ in type of affiliates, produced and purchased products, and in relationships with other bakeries or linkages. “Number of customers / delivery points” was based on delphi sessions, and was not previously mentioned in literature.

Complexity of the production process

Food production processes differ in e.g. number of process steps, specificity of production processes, and heterogeneity of raw materials due to seasonal harvesting and natural variation. This diversity is called complexity of the production process.

Table 4.5 shows that identified indicators for complexity of the production process were: number of production lines; average number of times that a production line is changed or adjusted in a day (due to e.g. change of product group, variability or heterogeneity of raw materials); average number of process steps; average number of critical control points; and degree of automation. NBC [63] mentioned that bakeries differ in degree of automation. The remaining indicators were based on qualitative research and delphi sessions, and were not previously mentioned in literature.

Table 4.5 Identified performance measurement indicators of the analysis phase, selection (qualitative research and delphi sessions) and verification phase resulting in the identified indicators for contextual factors.

* = identified indicators; x = indicator not identified for the instrument.

Indicators	Analysis	Selection		Verification (Identified indicators)
		Qualitative research	Delphi sessions	
Complexity of the organisation				
1. Number and composition of employees	*	*	*	*
2. Number of employees working at one location			x	
3. Percentage of not-producing affiliates	*	*	*	*
4. Location of affiliate			x	
5. Number of suppliers	*		*	*
6. Percentage of produced products	*	*		*
7. Number of customers / delivery points			*	*
8. Number of deliveries in a day			x	
9. Percentage of products sold to third parties	*	*		*
10. Number of relationships (co-operation)	*	*	*	*
11. Usage of external warehouse			x	
12. Percent of contracting out distribution		x		
13. Employees morale	x			
14. Skill level of employees	x			
15. Type of organisational structure	x		x	
16. Type of QA system	x	x	x	
Complexity of the production process				
1. Number of production lines		*	*	*
2. Average number of times changing a production line in a day		*	*	*
3. Average number of times adjusting a production line in a day		*		*
4. Average number of process steps			*	*
5. Average number of critical control points			*	*
6. Degree of automation	*	*	*	*
7. Number of different conditions	x			
8. Number of different actions	x		x	
9. Percentage of failures	x			
10. Extent that an employee influence the production quality			x	
11. Extent of batch vs. continuous process	x			
12. Degree of variation in processes	x			

Continue Table 4.5

Indicators	Analysis	Selection		Verification (Identified indicators)
		Qualitative research	Delphi sessions	
Complexity of the product assortment				
1. Number of product groups	*	*	*	*
2. Type of product groups	*	*	*	*
3. Number of dough types			x	
4. Number of recipes	*	*	*	*
5. Number of product numbers			x	
6. Percentage of products directly delivered or sold			*	*
7. Percentage of private label products		x		
8. Percentage of new products	x			
9. Percentage of exchange of products			x	
Total number of indicators	**20**	**15**	**25**	**17**
Number of new identified indicators	**10**	**3**	**4**	**0**
Total number of identified indicators	**10**	**12**	**14**	**17**
Overall number of indicators (Table 4.3, 4.4, 4.5)	**81**	**66**	**52**	**28**
Overall number of new identified indicators (Table 4.3, 4.4, 4.5)	**25**	**5**	**4**	**0**
Overall number of identified indicators (Table 4.3, 4.4, 4.5)	**25**	**25 (=89%)**	**25 (=89%)**	**28 (=100%)**

Complexity of the product assortment

The product assortment of food-producing companies consists mostly of a variety of products that have diverse product compositions. This diversity is called complexity of the product assortment.

Table 4.5 shows that identified indicators for complexity of the product assortment were: number of product groups; type of product groups; number of recipes; and percentage of products that are directly delivered or sold without stock.

"Number and type of product groups" and "number of recipes" were identified because several authors emphasised the effect of product complexity and product variety on quality management or on quality performance [43, 46, 47, 62, 64]. "Percentage of products that are directly delivered or sold without stock" was based on our delphi sessions, and was not previously mentioned in literature.

4.4 Relevancy, comprehensibility and availability

IMAQE-Food is composed based on the identified performance measurement indicators. These indicators were analysed, selected and verified on three practical requirements i.e. relevancy, comprehensibility and availability.

IMAQE-Food is relevant for measuring performance of quality systems in the bakery sector, because the identified indicators measure both performance of quality management and quality performance in the bakery sector to assess effectiveness. Besides, the contextual factors are measured to know why performance of quality systems differs.

The identified indicators were comprehensible, which means that contents of the indicators were understandable for all respondents in a face-to-face situation. The indicators were mostly clear, simple, and easy to use, although some indicators had to be clarified by the interviewer. Hence, our respondents understood the indicators and could give the appropriate information.

Nevertheless, the indicators of the instrument were not all available at the bakeries, because they were not recorded and collected by all respondents. It was not possible to obtain these indicators in another manner. For an appropriate measurement of effectiveness these missing indicators should be assessed as well. Table 4.6 presents the missing indicators. Obviously, more data about production quality should be recorded.

Table 4.6 Additional indicators about which bakeries should collect information for an appropriate measure of effectiveness of food quality systems.

Aspects	Indicators
Product Quality	Results of analyses (chemical, microbiological, physical) Complaints classified on level of risks and severe Percentage of rejected products Percentage of returns Results of audits Results of evaluation by consumer panels / customer satisfaction survey
Availability	Percentage of products complying with delivery specifications
Costs	Quality costs

4.5 Discussion

4.5.1 Performance measurement indicators

Our instrument IMAQE-Food differs in several aspects from other instruments such as application, aim, and type of indicators, which makes the instrument valuable for measuring effectiveness of food quality systems.

IMAQE-Food has been developed for the food sector and thus differs from other instruments that are generic [22, 43] or specific for non-food sectors [23, 24]. Additionally, IMAQE-Food measures the effectiveness by assessing relationships between performance of both quality management and production quality in contrast to other instruments that did not examine the impact of quality management on quality performance [22-24].

Our indicators for quality performance consist of product quality, availability and costs in contrast to other instruments that use only product quality [22- 24]. We identified strategy, supply control, production control, distribution control, and execution of production tasks as indicators for quality management. Saraph *et al.* [22], Flynn *et al.* [23] and Ahire *et al.* [24] exclude distribution control, although they include quality design in contrast to our instrument.

Contextual factors are used to explain why the performance of quality systems differs. Other instruments do not examine contextual factors [22-24] or the selected factors are not relevant for the food industry [43]. Corresponding indicators are organisational size, percentage of produced products, and product complexity.

Moreover, IMAQE-Food is partly normative, whereas other instruments are only descriptive [22-24, 43]. The normative instrument is focused on *how* quality management should be effectively performed, which facilitates the implementation of quality systems.

4.5.2 Availability of indicators

Due to lack of data not all indicators were available at the studied bakeries. For an appropriate measure of effectiveness, bakeries should measure more data about production quality. Other authors also measured production quality not comprehensively, although this was due to insufficient selected indicators e.g. Ahire *et al.* [24].

Especially if IMAQE-Food will be used for predicting performance of a quality system of a specific company, information about production quality will be required. For tests of relationships between quality management, production quality, and contextual factors, lack of data will reduce the explained variance. Thus, lack of relevant data limits validity and reliability of the instrument at the current stage. In future research, IMAQE-Food should be validated to evaluate reliability, validity, and generalisability.

4.5.3 Application in other sectors

Most identified indicators appear to be generic for the food sector. Although the indicators have been identified as appropriate for the bakery sector, we also selected almost the same indicators for the vegetable and fruit processing sector [65]. For application in other sectors qualitative research and delphi sessions are required to verify relevancy of these indicators and to specify the sub indicators.

4.6 Conclusion

The aim of this study was to identify performance measurement indicators for an instrument that measures effectiveness of food quality systems. The developed identification procedure revealed 28 appropriate indicators that measure performance of production quality, quality management, and contextual factors in the bakery sector. The indicators were relevant and comprehensible, but were not all available among the studied bakeries.

Most indicators appeared to be generic for the food sector. However, for application in other sectors additional qualitative research and delphi sessions are required to verify relevancy of these indicators and to specify the sub indicators.

The strength of IMAQE-Food as instrument is that it assesses the relation between food quality management, production quality and contextual factors. Based on this relationship, the effectiveness of food quality management is measured. Moreover, the instrument has been developed for the food sector. Due to food characteristics, quality assurance is of major importance for the agri-food sector.

Knowledge about the effectiveness of food quality systems will support food manufacturers in deciding which quality management activities are most suitable to achieve their objectives. Additionally, insight in factors that influence production quality will be useful to determine the required level of food quality management.

Next research involves validation of IMAQE-Food to evaluate reliability and validity and to improve the robustness of the instrument. Successive research should extend IMAQE-Food for assessing effectiveness of specific food QA systems. It should be tailored for these systems in order to know the actual contribution of QA systems to food quality assurance.

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5

Validation of IMAQE-Food: Instrument for Management Assessment and Quality Effectiveness in the Food sector

Abstract

This chapter describes the validation of IMAQE-Food: the instrument that measures effectiveness of food quality systems. Generalisability, reliability and validity of the instrument were analysed at a sample of 48 bakeries.

IMAQE-Food contains performance measurement indicators measuring production quality, quality management, and contextual factors. In this study, five individual variables for production quality were developed. Eight reliable and valid constructs for quality management were extracted using a procedure based on Cronbach's alpha and rotated factor analysis. Contextual factors were divided into six constructs assessing complexity of the organisation, five constructs assessing complexity of the production process, and two constructs assessing complexity of the product assortment.

It was concluded that IMAQE-Food is a reliable and valid tool to assess effectiveness of quality systems in the bakery sector. IMAQE-Food appears to be also applicable for the vegetable and fruit processing sector. It is expected that the instrument will be applicable for other food sectors as well after small modifications. Successive research can extend IMAQE-Food for other applications such as other food sectors and QA systems.

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5.1 Introduction

A broad range of instruments has been developed in other industries to measure performance of quality management [1]. Only a few researchers evaluated their instruments scientifically on reliability and validity [2-4]. Ahire *et al.* [4] proposed that a mixture of the three instruments developed by the before-mentioned authors could result in highly stable, reliable and valid variables of quality management. These measurement instruments are used for assessing quality management, but they can not be used for measuring effectiveness of food quality systems. In specific they are neither normative nor do analyse all relations between quality performance, quality management, and contextual factors [1].

In a previous study, the instrument IMAQE-Food has been developed. It measures effectiveness of food quality systems, consisting of production quality, quality management, and contextual factors [5]. The current chapter describes the validation of this instrument: generalisability, reliability and validity were analysed at a sample of 48 bakeries.

5.2 Method

5.2.1 Development of IMAQE-Food

In a previous study, IMAQE-Food has been developed as an instrument that measures effectiveness of food quality management (Chapter 4). Identification revealed indicators that were relevant, comprehensible, available, generic, reliable, and valid at all bakeries in practice [5]. Figure 1.1 shows the procedure that was followed to develop this instrument.

Sample

The bakery sector is characterised by a large variety in products differing in shelf life i.e. bread, confectionery, and biscuits. In 2000, the Dutch bakery sector consisted of 79 large bread companies and 2980 small and medium enterprises (SMEs) producing bread and confectionery [6]. Most bakeries (75%) consisted of less than 10 employees. Bakeries with more than 10 employees were responsible for the largest part of the production volume [7]. The bakeries differed in their contextual factors like company size, degree of automation, and type of products [6, 8]. For assurance of their production quality, bakeries used HACCP, the Hygiene code for bread and confectionery bakeries, ISO 9000-series, GMP, BRC and systems that integrate quality, health and safety at work, and environment.

In our study, only bakeries with more than 10 employees were examined. These bakeries were responsible for the highest production volumes in the bakery sector. They did apply QA systems and were willing to participate in contrast to smaller bakeries that did not yet apply QA systems, were unwilling to participate due to a high workload, and were only responsible for a small part of the production volume either.

Of 235 contacted bakeries 20% (48 bakeries) agreed to participate in the study. Persons responsible for quality management of bakeries were contacted by a phone call. Figure 5.1 shows several characteristics of the sample: the 48 bakeries differed in type of product groups, number of employees, degree of automation, type of outlets, relationships with other linkages or bakeries, and applied QA systems.

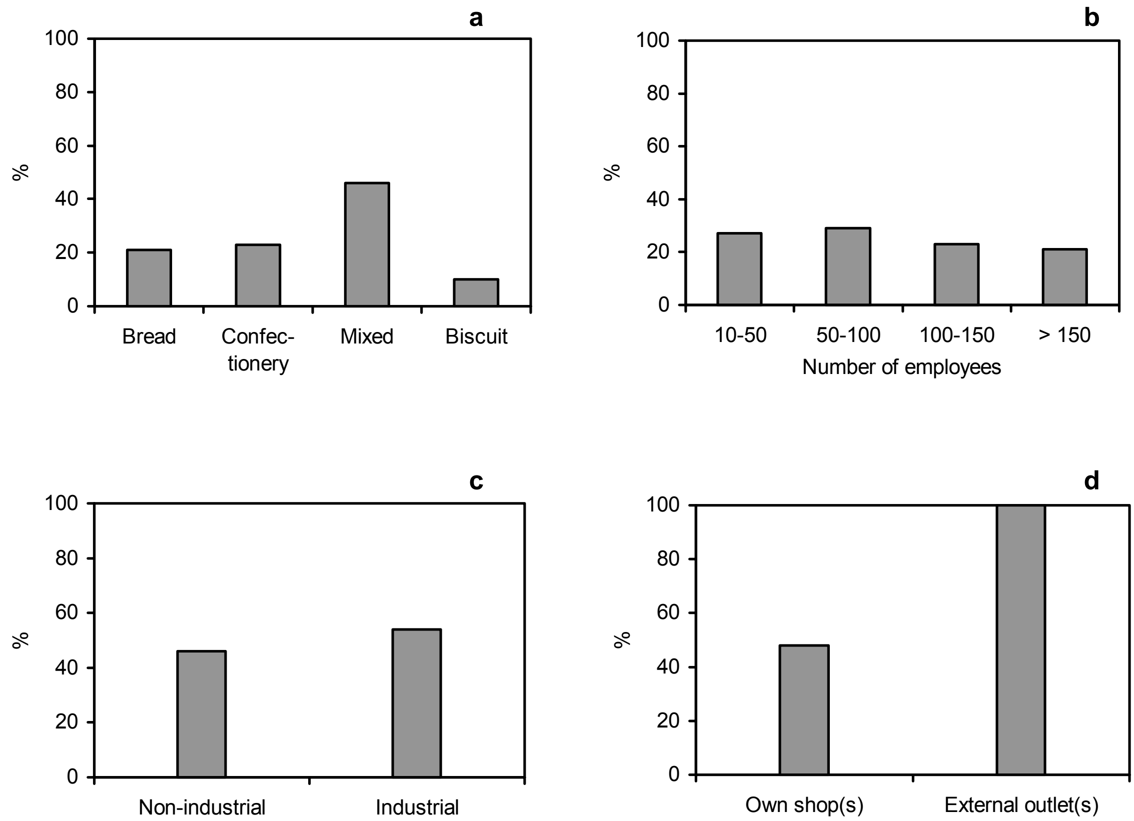

Figure 5.1 Percentage of bakeries with specific characteristics.
a) type of product groups; b) number of employees; c) degree of automation (based on type of ovens used); d) type of outlets.

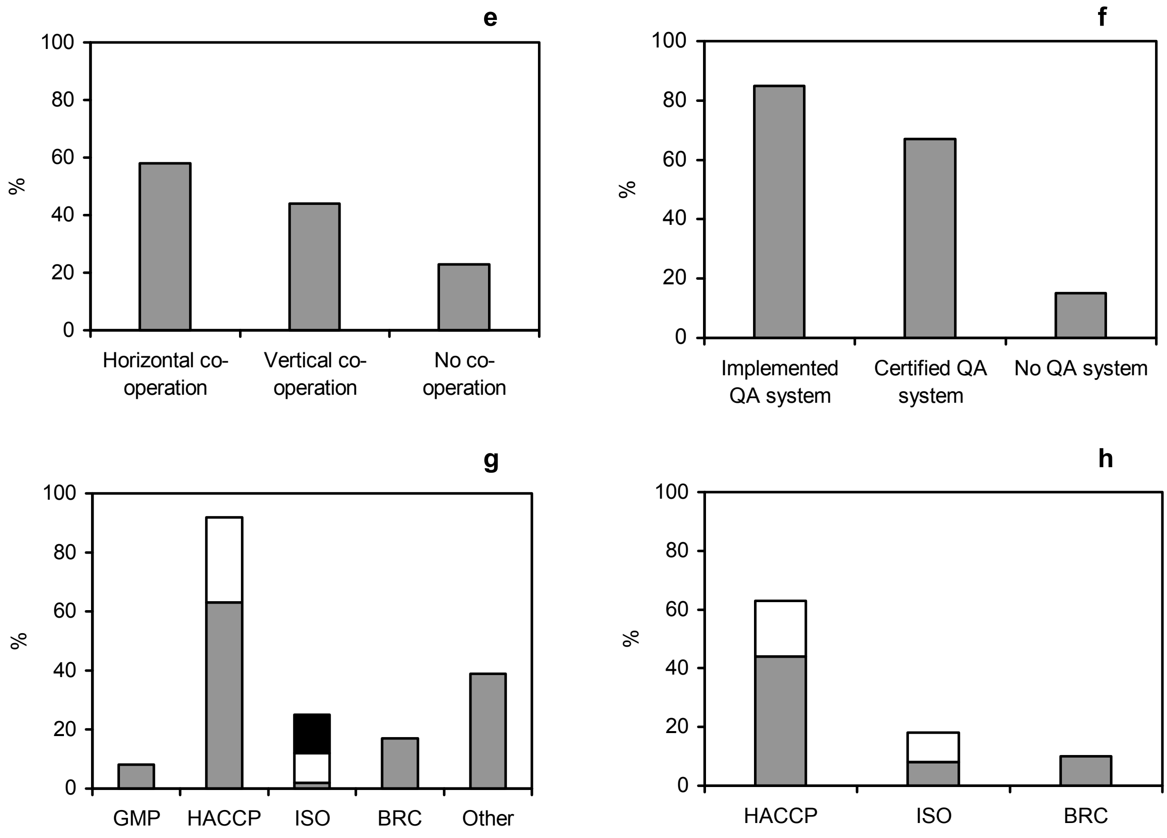

Figure 5.1 (continue) Percentage of bakeries with specific characteristics.
e) type of relationships; f) extent to which QA systems have been implemented; g) applied QA systems: HACCP consists of Hygiene code (□) and HACCP (■), ISO consists of ISO 9001(■), ISO 9002 (□), ISO 9001:2000 (■); h) Certified QA systems: HACCP consists of Hygiene code (□) and HACCP (■), ISO consists of ISO 9001 (□) and ISO 9002 (■).

With a response of 48 out of 765 bakeries with more than 10 employees, the reliability of the sample is 86.3%, which means that the representativeness of the sample is acceptable. In detail, the sample represented the bakery sector in type of product groups (Figure 5.2). We interviewed a higher percentage of bakeries with more than 100 employees. In the bakery sector the number of small bakeries is decreasing and the number of large bakeries is increasing due to scaling-up, competitiveness of supermarkets and non-bakery products, and lack of successors [6], which increases the usefulness of our sample. Moreover, the differences in characteristics of the companies in our sample enabled the development and validation of IMAQE-Food.

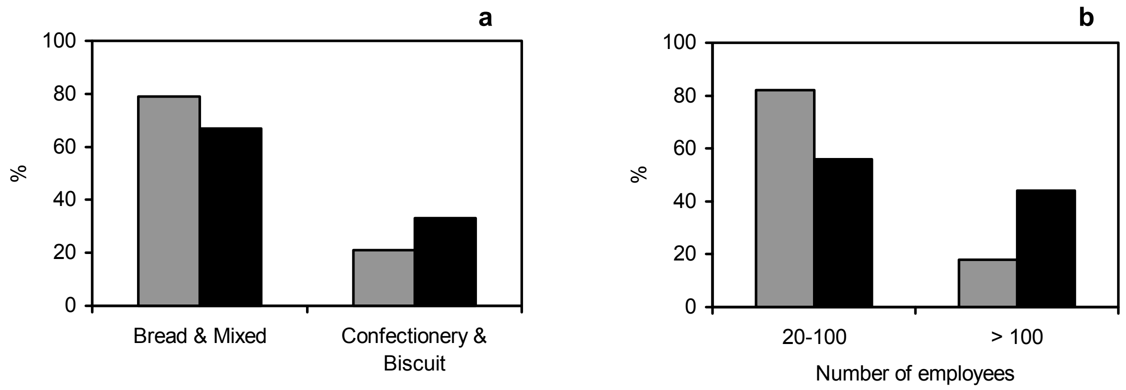

Figure 5.2 Representativeness of the sample (■) in relation to the bakery sector (■). Data obtained from CBS [7].

a) type of product groups; b) number of employees.

IMAQE-Food

Table 5.1 shows the identified indicators of IMAQE-Food as obtained from previous research [5]. These indicators were translated into a questionnaire (Appendix). This was built up according to the following aspects: background information, contextual factors, quality management, production quality, and a section about the experienced effect of implemented QA system(s). Questions about background information and contextual factors were answered beforehand using the internet or mail. Questions about quality management, production quality, and finishing questions were answered in a face-to-face interview. Both quantitative and qualitative indicators were used. Data were collected by open questions with field coding combined with absolute answers. A scoring system was applied that measures differences within the sample.

5.2.2 Evaluation of IMAQE-Food

According to Gamble [9] a measurement instrument that consists of several items should be evaluated on accuracy and applicability, which involves reliability, validity, and generalisability (Figure 5.3).

In our study, IMAQE-Food was tested on these three methodological requirements. The procedure to analyse reliability, validity, and generalisability is described below.

Table 5.1 Identified performance measurement indicators for production quality, quality management, and contextual factors (complexity of the organisation, complexity of the production process, and complexity of the product assortment) after identification [5].

Element	**Identified indicators**
Production quality	**Product quality** 1. Percentage of rejected products 2. Results of legislative evaluation 3. Results of technical evaluation 4. Percentage of complaints about product quality **Availability** 5. Percentage of complaints about availability **Costs** 6. Total costs
Quality management	1. Strategy 2. Supply control 3. Production control 4. Distribution control 5. Execution of production tasks
Contextual factors	**Complexity of the organisation** 1. Number and composition of employees a. Number of employees b. Number of part timers c. Number of temporary employees d. Number of shifts 2. Percentage of not-producing affiliates 3. Number of suppliers 4. Percentage of produced products 5. Number of customers / delivery points 6. Percentage of products sold to third parties 7. Number of relationships (co-operation)
	Complexity of the production process 1. Number of production lines 2. Average number of times changing a production line in a day 3. Average number of times adjusting a production line in a day 4. Average number of process steps 5. Average number of critical control points 6. Degree of automation
	Complexity of the product assortment 1. Number of product groups 2. Type of product groups 3. Number of recipes 4. Percentage of products directly delivered or sold

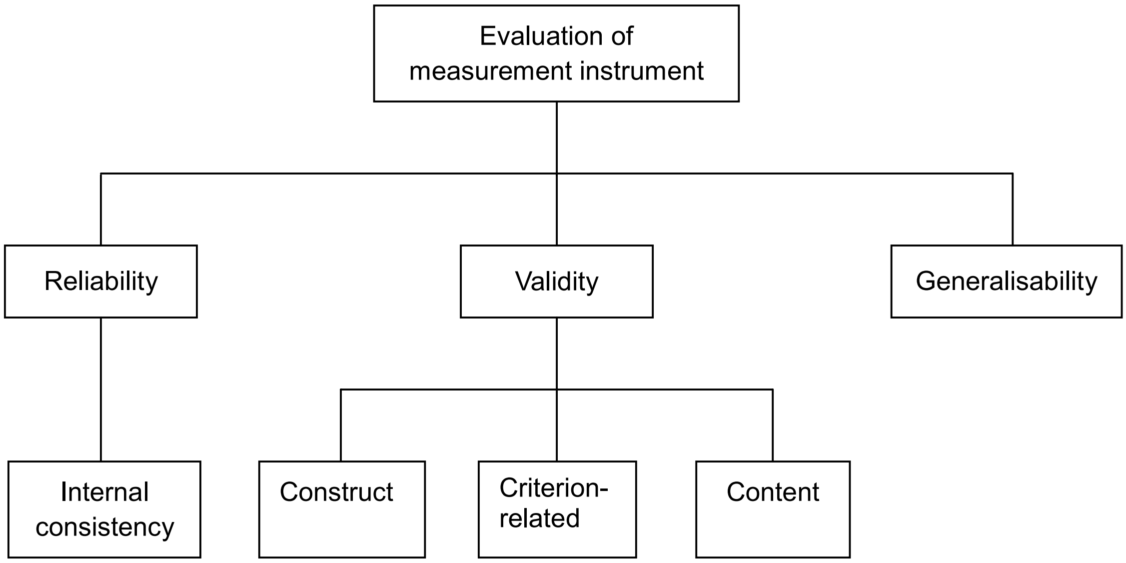

Figure 5.3 Evaluation of the measurement instrument (adapted from Gamble [9]).

Reliability

Reliability is the ability to reproduce the same results under the same conditions in a consistent way [3, 10-12]. Reliable indicators allow generalising from one particular use of the method to a wide variety of related circumstances [11].

Reliability of an indicator can be determined by the degree of correlation between the items that comprise an indicator. If the association is high, the instrument yields consistent results and is therefore reliable [9]. The reliability coefficient is an index of the effectiveness of the instrument, needed for validity reasons [11].

In our study, Cronbach's alpha was used as reliability coefficient to estimate the internal consistency of the indicators. For calculating alpha of a new instrument, a sample of 30 or more respondents is statistically sufficient [3]. In our study we sampled 48 bakeries which is considered to be sufficient to test Cronbach's alpha. A satisfactory level of reliability depends on how a measure is being used. Although reliability coefficients of 0.70 or more are often considered as a criterion for internally consistent established scales, the use of a minimum alpha value of 0.60 will be sufficient for new scales in early stages of validation research [9, 13]. For our newly developed instrument, indicators were accepted when the value of alpha was higher than 0.60.

All identified indicators that consisted of sets of items were tested on their internal consistency. For example, the identified indicator "number and composition of employees" was tested on internal consistency with the items “number of employees”, “number of part-timers”, “number of temporary employees”, and “number of shifts” (Table 5.1). In order to improve the internal consistency, a newly developed procedure was used that automatically removes items that show low inter-item correlations and calculates repeatedly Cronbach’s alpha. Starting with a set of items, Cronbach’s alpha is calculated for all subsets of items that could be formed by excluding one item from the set and keeping all other items in the set. For each subset Cronbach’s alpha was calculated and compared with the alpha value of the whole set. Now, two situations can be distinguished. (1) When Cronbach’s alpha improves, the excluded item correlates low with all the other items in the set. (2) When Cronbach’s alpha worsened, the excluded item correlates high with the all other items in the set. Definitely, this item should be incorporated in the indicator. Using the procedure, items were deleted one at the time, starting with the item with the largest change. This procedure of re-calculating Cronbach’s alpha for subsets was repeated until the value for the whole set was 0.70 or more. If the value of alpha did not improve to at least 0.60, the indicator was removed.

Subsequently, the reduced sets were analysed on construct validity, and reliability of the obtained constructs was recalculated (see below).

Validity

Validity means that the instrument measures indeed what it should measure [2, 3, 10-12, 14]. It denotes the scientific utility of a measurement instrument, in terms of how well it measures what it claims to measure [11]. In our study, three types of validity were assessed i.e. construct validity, criterion-related validity, and content validity.

<u>Construct validity</u>

Construct validity is the extent to which items of an indicator all measure the same construct [2, 3, 9, 11, 12]. A construct is a set of items that measure the same underlying variable. The goal of studying constructs is to obtain one or more indicators representing a set of items that use one name [11].

In our study, construct validity of each reliable set of items was tested by rotated factor analysis (varimax) to obtain constructs including items that all measure the same underlying variable. This method assesses the unidimensionality of a set of items. A multidimensional set needs more than one indicator to represent the value of a scale [15].

Meaningful items were selected based on factor loading. Items with high loadings (>0.20) have high correlations, which means that they measure the same construct [11]. Provided that at least one of the factor loadings was higher than 0.20, items were combined into a construct that had similar loadings on two dimensions. The developed constructs were screened on relationships concerning the content; those items with a low relationship were removed. For each construct, Cronbach's alpha was recalculated and compared with the criterion of internal consistency i.e. Cronbach's alpha > 0.60.

Criterion-related validity

Criterion-related validity is the extent to which the indicators are related to external independent referents [2, 3, 9, 11, 12, 14].

In our study, a set of constructs of quality management was correlated with a set of variables that measure production quality. The criterion-related validity was tested by canonical correlation analysis and redundancy index to study relations between the two sets of quality management and production quality.

Canonical correlation analysis maximises the correlation between two linear functions of sets of variables [16, 17]. The linear functions that yield the maximum (canonical) correlations are termed canonical variates. The correlations of the variables within the set with the canonical variate indicate the contribution of each variable to the canonical variate. The mean of the squared correlations is the proportion of the variance of each set that is accounted for by the first canonical variate [16].

The redundancy index summarises the overlap between two sets of variables. It quantifies the ability of one set of variables, expressed as a canonical variate, to explain the variation of the variables in the other set [11, 17].

Content validity

Content validity is the extent to which all aspects are measured [9-12, 14], in other words, whether IMAQE-Food is truly a comprehensive measure of performance of food quality systems. Content validity can be ensured whether the instrument contains a representative collection of indicators and whether methods of test construction are used [11]. In our study, the identification procedure was taken to assure content validity of the indicators. A balanced usage of different types of indicators and several measure units was also applied to be able to measure all relevant aspects.

Generalisability

Generalisability is the extent to which indicators can be applied in different research settings and situations [9-11, 14]. Indicators should be generic to be applicable as instrument within a specific sector and in other sectors. In this study, the applicability of IMAQE-Food in different settings and situations was examined by analysing characteristics of the bakery industry. Besides, in another study, we also adapted the instrument for the vegetable and fruit processing industry to study the applicability of the instrument in another food sector.

5.3 Results

Results of the evaluation of IMAQE-Food on reliability, validity and generalisability are described below. In the next section, the variables of IMAQE-Food are explained.

5.3.1 Evaluation of IMAQE-Food

Reliability and construct validity

Table 5.2 shows the variables of IMAQE-Food that comply with the criteria on reliability and construct validity. These variables are divided in the elements production quality, quality management, and contextual factors (i.e. complexity of the organisation, complexity of the production process, and complexity of the product assortment).

Items were selected for a construct, i.e. an indicator that consisted of a set of items, if the subset of items was internally consistent and unidimensional. All variables in Table 5.2 are unidimensional or valid constructs resulting from factor loading. As shown, the Cronbach's alpha value of 12 indicators was higher than 0.64, which is acceptable for a newly developed measurement instrument. Removing more items increased reliability but decreased validity, which makes the instrument less useful. Indicators that consisted of one item have obviously a Cronbach's alpha value of 1, and therefore they are marked (*).

Table 5.2 Overall internal consistency of valid constructs for the elements production quality, quality management, and contextual factors (complexity of the organisation, complexity of production process, complexity of product assortment); compliance with reliability of valid constructs.

* = variable consisting of one item (Cronbach's alpha = 1)

Element		Variables	Reliability (Cronbach's alpha)	Number of items
Production Quality		Percentage of rejected products	*	1
		Results of legislative evaluation	*	1
		Results of technical evaluation	*	1
		Percentage of complaints about product quality	*	1
		Percentage of complaints about availability	*	1
Quality management		Strategy: - Control of strategy	 0.6497	 3
		Supply control: - Allocation of supplying raw materials - Supply control	 0.7527 0.7792	 3 8
		Production control: - Planning of production - Control of production	 0.7859 0.7933	 3 5
		Distribution control: - Control of receiving orders - Planning of distribution	 0.7829 0.8486	 7 5
		Execution of production tasks: - Control of execution of production tasks	 0.7386	 5
Contextual factors	Complexity of organisation	Number of external relations	0.6747	2
		Number of temporary employees	*	1
		Percentage of not-producing affiliates	*	1
		Percentage of produced products	*	1
		Number of customers / delivery points	*	1
		Number of employees (log)	0.8192	2
		Number of relationships (co-operation)	*	1
	Complexity of production process	Degree of automation	0.8057	2
		Average number of times changing a production line in a day (log)	*	1
		Average number of times adjusting a production line in a day (log)	*	1
		Average number of process steps	*	1
		Average number of critical control points	*	1
	Complexity of product assortment	Number of product groups	0.7336	3
		Type of product groups	*	1

Criterion-related validity

The statistical data were evaluated, although production quality was not a sufficient measure for quality management because it could not be determined completely due to lack of data in practice [5]. A set of constructs of quality management was correlated with a set of variables that measure production quality. For production quality, the first canonical variate accounted for 24% of the variance of the set. The redundancy index in the set of production quality was 0.10 meaning that only 10% of the variance in this set was accounted for by the canonical variate of the set of quality management variables.

It was concluded that IMAQE-Food had low criterion-related validity, which means that the indicators of quality management were not strongly related to the variables of production quality. Therefore, effects of quality management on production quality could not be confirmed nor rejected for the current sample.

Content validity

Based upon the identification procedure the majority of the identified indicators were found in the beginning. Figure 5.4 shows the relation between the number of respondents interviewed and the percentage of identified indicators.

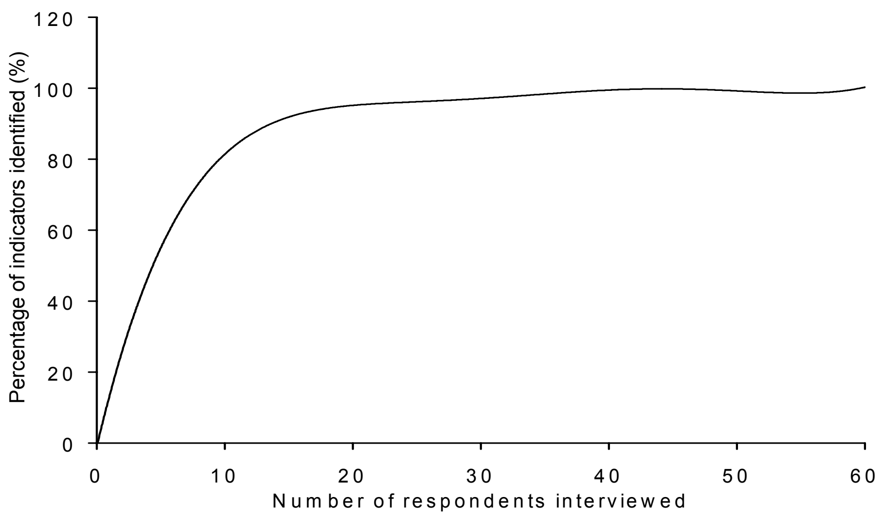

Figure 5.4 Percentage of the performance measurement indicators identified by N respondents (where 62 respondents* = 100%).

* = qualitative research: N=8; delphi sessions: N=6; quantitative research: N=48

Most indicators (89%) were identified in the qualitative research (N=8 interviews) and the delphi sessions (N=6 interviews). The latter method did not alter the percentage but was required to develop an instrument that is applicable in practice. The verification phase adjusted 11% of the indicators resulting in the current identified performance measurement indicators. Our results correspond with research of Griffin and Hauser [18]; they hypothesised that 20-30 interviews are necessary to get 90-95% of the identified items. Although some indicators may have been missed, the major number of our indicators has been identified for the bakery sector. Therefore, it is concluded that the indicators with a Cronbach's alpha value of 1 (Table 5.2) are indeed represented by one item.
Because content validity was obtained by a structured identification procedure, which resulted in a representative collection of indicators and methods of test construction (i.e. construction, pre-testing, and evaluation), it was concluded that IMAQE-Food is truly a comprehensive measure of performance of food quality systems.

Generalisability

Indicators should be generic to be applicable as instrument within a specific sector and in other food sectors. The sample of our study produced the largest part of production volumes in the bakery sector. It represents the bakery sector with the exception of small non-industrial mixed bakeries. However, the number of small bakeries is decreasing, whereas the number of large companies is increasing. Therefore, the indicators of validated IMAQE-Food are considered to be generic for the bakery sector.
Moreover, although a specific food sector make results less generalisable for others, the bakery industry includes differences in e.g. shelf life of products, type of processes, type of customers and organisation size, which are relevant for other food sectors as well. Therefore, a wider application of IMAQE-Food is expected.
In addition, in another study, we adapted the instrument for the vegetable and fruit-processing sector. Only small modifications of the indicators were needed to make the instrument suitable for that specific sector [19]. Table 5.3 shows the selected indicators for the vegetable and fruit-processing sector compared to the validated indicators in the bakery industry. The results suggest that IMAQE-Food is also applicable in other food sectors as well, with relatively small modifications.

Table 5.3 Indicators for the vegetable and fruit processing sector (obtained by delphi sessions (N=4) and qualitative research (N=6)) compared to validated indicators in the bakery sector (N=62).

Element		**Indicators for the vegetable and fruit processing sector (non-validated)**	**Indicators for the bakery sector (validated)**
Production Quality		**Product quality** Results of legislative evaluation Percentage of complaints about product quality **Availability** Percentage of undelivered products Percentage of additional deliveries Percentage of out-of-stock Percentage of overproduced products **Costs** Turnover	**Product quality** Percentage of rejected products Results of legislative evaluation Results of technical evaluation Percentage of complaints about product quality **Availability** Percentage of complaints about availability
Quality management		Strategy	Control of strategy
		Supply control	Allocation of supplying raw materials Supply control
		Production control	Planning of production Control of production
		Distribution control	Control of receiving orders Planning of distribution
		Execution of production tasks	Control of execution of production tasks
Contextual factors	Complexity of organisation	**Complexity of organisation** Number of employees Percentage of produced products Number of relationships (co-operation) Percentage of contracted distribution	Number of employees (log) Number of temporary employees Percentage of produced products Number of external relations Number of relationships (co-operation) Percentage of not-producing affiliates Number of customers / delivery points
		Complexity of purchase Percentage of unchanging points of purchase Number of co- operative relations with suppliers / number of points of purchase Maximum distribution time of raw materials	
		Complexity of sales Percentage of frequently buying customers Number of co-operative relations with suppliers / number of customers Maximum distribution time of final products	

Continue Table 5.3

Element		**Variables for the vegetable and fruit processing sector (non-validated)**	**Variables for the bakery sector (validated)**
Contextual factors	Complexity of production process	Degree of automation Average number of times changing a production line in a day Number of cutting machines Average number of washing steps Percentage of products with preparing steps	Degree of automation Average number of times changing a production line in a day (log) Average number of times adjusting a production line in a day (log) Average number of process steps Average number of critical control points
	Complexity of product assortment	Number of product groups Type of product groups Percentage of stored products Total number of products	Number of product groups Type of product groups

5.3.2 Variables of IMAQE-Food

Table 5.2 shows the reliable and valid variables of IMAQE-Food divided in production quality, quality management, and contextual factors.

Production quality

In a previous study, production quality was divided into physical product quality, availability and costs [5]. Table 5.1 shows the four identified items of physical product quality: percentage of rejected products; results of legislative evaluation; results of technical evaluation; percentage of complaints about product quality. For availability, the identified indicator was percentage of complaints about availability. For costs, no indicators were identified because of lack of data in practice [5].

In this study, after removal of items the set of product quality resulted in only two internally consistent items, which is too few for a response variable to measure effectiveness of food quality systems. Therefore, to explain the response variable production quality with more items, the five identified items were considered as five independent response variables (Table 5.2). The use of independent variables increased the validity, which results in a better measure of production quality.

Quality management

Table 5.2 shows that quality management consisted of eight internally consistent and valid variables.

The variables of quality management were divided in planning and control. Planning is the process of determining exactly what a company will do to accomplish its objects. Controlling is the process of measuring performance, comparing performance to planning, and taking corrective actions if necessary.

Contextual factors

Table 5.2 shows that the contextual factors included four constructs i.e. number of external relations; number of employees; degree of automation; and number of product groups. These constructs and the identified indicators with a Cronbach's alpha value of 1 were used as individual variables to analyse the influence of these variables on the five variables of production quality.

The contextual factor complexity of the organisation consisted of six reliable and valid variables, whereas five variables were found for complexity of the production process. Complexity of the product assortment consisted of two reliable and valid variables (Table 5.2).

Table 5.2 shows that three variables i.e. number of employees, average number of times changing a production line in a day, and average number of times adjusting a production line in a day, were transformed into the natural logarithm (log). This was done to diminish the influence of extreme observations and to get a more even spread along the scale.

5.4 Conclusions and considerations

5.4.1 Evaluation of IMAQE-Food

Our instrument IMAQE-Food that measures effectiveness of food quality systems was evaluated on reliability, validity, and generalisability. In quality management literature, measurement issues related to reliability and validity are slightly substantiated [3]. Although some studies have focused on the relationship between various quality management elements and performance, they did not identify and validate the quality management constructs, nor did they analyse relationships among the constructs [4]. A few researchers have developed instruments for quality management, which were scientifically validated: Saraph *et al.* [2], Flynn *et al.* [3], Ahire *et al.* [4], Black and Porter [20], and Benson *et al.* [21]. These researchers used various types of validation and reliability tests. The application of their instruments differed and was not specific for the food sector. Our instrument IMAQE-Food was developed for the food industry in specific.

Although Ahire *et al.* [4] studied correlations among constructs, they emphasised that their results could not be used directly to confirm interactions among the various constructs and their impact on product quality. They revealed possible second-order relationships and therefore the interactions could be mediated by another construct. Only Benson *et al.* [21] studied relationships between quality management and context, but they did not examine the impact on quality performance in contrast to our instrument.

5.4.2 Usefulness of IMAQE-Food for application in the food sector

IMAQE-Food

IMAQE-Food is a reliable and valid instrument that determines the relations between quality management, production quality, and contextual factors. The instrument is considered to be generic for the bakery sector. Adaptation of the instrument in the vegetable and fruit-processing sector required only small modifications, indicating that IMAQE-Food will be easily applicable in other food sectors as well. For application of IMAQE-Food in other sectors, qualitative research and delphi sessions will be required to verify relevancy of indicators for that sector and to specify the sub indicators or items [5]. These items should be evaluated on reliability and validity by use of our developed procedure before effectiveness can be assessed by regression analysis.

Improvement of IMAQE-Food

IMAQE-Food can be improved if more data are available and a larger sample size is obtained. An appropriate data collection and a larger sample size will improve validity and reliability of the current instrument and will enable the assessment of effectiveness by IMAQE-Food. An appropriate measure of production quality enables to use the criterion-related validity between quality management and production quality for assessment of effectiveness of food quality management. Only a full data set enables the direct rejection or confirmation of the hypotheses of the conceptual model that quality management and/or contextual factors influence production quality. Moreover, a more comprehensive reliability test can be used that

not only tests the internal consistency of the instrument but also compares with other moments or methods by performing test-retest and parallel-forms reliability estimates.
Although improvement is possible, IMAQE-Food is a reliable and valid instrument. The sample size was sufficient for calculating Cronbach's alpha of a new instrument [3]. The studied bakeries differ in relevant aspects for measuring effectiveness whereas disturbing factors have been reduced.

Application of IMAQE-Food

IMAQE-Food can be used for obtaining knowledge about effectiveness of food quality systems. The developed procedure is useful for obtaining insight in which contextual factors should be managed, which technological and managerial measures should be taken, and what level of quality management should be achieved in order to assure food quality. This supports food manufacturers in deciding which system is most suitable and how to achieve their objectives. This can result in a higher production quality, a better compliance with expectations of consumers, regaining and maintaining trust of consumers in food production quality, and maintaining and improving competitiveness of food manufacturers.
IMAQE-Food can be detailed for existent QA systems in order to know the actual contribution of these QA systems to food quality assurance. Furthermore, the instrument can be applied in other food sectors using qualitative research, delphi sessions, and our developed procedure to evaluate reliability and validity and to analyse relationships.

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6

Measuring effectiveness of food quality management in the bakery sector

Abstract

This chapter investigates the effectiveness of food quality management. The bakery sector was selected to study the effectiveness. Relations between production quality, quality management and contextual factors were studied from a generic and a specific point of view. On the generic level, performance of quality management was related to contextual factors i.e. complexity of respectively organisation, production process, and product assortment. Assessment on the specific level revealed that effective quality management activities in the bakery sector were (1) control of strategy, (2) allocation of supplying raw materials, (3) supply control, (4) control of production, (5) control of execution of production tasks, (6) control of receiving orders, and (7) planning of distribution. These quality management activities were effective, since interdependency was found between a higher level of these activities and a higher score for specific indicators for production quality i.e. higher results of respectively legislative and technical evaluation, lower percentage of rejected products, and lower percentage of complaints about respectively product quality and availability. Each bakery has a different set of contextual factors such as type of QA systems, size of the company, degree of automation, and product assortment. Depending on these differences in context, bakeries should select and implement specific quality management activities suitable to their situation to increase their production quality.

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6.1 Introduction

Inappropriate management of food production operations can cause several problems on quality aspects like food safety, customer satisfaction, and availability. For example, inappropriate temperature control of confectionery containing e.g. cream, fresh fruit and meat causes growth of micro-organisms, which can result in safety problems, product failures, and customer complaints. Inappropriate planning of production and distribution causes either overproduction resulting in loss of materials or unavailability of products, which require additional production and deliveries leading to customer complaints and failure costs.

Food manufacturers have to decide which quality management activities are most suitable for their specific situation and how they should be implemented. Therefore, the actual contribution of food quality management, i.e. the effectiveness, has to be established. Food quality management is considered to be effective when a higher level of quality management results in a higher production quality. Moreover, quality management is effective when it reduces the influence of contextual factors on production quality. IMAQE-Food measures effectiveness by assessing relations between quality management activities, production quality and contextual factors.

When evaluating the appropriateness of an assessment method, a tension exists between approaching reality and performing a robust analysis. To approach reality as best as possible, all identified indicators should be used. However, the analysis of relations is more robust by using only necessary indicators based on statistical calculations [1].

This chapter investigates the measurement of effectiveness of food quality management, specifically for the bakery sector. Relations between production quality, quality management and contextual factors are studied from two points of view i.e. a generic approach that estimates reality as best as possible by using identified indicators, and a specific approach that estimates relations by using only statistically relevant constructs.

6.2 Measurement method of effectiveness

For measuring the effectiveness of food quality management on the generic level, content-validated indicators were used, whereas on the specific level constructs were used.

Effectiveness was measured by the assessment of relations between quality management, production quality and contextual factors using appropriate indicators (Figure 1.1). These indicators were identified and validated through interviews with experts and (quality) managers in the bakery sector [2, 3], i.e. content validity. Subsequently, these indicators were statistically analysed to reduce the number of indicators to relevant constructs, i.e. construct validity. Constructs are sets of indicators that measure the same relations. Their use results in a more robust instrument [3].

6.2.1 Generic approach

In the generic approach relations were analysed between the elements of Figure 3.1 using content-validated indicators.

Before identifying relations, firstly the internal consistency of the elements was determined by calculating Cronbach's alpha and the total score of each element. Table 6.1 shows the internal consistency of the elements and the indicators that comprise the elements. An element was relevant when Cronbach's alpha was at least 0.60. Results show that for production quality Cronbach's alpha was not calculated. This was due to the fact that data for several indicators were not available at all bakeries, reducing the number of respondents. Consequently, the indicators of production quality could not be used as measures of the element. The indicator with the highest number of available data was "results of legislative evaluation" ($N=44$ out of $N=48$).

Data for the indicators were collected among a sample of 48 bakeries. These data were quantified with scores in a range of 0-10 to measure differences within the sample. The total score of each element was calculated by summarising the scores of indicators that comprise one internal consistent element. No weight factors were used.

Secondly, the relations were explored using regression analysis. Relations were considered significant at the 5%-level ($p<0.05$).

Finally, the effectiveness of food quality management was determined by evaluating the relations. Food quality management was considered effective when a higher level of quality management was related to a higher production quality, and when relations of contextual factors and a lower production quality were turned into relations with a higher production quality due to food quality management.

Table 6.1 Indicators of the internal consistent elements on the generic level and indicators of the internal consistent constructs on the specific level.

* = variable consisting of one item (Cronbach's alpha = 1)

Element	Indicators	Cronbach's alpha	Constructs	Cronbach's alpha
Complexity of organisation	1. Number and composition of employees	0.7255	Number of external relations	0.6747
	2. Number of suppliers		Number of temporary employees	*
	3. Number of customers / delivery points		Percentage of not-producing affiliates	*
	4. Percentage of products sold to third parties		Percentage of produced products	*
			Number of customers / delivery points	*
			Number of employees (log)	0.8192
			Number of relationships (co-operation)	*
Complexity of production process	1. Number of production lines	0.7367	Degree of automation	0.8057
	2. Average number of times changing a production line in a day		Average number of times changing a production line in a day	*
	3. Average number of times adjusting a production line in a day		Average number of times adjusting a production line in a day	*
	4. Average number of critical control points		Average number of process steps	*
			Average number of critical control points	*
Complexity of product assortment	1. Number of product groups	0.7029	Number of product groups	0.7336
	2. Type of product groups		Type of product groups	*
	3. Number of recipes			
	4. Percentage of products directly delivered or sold			
Quality management	1. Strategy	0.6765	Control of strategy	0.6497
	2. Supply control		Allocation of supplying raw materials	0.7527
	3. Production control		Supply control	0.7792
	4. Distribution control		Planning of production	0.7859
	5. Execution of production tasks		Control of production	0.7933
			Control of receiving orders	0.7829
			Planning of distribution	0.8486
			Control of execution of production tasks	0.7386
Production quality	Percentage of rejected products	*	Percentage of rejected products	*
	Results of legislative evaluation	*	Results of legislative evaluation	*
	Results of technical evaluation	*	Results of technical evaluation	*
	Percentage of complaints about product quality	*	Percentage of complaints about product quality	*
	Percentage of complaints about availability	*	Percentage of complaints about availability	*

6.2.2 Specific approach

In the specific approach relations between the elements were also analysed. However, in this study we used statistically established constructs of indicators. This approach obtains unambiguous results due to modification of data and relations into high orthogonal data and linear relations, which are requirements for a regression analysis.

Before identifying relations, firstly construct validity of each reliable set of indicators was tested by rotated factor analysis (varimax) to obtain constructs consisting of indicators that all measure the same underlying variable. The internal consistency of the constructs was determined by calculating Cronbach's alpha, and the total score of each construct was calculated. Table 6.1 shows the constructs and their internal consistency. Results show that a large number of constructs was developed all measuring another aspect. Therefore, on a statistical basis, these constructs were not a measure for the elements but should be considered separately. Like the generic approach, production quality was divided in five separate indicators.

For each studied bakery the total score of each construct was established by the average of indicators that comprise one construct of an element without weight factors.

Secondly, relations were assessed using GenStat procedure RSELECT [4]. This procedure evaluates all sets of possible relations and selects a small number of best sets, which prevents that possible relations are overlooked due to the large number of highly orthogonal constructs. The relations were identified by using three criteria for measuring goodness of fit i.e. R^2, R^2 adjusted, and Mallow's Cp.

R^2 is the percentage of variance accounted for and shows the extent to which indicators of production quality relate to constructs of quality management and contextual factors. It always improves with the addition of another construct. The adjusted version of R^2 is usually a better guide in the selection of sets because it takes into account the number of constructs. R^2 adjusted improves when the F-ratio due to the addition of a construct is larger than 1. Mallow's Cp is a measure for the robustness of the relations and is related to the Akaike information criterion. Mallow's Cp tends to select smaller subsets than R^2 and R^2 adjusted. It improves when the F-ratio due to the addition of a construct is larger than 2.

A construct was added when Mallow's Cp value improved. Occasionally, the calculation of Mallow's Cp failed due to the number of not available values in the response variable. In those cases, selecting best sets of relations was based on R^2 adjusted. Although all three criteria were used, Mallow's Cp was used as the predominant one. The selection was complicated due to the high degree of correlation among constructs in our data. To obtain stable relations, only those relations were selected that showed the lowest degree of correlation.

When selection is governed by statistical criteria only, alternative sets of relations with good interpretative purposes may easily been overseen. Therefore, for indicators of production quality three or four alternative sets of relations (see Table 6.2 and 6.3) were selected which all fit equally well differing in priority of the above-mentioned criteria.

Finally, effectiveness was determined similar to the generic approach.

6.3 Results

In this section, we first describe the relations on both a generic and a specific level. Next the effectiveness of food quality management is discussed.

6.3.1 Generic approach

Figure 6.1 shows the significant relations between "results of legislative evaluation", quality management and complexity of respectively organisation, production process and product assortment. As shown "results of legislative evaluation" was negatively related to complexity of the production process. Between the level of quality management and the score of "results of legislative evaluation" no effect was found. Complexity of respectively organisation and production process were positively related to quality management, whereas complexity of product assortment was negatively related.

These relations mean that bakeries with a higher complexity of respectively the organisation and production process and a lower complexity of the product assortment performed at a higher level of quality management. However, this had no effect on "results of legislative evaluation".

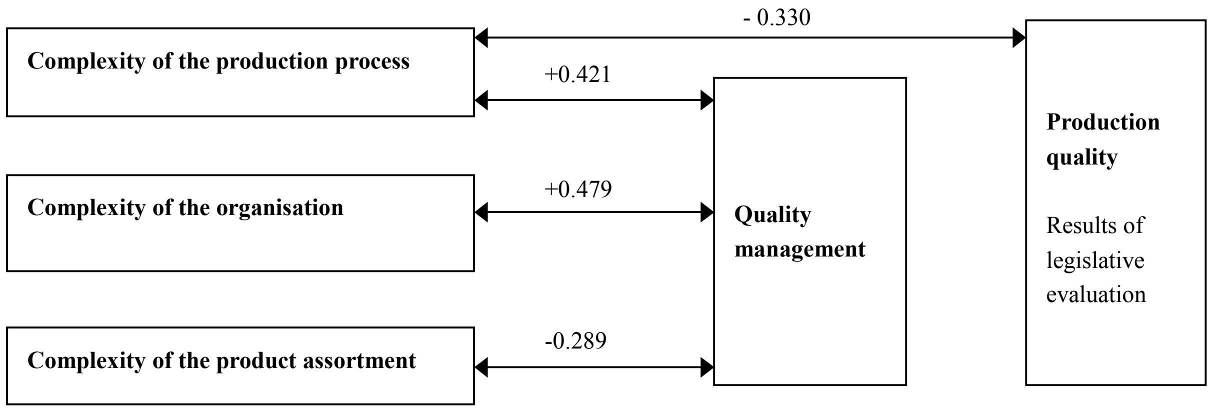

Figure 6.1 Identified relations between "results of legislative evaluation", quality management and contextual factors obtained by regression analysis using the generic approach (R^2 = 14.3%, $p<0.05$).

+ = positive relation, - = negative relation, numbers express the regression coefficient

6.3.2 Specific approach

To study the generic relations in more detail and to examine the robustness of the instrument, we used constructs of the identified indicators. In Table 6.2, significant relations between indicators of production quality and constructs of quality management and contextual factors are marked (+/-). A plus indicates a positive relation and a minus a negative relation. Table 6.3 shows the relations between constructs of quality management and contextual factors.
Table 6.2 and 6.3 show that robustness of the instrument was obtained, because maximal seven constructs were necessary. Moreover, these constructs explain a large part of the indicators of production quality. The explained variance varied dependent on the indicator of production quality. The indicators of production quality were related to the constructs of quality management and contextual factors in a range of R^2=42.8-73.3%. The constructs of quality management were related to constructs of contextual factors in a range of R^2=16.0-52.5%.

Table 6.2 and 6.3 show that all indicators of production quality were related to the constructs of quality management and contextual factors, whereas all constructs of quality management related to the constructs of contextual factors.

Table 6.2 Relations between five indicators for production quality, and constructs for quality management and contextual factors obtained by regression analysis (1 to 4 = number of fitted sets of relations, + = positive relation, - = negative relation)

Constructs	% Rejected products				% Complaints about product quality			Results of legislative evaluation			Results of technical evaluation			% Complaints about availability		
	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3
Complexity of the organisation																
Number of external relations											-	-	-			
Percentage of non-producing affiliates					+	+	+				-	-	-			
Percentage of produced products			-													
Number of customers / delivery points								-	-							
Number of employees (log)										-	+	+	+		-	-
Number of temporary employees	-	-	-	-		+	+	+	+	+						
Number of relationships (co-operation)													+			
Complexity of the production process																
Degree of automation					+	+	+				-	-	-		+	+
Average number of times changing a production line in a day (log)								-	-	-						
Average number of times adjusting a production line in a day (log)		+		+												
Average number of process steps				-												
Average number of critical control points								+	+	+	+	+	+			
Complexity of the product assortment																
Number of product groups																
Type of product groups																
Quality management																
Control of strategy						-						+				-
Allocation of supplying raw materials														-		
Supply control	-	-	-	-					+	+						
Planning of production														+		
Control of production					-		-							-	-	-
Control of execution of production tasks					-	-	-									
Control of receiving orders	-	-	-	-												
Planning of distribution					-	-	-				+	+	+	-	-	-
R^2 (%)	42.8	48.6	46.8	55.5	54.5	59.3	57.4	45.0	47.4	47.0	57.6	64.7	63.2	66.7	66.3	73.3
R^2_{adj} (%)	34.7	38.4	36.2	43.7	45.8	49.5	47.2	39.0	40.1	39.7	47.0	54.0	52.0	60.4	60.1	66.5

Table 6.3 Relations between seven constructs for quality management, and constructs for contextual factors obtained by regression analysis

(1 to 3 = number of fitted sets of relations, + = positive relation, - = negative relation)

Constructs	Control of strategy			Allocation of supplying raw materials			Supply control			Planning of production		Control of produc-tion	Control of execution of production tasks			Control of recei-ving orders	Planning of distribution	
	1	2	3	1	2	3	1	2	3	1	2	1	1	2	3	1	1	2
Complexity of the organisation																		
Number of external relations	+		+			+							-	-	-			
Percentage of non-producing affiliates		+	+	+	+	+	+				+	+						
Percentage of produced products				+	+		-	-	-									
Number of customers / delivery points						-										+	+	+
Number of employees (log)					+					+								
Number of temporary employees													+	+	+			
Number of relationships (co-operation)		+										-	+					+
Complexity of the production process																		
Degree of automation	+	+	+	+						+	+		+	+	+			
Average number of times changing a production line in a day (log)	-	-	-				-	-	-					-		-		
Average number of times adjusting a production line in a day (log)												+			-			
Average number of process steps	-		-	-	-	-		+								-	+	+
Average number of critical control points		-							+							+		
Complexity of the product assortment																		
Number of product groups	+		+	-	-													
Type of product groups	+	+	+			+		-	-									
R^2 (%)	42.0	40.3	46.1	52.5	50.8	50.5	34.1	37.3	37.2	44.7	44.5	16.0	48.2	47.0	46.9	19.7	28.5	31.6
R^2_{adj} (%)	33.0	31.0	36.2	46.5	44.6	44.3	29.0	31.2	31.1	42.1	41.9	10.1	43.6	41.8	41.7	11.8	25.2	26.7

Table 6.2 reveals that the relations with “percentage of complaints about availability” are best explained by the constructs (R^2=66.7-73.3%). The most stable relations of this indicator are those with the constructs “planning of distribution” and “control of production”, because they are found in the three possible sets of relations. “Planning of distribution” combines information on delivery requirements like delivery time, location, distribution conditions, orders and capacity, into a distribution schedule. Bakeries with a higher level of this construct used more information for the planning and changed their schedule when necessary. This may result in a better compliance of the delivery of products with customer requirements, which in turn decreases the percentage of complaints. Bakeries with a higher level of “control of production” evaluated products and processes on a larger number of aspects using many types of information, and they used registrations and evaluations to improve the production process including procedures and communication to employees. This may result in a higher quality of products and processes, which leads to a decrease in the percentage of complaints.

In Table 6.2 is also shown that “results of technical evaluation” have the most stable relations, since six relations were found in the three possible sets of relations of this indicator. For example, higher “results of technical evaluation” were related to a smaller number of external relations (e.g. suppliers). Possibly a smaller number of suppliers causes less variation of raw materials resulting in a higher product quality. Besides, the results were positively related to number of employees. In general, larger organisations have more facilities and knowledge than smaller organisations, which may result in a higher level of product quality and food safety. Another relation was shown between higher “results of technical evaluation” and a lower degree of automation. Possibly professional skills and experience of bakers improved the product quality. Furthermore, “results of technical evaluation” were positively related to number of critical control points. When more critical control points are established, more potential food safety hazards are identified and controlled, which may result in a higher level of food safety.

6.3.3 Effectiveness of food quality management

The found relations were used to assess the effectiveness of food quality management among the group of studied bakeries. Food quality management is considered to be effective when a higher level of quality management and a higher production quality are interdependent. Quality management is also effective when it changes the relation between contextual factors and a lower production quality into a relation with a higher production quality.

Seven activities of food quality management were effective in the bakery sector: (1) control of strategy, (2) allocation of supplying raw materials, (3) supply control, (4) control of production, (5) control of execution of production tasks, (6) control of receiving orders, and (7) planning of distribution. Table 6.4 shows the indicators of production quality for which the quality management activity is effective and the related contextual factors.

The quality management activities were effective, since interdependency was found between a higher level of these activities and a higher score for indicators of production quality i.e. higher results of respectively legislative and technical evaluation, lower percentage of rejected products, and lower percentage of complaints about respectively product quality and availability. The activities were effective for bakeries with various characteristics of organisation, production process and product assortment.

6.4 Discussion and conclusions

6.4.1 Measurement of production quality

Production quality was measured by the bakeries themselves and by inspection agencies. We studied five indicators of production quality separately, because we could not use one measure for production quality due to unavailability of data in the bakery sector [2, 3]. For an appropriate measure of effectiveness, bakeries should collect more data about production quality. As a consequence of measuring the indicators of production quality separately, we have only been able to study the effects of quality management and contextual factors on one specific indicator of production quality. If production quality was assessed as one single measure, other relations have been found with effective quality management activities for more aspects of production quality.

6.4.2 Relevancy of indicators

Relations were found between the five indicators of production quality and constructs of quality management and contextual factors. The total variance varied in a range of R^2=42.8-73.3%. The variance shows that our procedure selected relevant indicators and omitted disturbing influences, although the indicators for production quality were also associated with other unknown variables. Examples of possible variables are: experience, organisational culture, quality strategy and policy, quality design and quality improvement. These variables should be evaluated on relevancy, reliability and validity using our structured procedure.

Table 6.4 Effective activities of food quality management for indicators of production quality in the bakery sector.

O = complexity of the organisation; PP = complexity of the production process; PA = complexity of the product assortment

Quality management		Indicator of production quality	Contextual factors related with quality management
Effective activity	**Description**		
Control of strategy	In the strategy is formulated how the organisation's mission and objectives have to be accomplished. Items were focused on the evaluation of a long-term plan.	% Complaints about product quality Results of technical evaluation % Complaints about availability	Number of external relations (O) % Non-producing affiliates (O) Number of relationships (O) Degree of automation (PP) Number of changes (PP) Number of process steps (PP) Number of critical control points (PP) Number of product groups (PA) Type of product groups (PA)
Allocation of supplying raw materials	The activities of supplying raw materials can be performed by the bakery itself and can be allocated to a concern or a purchase organisation. Items: • allocation of purchasing raw materials • allocation of selecting suppliers • allocation of making agreements with suppliers.	% Complaints about availability	Number of external relations (O) % Non-producing affiliates (O) % Produced products (O) Number of customers / delivery points (O) Number of employees (O) Degree of automation (PP) Number of process steps (PP) Number of product groups (PA) Type of product groups (PA)
Supply control	Supply control is that part of quality control that focuses on the purchase process. It is an ongoing process of evaluating performance of suppliers and raw materials, and taking corrective actions when necessary. Items: • purchase and selection of raw materials; • selection and evaluation of suppliers; • co-operation with suppliers.	% Rejected products Results of legislative evaluation	% Non-producing affiliates (O) % Produced products (O) Number of changes (PP) Number of process steps (PP) Number of critical control points (PP) Type of product groups (PA)

Continue Table 6.4

Quality management		Indicator of production quality	Contextual factors related with quality management
Effective activity	**Description**		
Control of production	Part of quality control that is focused on the production process. Items: • product and process control including control of food safety and product quality; • improvement of the process.	% Complaints about product quality % Complaints about availability	% Non-producing affiliates (O) Number of relationships (O) Number of adjustments (PP)
Control of execution of production tasks	Part of quality control that is focused on the execution of production tasks. Items: • information, instruction and supervision; • evaluation of results and communication; • flexibility of procedures and methods.	% Complaints about product quality	Number of external relations (O) Number of temporary employees (O) Number of relationships (O) Degree of automation (PP) Number of changes (PP) Number of adjustments (PP)
Control of receiving orders	Items: analysis, acceptation and processing of orders.	% Rejected products	Number of customers / delivery points (O) Number of process steps (PP) Number of changes (PP) Number of critical control points (PP)
Planning of distribution	Items: development and evaluation of distribution planning.	% Complaints about product quality Results of technical evaluation % Complaints about availability	Number of customers / delivery points (O) Number of relationships (O) Number of process steps (PP)

6.4.3 Measurement method

Two measurement methods were used to study the effectiveness of food quality management i.e. on a generic and a specific level. On the generic level only "results of legislative evaluation" was examined since most respondents measured this indicator. Typical examples of legislative evaluation are inspections on food safety (e.g. contamination by bacteria), product quality (e.g. compliance of ingredients with labelling), hygiene, application and implementation of food safety systems like HACCP. Thus legislative production quality involves the minimal requirements for a food product. No relations were found between quality management and "results of legislative evaluation", probably because all bakeries have to comply with legislative standards. The other indicators of production quality showed no significant relations with quality management and contextual factors due to unavailable and low orthogonal data.

We performed the analysis on the specific level to examine the relations in detail with a robust instrument. The set of data and relations were modified into high orthogonal data by using the statistically established constructs. In contrast to the results on the generic level, this analysis resulted in unambiguous relations. On the detailed level, relations with the indicators of production quality were found.

The measurements on both levels consist of positive and negative aspects. On the generic level, total scores for the elements were obtained which are useful for prediction. The reliability of the elements was acceptable for developing a new instrument. However, indicators that measure the same aspect were also included in the elements, whereas opposite effects neutralised each other. Consequently, the total score of the elements need not be the actual score. On the specific level, all constructs measured different aspects, which makes the instrument robust. The reliability of the constructs was acceptable as well. Many constructs were used which enables examination of the relations in detail. However, the constructs cannot be used for one measure of an element because the element is not the underlying variable. Therefore, we selected only indicators for a construct that belong to a specific element, which enables extrapolation of scores of the constructs to those of the elements. Therefore, specific relations could be translated into generic relations.

6.4.4 Relations

The results confirmed our hypothesised relations: a higher level of quality management is interdependent with a higher production quality; and a higher level of quality management changes the relation between contextual factors and a lower production quality into a relation with a higher production quality.

Evaluation of our results on causality by observations in literature shows that our relations are in compliance with results by other researchers. Several authors emphasised relations between quality management and production quality [5-11]. Moreover, others describe the relation of the business environment to quality management or production quality [11-22].

Although other researchers obtained comparable relations, they did not study how an effective food quality management could be achieved in order to obtain an optimal production quality within the context of the organisation. Most studies were performed for other sectors than the agri-food sector.

6.4.5 Effectiveness of food quality management

This study shows that effective activities of quality management in the bakery sector were: (1) control of strategy, (2) allocation of supplying raw materials, (3) supply control, (4) control of production, (5) control of execution of production tasks, (6) control of receiving orders, and (7) planning of distribution. Interdependency was found between a higher level of these activities and a higher score on specific indicators of production quality i.e. higher results of respectively legislative and technical evaluation, lower percentage of rejected products, and lower percentage of complaints about respectively product quality and availability.

Some of these effective activities have been suggested by others as well. For example, “supply control” and “results of legislative evaluation”. Luning *et al.* [5], Ahire *et al.* [23] and Achten and Roodhooft [24] mention that the quality of raw materials has a major influence on production quality of final products, which requires supply control. Besides, selection of suppliers on criteria (such as quality, price, flexibility, and reliability) and audits of their quality assurance systems have an influence on performance of suppliers, and therefore on production quality of final products [5, 8, 23-30].

Others also found that "supply control" and "control of receiving orders" decrease the variation of raw materials. This results in prevention of loss of materials during the production process. In addition, customer requirements are analysed on their feasibility. Agreements made before production (e.g. customer orders) and order analysis facilitate both compliance with requirements of customers and development of the planning [25, 27, 28, 31, 32].

Several authors emphasise that the primary process is prepared and evaluated by “control of strategy”, “allocation of supplying raw materials”, “control of production”, and “planning of distribution". Preparation and evaluation control failures and result in delivery of products according to delivery requirements (amount of products, location, time) [5, 25-28, 32, 33], which may reduce complaints about availability. Anticipation on delivery times and conditions controls also the physical product quality [5, 25, 32], which may reduce complaints about product quality. Acquiring and allocation of resources and employees result in production conditions needed to obtain the desired product quality [5, 25, 28].

In addition, several authors mention that "control of production" and "control of execution of production tasks" decrease failures during production, which may reduce complaints about product quality. Training of employees and communication improve performance of execution [5, 23, 26-29, 33]. Product and process control, and evaluation of assigned tasks and established procedures control performance of production tasks and consequently product quality [25].

Remarkably, "planning of production" was identified to be significantly not effective; a lower score of "percentage of complaints about availability" was related to a lower level of "planning of production". The bakeries probably compensate the lower level of quality management with experience and skills to obtain the desired production quality.

6.4.6 IMAQE-Food

The effectiveness of quality management activities is shown for bakeries with various contextual factors. The relation of the context to a lower production quality can be converted into a higher production quality by improving the level of quality management activities. Changes in the complexity of the bakeries can also improve the production quality. Our findings show that bakeries should take into account their organisation, production process, product assortment, and quality management activities. Development and change of the business environment modify the production quality, which requires an effective selection and implementation of specific quality management activities to obtain an appropriate production quality.

Bakeries can use IMAQE-Food to obtain a better implementation and an effective food quality management. IMAQE-Food measures the level of both quality management activities and production quality, and anticipates on the context of the company. The instrument can measure the effectiveness of quality management activities for bakeries with a specific context. If a bakery has a lower score on a specific quality management activity that is effective for bakeries with a comparable context, it should improve that activity to obtain a higher production quality. In this way, bakeries can select and implement quality management activities suitable to their situation in order to obtain an effective food quality management.

6.4.7 Future research

In future research, measurement of effectiveness should be performed with the method on specific level due to its robustness and non-neutralising effects. However, the underlying variables of the constructs should be investigated in order to use fewer measures for prediction. More data about production quality should be collected and registered for an appropriate measure of effectiveness. Successive research can develop methods to support bakeries with data collection and registration. IMAQE-Food can be used for predicting and benchmarking the level of food quality management or production quality. The relation of the contextual factors of bakeries (e.g. type of product groups, organisational size, degree of automation) to food quality management can be investigated by studying differences of activities within specific groups of the bakeries. Knowledge about this relation of contextual factors can be used to advise bakeries how to optimally implement and execute their quality management.

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7

How to improve food quality management in the bakery sector

Abstract

This chapter investigates the interdependency between contextual factors of bakeries and their level of food quality management. Contextual factors that are studied are (1) QA systems, (2) organisational size, (3) degree of automation, and (4) type of product groups. Implications for bakeries are provided. The level of food quality management within these groups was analysed by ANOVA. The context of bakeries revealed differences in the level of five quality management activities i.e. “control of strategy”, “allocation of supplying raw materials”, “supply control”, “planning of production”, and “control of execution of production tasks”. Bakeries that applied BRC, bakeries with more than 150 employees, industrial bakeries, and confectionery and biscuits bakeries performed a higher level of some of these activities. Food manufacturers can select suitable quality management activities and QA systems for their specific situation by using IMAQE-Food in order to obtain an effective quality management.

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7.1 Introduction

QA systems that are applied in the bakery sector are HACCP, Hygiene code for bread and confectionery, ISO 9000-series and BRC. Most QA systems are too generic in nature to be applicable for each company [1]. Consequently, bakeries have several options to apply the QA systems. Each bakery has to interpret the systems in a different way by translating the generic aspects into their specific situation. Therefore, methods should be applicable to make QA systems suitable for specific situations in order to prevent failures due to inappropriate management of food production operations and inappropriate methods of design, implementation, and improvement.

Bakeries have to decide which activities of food quality management and which QA system(s) are most suitable to their specific needs, and how this system should be implemented. To apply QA systems for specific situations, insight is needed in the interdependency between contextual factors of bakeries and their level of quality management activities.

The aim of this study is to investigate how contextual factors of bakeries relate to the level of food quality management. Implications for bakeries are provided. Contextual factors that are studied are (1) QA systems, (2) organisational size, (3) degree of automation, and (4) type of product groups.

7.2 Assessment method

The interdependency between contextual factors and level of food quality management in the bakery sector was investigated by using IMAQE-Food. The contextual factors were classified and the relations were analysed.

7.2.1 Classification of contextual factors

In order to study the relations between contextual factors and the level of food quality management in the bakery sector, a secondary analysis of data among the 48 respondents was applied. The respondents were classified according to (1) type of applied QA systems, (2) organisational size, (3) degree of automation (based on type of oven used), and (4) type of product groups (Table 7.1). Each class consisted of specific subgroups.

Table 7.1 Differences in quality management activities within subgroups of bakeries classified according to type of QA system, organisational size, degree of automation, and type of bakery. Significant differences of these quality management activities ($p<0.05$, Student t-test) are marked with a, b, or c. N = number of cases.

Contextual factors		**N**	**Quality management activities**							
			Control of strategy	Allocation of supplying raw materials	Supply control	Planning of production	Control of production	Control of execution of production tasks	Control of receiving orders	Planning of distribution
QA systems	No QA system	3	5.8	2.6	10.0 [b]	3.1 [a]	4.8	2.5 [a]	5.5	6.4
	Hygiene code	8	4.4	2.3	9.1 [b]	3.9 [a]	7.9	4.0 [b]	6.1	6.1
	HACCP	17	4.6	3.0	9.4 [b]	5.3 [a]	6.5	4.4 [b]	6.3	6.7
	ISO	5	5.5	3.0	5.1 [a]	7.6 [b]	7.6	5.9 [b]	6.3	7.2
	BRC	15	5.7	4.6	8.3 [b]	7.4 [b]	7.4	6.6 [c]	5.4	6.6
Organisational size (in number of employees)	10-49	13	4.4 [a]	1.9 [a]	9.1	3.7 [a]	6.3	3.7 [a]	5.7	5.7
	50-99	14	4.8 [a]	3.7 [b]	9.2	5.7 [b]	6.7	4.7 [a]	6.3	6.4
	100-149	11	4.5 [a]	3.2 [b]	7.6	7.1 [b]	7.8	5.7 [a]	4.9	7.6
	>150	10	7.1 [b]	5.0 [b]	8.1	7.4 [b]	7.4	6.6 [b]	6.8	7.1
Degree of automation [1]	Non-industrial	22	4.3 [a]	2.3 [a]	9.2	4.2 [a]	6.8	3.9 [a]	5.6	6.7
	Industrial	26	5.7 [b]	4.3 [b]	8.1	7.2 [b]	7.2	6.0 [b]	6.2	6.6
Type of bakery	Bread	10	5.1	3.9	6.6 [a]	7.0	8.0	7.2 [b]	5.7	6.2
	Confectionery	11	5.7	4.0	9.3 [b]	5.5	6.9	5.3 [b]	6.5	5.2
	Mixed	22	4.7	2.5	8.8 [b]	5.1	6.9	3.7 [a]	5.4	7.9
	Biscuits	5	5.4	4.9	10.0 [b]	7.5	5.8	6.4 [b]	7.4	5.0

[1] based on type of oven used

Subgroups of the type of QA systems were made based on the common situation in practice in the bakery sector. Bakeries were classified according to their most comprehensive QA system. For example, bakeries with the Hygiene code and HACCP were classified in the subgroup HACCP, and bakeries with BRC and other systems were classified in the subgroup BRC. Classification on organisational size has not explicitly been used in literature or in practice. Therefore, subgroups were established by classification of the respondents in four groups of similar size. Subgroups of degree of automation and type of bakery were based on classifications used in practice [2, 3].

7.2.2 Analysis of relations

For each subgroup, the relations to the level of quality management activities were analysed by using ANOVA. The level of food quality management was measured by indicators that were identified and validated [4, 5] (Chapter 4, 5). The following indicators for quality management were assessed: (1) control of strategy, (2) allocation of supplying raw materials, (3) supply control, (4) planning of production, (5) control of production, (6) control of execution of production tasks, (7) control of receiving orders, and (8) planning of distribution. Differences in the level of quality management activities between subgroups were analysed using Student's t-test and were considered significant at $p \leq 0.05$. On the basis of these relations, the interdependency between contextual factors and level of food quality management was analysed. This interdependency was investigated in detail by a qualitative analysis of the typical quality management activities within the subgroups to obtain more insight why contextual factors and quality management activities are related.

7.3 Results

Table 7.1 shows the significant differences in the level of quality management activities within the subgroups of bakeries classified according to type of QA systems, organisational size, degree of automation, and type of bakery. To obtain insight in relations between contextual factors and quality management activities, these differences were qualitatively analysed. Results of this analysis are shown in detail in Table 7.2 to 7.5.

7.3.1 Type of Quality Assurance systems

The first classification was on type of QA systems. Table 7.1 shows that subgroups of the classified types of QA systems were bakeries that applied the Hygiene code, HACCP, HACCP combined with ISO 9001:1994 or ISO 9002:1994, BRC, or no QA system. Most bakeries without HACCP applied the Hygiene code. The bakeries with ISO and HACCP applied first ISO due to requirements by customers and next HACCP due to legislative requirements. Bakeries with BRC applied first HACCP and some performed also ISO.

Table 7.1 shows that most bakeries performed HACCP (N=17) or BRC (N=15). Only three bakeries applied no QA system and only five bakeries applied ISO. In spite of these variations in sample size, we revealed significant differences. The subgroups of bakeries differed significantly in the level of “supply control”, “planning of production” and “control of execution of production tasks”. Bakeries with BRC performed all activities on a higher level. Bakeries that applied ISO performed “supply control” on a lower level than the other bakeries, and “planning of production” on the same higher level as BRC. Moreover, bakeries with a Hygiene code, HACCP and/or ISO performed “control of execution of production tasks” on a higher level than bakeries without a QA system and on a lower level than bakeries with BRC.

Table 7.2 shows in detail the interdependency between type of QA systems and level of the quality management activities. The activities of bakeries with BRC and the differences with other QA systems are described below.

Most bakeries with BRC selected suppliers on criteria. They selected only other suppliers if failures were noticed or if no improvements were perceived after making agreements. These bakeries evaluated raw materials mainly by a random check. Bakeries with BRC used always the same design of production plan and established their product order. They included failures and unexpected orders in the planning or they used margins for quiet days. Most bakeries with BRC scheduled the tasks of employees per week or per day. They used information, demonstration and supervision for instruction. When shifts changed, they communicated by consultation. Product quality was evaluated by registration and control. Most bakeries gave feedback of results by consultation, and they improved their procedures after evaluation.

Table 7.2 Differences in quality management activities within subgroups of bakeries classified according to type of QA system.

% = Percentage of bakeries within a subgroup that performs that level of the quality management activity, explained per aspect of the quality management activity.

Quality management activities	**Hygiene code**	**HACCP**	**ISO**	**BRC**
Supply control	- No selection (50%) or selection of suppliers on criteria (25%): product quality, price, delivery time. - Other suppliers are selected if failures are noticed (38%) or if no improvements after making agreements (50%). - Selection by one person who is always involved (88%). - Raw materials are evaluated by a random check (75%)	- No selection (35%) or selection of suppliers on criteria (65%): product quality, price, delivery time, application of QA system. - Other suppliers are selected if no improvements after making agreements (65%). - Selection by one (29%) or more persons (47%) who are always involved. - Raw materials are evaluated by a random check (71%).	- Selection of suppliers selected by purchase organisation (80%): product quality, price, delivery time, flexibility, application and implementation of QA system. - Suppliers are always selected and evaluated (40%). Other suppliers are selected if no improvements after making agreements (60%). - Selection by more persons who are always (60%) or sometimes (40%) involved. - Raw materials are evaluated by receiving inspection, analyses and audits (60%).	- Selection of suppliers on criteria (73%): product quality, price, reliability, information about specifications, application and implementation of QA system. - Other suppliers are selected if failures are noticed (27%) or if no improvements after making agreements (53%). - Selection by more persons who are always involved (87%). - Raw materials are evaluated by a random check (53%) or by receiving inspection, analyses and audits (40%).
Planning of production	- Design of production plan is always the same (75%) or based on experience (25%). - Product order is based on experience (38%) or established (55%) by: possibilities of contamination, types of dough, temperature of the oven, baking time, cooling, delivery time of products, capacity.	- Design of production plan is always the same (65%) or based on experience (24%). - Product order is based on experience (47%) or established (41%) by: possibilities of contamination, number of times of cleaning, temperature of the oven, baking time, types of dough, packaging, amount of products.	- Design of production plan is always the same (100%). - Product order is established (100%) by: temperature of the oven, types of dough, cutting, number of changing of equipment, possibilities of contamination, baking and rise time, packaging, specific product requirements, number of times of cleaning, delivery time of products.	- Design of production plan is always the same (87%). - Product order is established (80%) by: possibilities of contamination, number of times of cleaning, number of changing of equipment, capacity, temperature of the oven, baking time, types of dough, specific product requirements, packaging.

Continue Table 7.2

Quality management activities	Hygiene code	HACCP	ISO	BRC
Planning of production	- Failures and unexpected orders are not included (50%) or are included in margins for only quiet days (50%).	- Failures and unexpected orders are not included (59%) or are included in margins for only quiet days (29%).	- Failures and unexpected orders are included in margins for only quiet days (60%) or in the planning (20%).	- Failures and unexpected orders are included in the planning (40%), or in margins for only quiet days (33%), or are not included (27%).
Control of execution of production tasks	- Tasks of employees were scheduled per week (38%), per day (25%), or the tasks per day were the same (38%). - Instruction by demonstration and supervision (75%) and information (25%) or only demonstration (25%). No shifts (63%). Communication for changing shifts by consultation (38%). - Product quality evaluated by supervision (88%). - Feedback of results by communication and evaluation (63%) or written (25%). - Procedures are improved (50%) after evaluation (25%) or are not improved (50%).	- Tasks of employees were scheduled per week (18%), per day (41%), or the tasks per day were the same (41%). - Instruction by demonstration and supervision (83%) and information (24%) or only demonstration (18%). No shifts (29%). Communication for changing shifts by consultation (65%). - Product quality evaluated by supervision (59%) or registration and control (29%). - Feedback of results by communication and evaluation (47%) or ad hoc (41%). - Procedures are improved (59%) after evaluation (41%).	- Tasks of employees were scheduled per week (60%) or per day (40%). - Instruction by demonstration and supervision (100%) and information (20%). - Communication for changing shifts by consultation (60%). - Product quality evaluated by registration and control (80%). - Feedback of results by communication and evaluation (20%), written (60%) or ad hoc (20%). - Procedures are improved after evaluation (80%).	- Tasks of employees were scheduled per week (53%), per day (20%), or the tasks per day were the same (27%). - Instruction by demonstration and supervision (80%) and information (53%). - Communication for changing shifts by consultation (93%). - Product quality evaluated by registration and control (87%). - Feedback of results by communication and evaluation (60%) or written (27%). - Procedures are improved after evaluation (80%).

Bakeries applying ISO performed selection and evaluation of suppliers (as a part of “supply control”) on a lower level than other bakeries. Bakeries with ISO selected suppliers from a list of the purchase organisation. Some bakeries (40%) selected and evaluated their suppliers every time by several varying persons. However, they evaluated raw materials on a higher level by receiving inspection, analyses and audits than the other bakeries. For “control of execution of production tasks”, bakeries with ISO differed from BRC because they used mainly demonstration and supervision for instruction. Moreover, they used a written paper on a publication board to give feedback of results.

Bakeries with HACCP or Hygiene code performed a lower level of “planning of production” in contrast to bakeries with BRC or ISO (Table 7.1). They based their production plan and product order also on experience (Table 7.2). They did not include time for unexpected situations in the planning. For “control of execution of production tasks”, 41% of the bakeries with HACCP and 38% of the bakeries with Hygiene code performed the same tasks per day in contrast to the bakeries with BRC and ISO. They applied mainly demonstration and supervision for instruction, and not all bakeries used shifts. They evaluated product quality by supervision and did not improve their procedures after evaluation.

In conclusion, HACCP and Hygiene code scored lower on “planning of production” due to less flexibility and based on experience. ISO scored lower on “supply control” due to a less extensive and ambiguous selection and evaluation of suppliers. Considering these findings and the higher level of quality management by BRC, a combination of HACCP and ISO appears to result in a higher level of quality management.

7.3.2 Organisational size

The second classification was on organisational size. Table 7.1 shows that four subgroups were made on the basis of the number of employees i.e. 10-49; 50-99; 100-149; and more than 150 employees. The subgroups of bakeries differed significantly in level of “control of strategy”, “allocation of supplying raw materials”, “planning of production”, and “control of execution of production tasks”. Bakeries involving 10-49 employees performed a lower level of these four quality management activities than bakeries with more than 150 employees (Table 7.1). Bakeries with 50-149 employees also performed a higher level of “supply control” and “planning of production”, although they performed a lower level of “control of strategy” and “control of execution of production tasks”.

Table 7.3 shows in detail the interdependency between organisational size and level of quality management activities.

Most bakeries with more than 150 employees used a relatively long-term strategy in contrast to smaller bakeries that used mainly a simple plan. Besides long-term aspects, the long-term plan was evaluated on several aspects like certification and market situation in contrast to the smaller bakeries that evaluated on amount of produced products. Only large bakeries used the evaluation for improvement of the long-term plan and integrated data in an information system. Furthermore, larger bakeries improved their procedures after evaluation, whereas smaller bakeries used not always evaluation for improvement.

Bakeries with more than 50 employees purchased raw materials and selected suppliers not only by themselves but also via their trading company. They used the same design of production plan whereas smaller bakeries based their production plan also on experience. Bakeries with more than 50 employees adjusted the production plan on basis of realisation and used it for improvement of the long-term plan in contrast to the smaller bakeries. Bakeries with more than 100 employees established the product order, whereas smaller bakeries based the product order also on experience. Most bakeries evaluated product quality by product and process control in contrast to smaller bakeries that evaluated mainly by supervision.

In conclusion, larger bakeries (>150 employees) performed a higher level of quality management activities due to a long-term perspective and improvement. Smaller bakeries (<100 employees) performed a lower level due to less evaluation and improvement and based their activities on experience.

7.3.3 Degree of automation

The third classification is based on degree of automation. Table 7.1 shows that subgroups were non-industrial and industrial bakeries. The classification was based on the type of ovens used. Industrial bakeries used mechanical moving ovens. Non-industrial bakeries used ovens that require removal of products manually. Each subgroup consisted of a similar sample size (Table 7.1). The subgroups of bakeries differed significantly in level of “control of strategy”, “allocation of supplying raw materials”, “planning of production”, and “control of execution of production tasks”. The industrial bakeries performed a higher level of these four quality management activities than the non-industrial bakeries.

Table 7.3 Differences in quality management activities within subgroups of bakeries classified according to organisational size.

% = Percentage of bakeries within a subgroup that performs that level of the quality management activity, explained per aspect of the quality management activity.

Quality management activities	**10-49 employees**	**50-99 employees**	**100-149 employees**	**>150 employees**
Control of strategy	- A simple long-term plan (<1 week) based on production process (62%), comparable with production plan. - Evaluation on the amount of produced products (54%).	- A relatively long-term strategy (1-5 years) (50%) or a simple long-term plan (<1 week) based on production process (36%). - Evaluation on long term aspects like capacity, sales, etc. (57%).	- A simple long-term plan (<1 week) based on production process (73%), comparable with production plan. - Evaluation on long term aspects like capacity, sales, etc. (55%).	- A relatively long-term strategy (1 month to 5 years) (80%). - Evaluation on aspects like quality policy, certification, investments, prognoses, market situation, product development, volumes, employees, and supply of raw materials (80%). - Improvement of long-term plan.
Allocation of supplying raw materials	- Purchase of raw materials and selection of suppliers by bakery itself (100%).	- Purchase of raw materials by bakery itself (86%), selection of suppliers by bakery itself (93%).	- Purchase of raw materials and selection of suppliers by bakery itself (64%) or via trading company (18%).	- Purchase of raw materials by bakery itself (70%) or via trading company (20%).

Continue Table 7.3

Quality management activities	10-49 employees	50-99 employees	100-149 employees	>150 employees
Planning of production	- Design of production plan is always the same (50%) or based on experience (29%). - Product order is based on experience (50%) or established (43%) by: possibilities of contamination, temperature of the oven, baking time. - Production plan is adjusted on the basis of realisation (43%) or not adjusted (43%).	- Production plan has always the same design (64%) or is always new designed (36%). - Product order is based on experience (50%) or established (50%) by: possibilities of contamination, temperature of the oven, packaging, capacity, delivery time. - Production plan is adjusted on the basis of realisation (91%), and used for adjustment of the long-term plan (57%).	- Design of production plan is always the same (100%). - Product order is established (91%) by: temperature of the oven, baking time, types of dough, cutting, packaging, delivery time, number of changing equipment - Production plan is adjusted on the basis of realisation (81%), and used for adjustment of the long-term plan (45%).	- Design of production plan is always the same (100%). - Product order is established (80%) by: possibilities of contamination, temperature of the oven, baking time, types of dough, specific product requirements, cutting, packaging, capacity, number of times of cleaning, number of changing equipment. - Integration of data in an information system. - Production plan is adjusted on the basis of realisation and used for adjustment of the long-term plan (70%).
Control of execution of production tasks	- Product quality evaluated by supervision (100%). - Procedures are improved if necessary (54%) after evaluation (31%).	- Product quality evaluated by supervision (57%) and product and process control (36%). - Procedures are improved if necessary after evaluation (50%).	- Product quality evaluated by product and process control (64%). - Procedures are improved if necessary (91%) after evaluation (55%).	- Product quality evaluated by product and process control (80%). - Procedures are improved if necessary after evaluation (80%).

Table 7.4 shows in detail the interdependency between degree of automation and level of quality management activities.

Industrial bakeries used mainly a long-term strategy, which was evaluated on long-term aspects or aspects like quality policy, certification, market situation. They purchased raw materials not only by themselves but also via their trading company. For “planning of production”, industrial bakeries established their product order. They used the evaluation of the production plan for improvement of the long-term plan. They communicated by consultation when shifts change. Industrial bakeries evaluated product quality by product and process control. They improved their procedures after evaluation.

Non-industrial bakeries performed the quality management activities on a lower level. They used a simple plan comparable with the production plan, which was evaluated on the amount of produced products. They purchased raw materials by themselves. For “planning of production”, they established their product order or it was based on experience. Evaluation of the production plan was not used to improve the production plan in stead of the long-term plan. Most non-industrial bakeries produced without shifts. They evaluated product quality by supervision, and did not improve their procedures after evaluation.

In conclusion, industrial bakeries performed a higher level of quality management activities due to their long-term perspective and improvement. Non-industrial bakeries performed a lower level due to less evaluation and improvement and based their activities on experience.

7.3.4 Type of product groups

The last classification was based on type of product groups. Table 7.1 shows that the bakeries were classified in the subgroups: bakeries that produce bread, confectionery, a mix of bread and confectionery (i.e. mixed bakeries), and biscuits.

Table 7.1 shows that most bakeries produced a mix of bread and confectionery (N=22). Only five bakeries produced biscuits, but they revealed significant differences. The subgroups of bakeries differed significantly in level of “supply control” and “control of execution of production tasks”. Especially confectionery and biscuit bakeries performed these activities on a higher level. Bread bakeries performed “supply control” on a lower level, while mixed bakeries performed “control of execution of production tasks” on a lower level.

Table 7.4 Differences in quality management activities within subgroups of bakeries classified according to degree of automation.

% = Percentage of bakeries within a subgroup that performs that level of the quality management activity, explained per aspects of the quality management activity.

Quality management activities	**Industrial**	**Non-industrial**
Control of strategy	- A relatively long-term strategy (1 month to 5 years) (65%). - Evaluation on long-term aspects (42%) or aspects like quality policy, certification, investments, prognoses, market situation, product development, volumes, employees, and supply of raw materials (35%). Improvement of long-term plan.	- A simple long-term plan (<1 week) based on production process (64%), comparable with production plan. - Evaluation on the amount of produced products (60%).
Allocation of supplying raw materials	- Purchase of raw materials by bakery itself (69%) or via trading company (16%).	- Purchase of raw materials by bakery itself (95%).
Planning of production	- Product order is established (81%) by: possibilities of contamination, temperature of the oven, types of dough, specific product requirements, packaging, number of times of cleaning, number of changing equipment. - Production plan is adjusted on the basis of realisation (92%) and used for adjustment of the long-term plan (65%).	- Product order is based on experience (55%) or established (41%) by: possibilities of contamination, temperature of the oven, baking time, delivery time. - Production plan is adjusted on the basis of realisation (68%) and used for adjustment of the long-term plan (23%) or not adjusted (32%).
Control of execution of production tasks	- Communication for changing shifts by consultation (90%). - Product quality evaluated by product and process control (65%) or supervision (27%). - Procedures are improved after evaluation (65%).	- Communication for changing shifts by consultation (36%) or no shifts (55%). - Product quality evaluated by supervision (86%). - Procedures are improved after evaluation (32%) or are not improved (50%).

Table 7.5 shows in detail the interdependency between type of product group and level of quality management activities.

Confectionery and biscuits bakeries performed both “supply control” and “control of execution of production tasks” on a higher level. They ordered raw materials mainly at the same time and used also contracts for delivering raw materials frequently. They selected suppliers mainly on criteria. One or more unchanging persons performed supervision of production tasks. Confectionery bakeries evaluated product quality by supervision, and biscuits and bread bakeries by product and process control. Most confectionery, bread and biscuits bakeries improved procedures after evaluation.

Bread bakeries performed “supply control” on a lower level than other bakeries (Table 7.1). Table 7.4 shows that they ordered raw materials mainly at the same time but used no contracts. They selected suppliers not mainly on criteria but also within the selection made by a purchase organisation. However, bread bakeries evaluated their raw materials by receiving inspection, analyses and audits in contrast to other bakeries that mainly used a random check.

Mixed bakeries performed “control of execution of production tasks” on a lower level than other bakeries. Several varying persons performed supervision. They instructed their employees by supervision and/or demonstration but used no information. Mixed bakeries evaluated product quality by supervision. They did not improve procedures or did not evaluate procedures before improvement.

In conclusion, confectionery and biscuits bakeries performed a higher quality management due to an unambiguous supervision and a more extensive selection, evaluation and improvement. Bread bakeries performed a lower level of “supply control” due to a less extensive selection of suppliers and ordering of raw materials. Mixed bakeries performed a lower level of “control of execution of production tasks” due to an ambiguous supervision and a less extensive evaluation and improvement.

Table 7.5 Differences in quality management activities within subgroups of bakeries classified according to type of bakery.

% = Percentage of bakeries within a subgroup that performs that level of the quality management activity, explained per aspect of the quality management activity.

Quality management activities	**Bread**	**Confectionery**	**Mixed**	**Biscuits**
Supply control	- Raw materials are always ordered at the same time (50%). - Selection of suppliers is done within selection by purchase organisations (40%) or selection on criteria (40%): product quality, price, delivery time, relation to suppliers, reliability, quality of the products, information about specifications, product quality, and production method, flexibility, application and implementation of QA system. - Raw materials are evaluated by a receiving inspection, analyses and audits (70%).	- Raw materials are always ordered at the same time (45%) or contracts are made (27%). - No selection (36%) or selection of suppliers on criteria (64%): product quality, price, delivery time, reliability, variation in assortment, flexibility. - Selection is based on evaluation of former deliveries, experience by other bakeries, results of tests, information by suppliers and purchase organisation. - Raw materials are evaluated by a random check (55%) or by receiving inspection, analyses and audits (27%).	- Raw materials are always ordered at the same time (55%) or contracts are made (27%). - No selection (36%) or selection of suppliers on criteria (50%): product quality, price, delivery time, application of QA system. - Selection is based on evaluation of former deliveries, experience by other bakeries, results of tests, information by suppliers and purchase organisation. - Raw materials are evaluated by a random check (73%).	- Raw materials are always ordered at the same time (20%) or contracts are made (40%). - Selection of suppliers on criteria (100%): product quality, price, delivery time, reliability, information about specifications, product quality, and production method, flexibility, application and implementation of QA system. - Raw materials are evaluated by a random check (80%).

Continue Table 7.5

Quality management activities	**Bread**	**Confectionery**	**Mixed**	**Biscuits**
Control of execution of production tasks	- Supervision by 1 same person (30%), by more the same persons (30%) or by various persons (40%). - Instruction by demonstration and supervision (100%) and information (50%). - Product quality evaluated by product and process control (80%). - Feedback of results by consultation (80%). - Procedures are improved after evaluation (70%).	- Supervision by 1 same person (45%) or by more the same persons (45%). - Instruction by demonstration and supervision (91%) and information (27%). - Product quality evaluated by supervision (64%). - Feedback of results by consultation (73%). - Procedures are improved after evaluation (55%) or are not improved (36%).	- Supervision by 1 same person (36%) or by various persons (55%). - Instruction by demonstration and supervision (45%) or only demonstration (36%). - Product quality evaluated by supervision (68%). - Feedback of results by consultation (41%), or written (23%) or ad hoc (36%). - Procedures are improved (59%) after evaluation (32%) or are not improved (41%).	- Supervision by 1 same person (60%) or by more the same persons (40%). - Instruction by demonstration and supervision (100%) and information (40%). - Product quality evaluated by product and process control (80%). - Feedback of results by written (60%). - Procedures are improved after evaluation (80%).

7.4 Implications for the bakery sector

7.4.1 Contextual factors and quality management

This study revealed that specific groups of bakeries performed some quality management activities on a lower level than other bakeries. The required level of quality management and contextual factors were interdependent. In literature, only a few relations between quality management and contextual factors were investigated. Ziggers [6] revealed that the number of non-temporary and part-time employees was related to the execution of cultivation of pot-plants. However, Benson *et al.* [7] showed no relationships between company size and quality management. They also suggested that process and product contextual factors have little effect on quality management in manufacturing companies, although product complexity affected service companies. However, other authors did observe positive relationships i.e. between product complexity and vertical integration [8], between number of products and execution of cultivation [6], and between type of industry and delegation, participation, and measurement in distribution [9].

7.4.2 Improvement of production quality

A previous study showed that the level of quality management and production quality are interdependent [10]. We assume that this relation will also be found for the differences within the groups, although we could not investigate the differences in production quality per classification due to unavailability of data. The interdependency between level of quality management and production quality shows that bakeries should improve their quality management activities to increase the level of production quality. However, this study revealed that a lower level of food quality management does not necessarily lead to a lower production quality, because several companies with a low food quality management executed activities based on experience.

7.4.3 Application of IMAQE-Food

In practice, established QA systems have a generic approach. They focus on processes, products, linkages of the supply chain, or company size. QA systems are often combined, because each QA system covers different aspects of the complete quality system [1, 11-14]. However, the implementation of QA systems is still not optimal [15-20].

Due to the interdependency between contextual factors and quality management, it is of major importance that contextual factors are integrated into implementation methods of quality management. Van der Bij and Broekhuis [21] also propose this contingency approach for contextual factors and quality systems.
However, development of new QA systems can not be suitable for specific situations of each organisation. QA systems should be generic and transparent in order to inspect and certify a QA system in various organisations and sectors. Thus, the implementation method should be optimal for a group of companies by selecting generic methods and each company should adjust generic QA systems to their specific situation. This results in a better application whereas an unambiguous inspection and certification method is also possible.
Jonker [22] proposes to investigate the implementation of integrated QA systems in small and medium companies due to their non-specialised functions in an informal organisation, whereas individual QA systems could be more useful for large companies due to specialised functions. However, to our opinion the classification of companies should be studied in a broader perspective; relevant contextual factors should be considered.
IMAQE-Food can be used to identify the contextual factors that should be integrated into implementation methods. Moreover, the instrument can identify which quality management activities are important for a specific situation to obtain an optimal production quality. IMAQE-Food can also be used to analyse which quality management activities are improved by a specific QA system. Finally, IMAQE-Food can also be detailed to measure effectiveness of established QA systems.

7.4.4 Future research

Future research should analyse the interdependency between level of food quality management and production quality to measure the effectiveness of quality management activities for the subgroups. This will show which quality management activities should be improved and/or added by the subgroups of bakeries. Moreover, insight will be obtained which effective quality management activities will be improved by applying a specific QA system.
Experience can replace the need for a high level of quality management to obtain an appropriate quality production. In IMAQE-Food, experience is a part of food quality management. The relation between experience and production quality can be quantitatively

studied by the addition of experience as an indicator of contextual factors in IMAQE-Food. Scenarios can be used to measure the intangible experience.

Due to the interdependency between contextual factors and quality management, it is of major importance that contextual factors are integrated into implementation methods of quality management. In successive research implementation methods can be developed that uses a contingency approach. This will improve the applicability and can result in an effective quality management and an optimal production quality.

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8

General discussion

8.1 Research motives

Food quality management is of major importance in the agri-food sector. It is complicated because it involves both complex characteristics of food and effects of human behaviour. Therefore, food production systems need both technological and managerial measures (Chapter 1). Food manufacturers use various QA systems to assure food quality. However, these systems focus on different aspects of a complete quality system (Chapter 1, 2, 3, 4). The different situations of food companies and the specific characteristics of food production require a selection of appropriate QA systems and an effective implementation. Therefore, the food sector needs an instrument that measures effectiveness. A broad range of instruments has been developed to measure performance of quality management (Chapter 2). However, they do not measure effectiveness of food quality management, whereas many quality costs are spend to obtain an appropriate quality level. The aim of this thesis is to develop and validate an instrument that measures effectiveness of food quality management.

8.2 Methodology

Our instrument IMAQE-Food has been developed and validated by a structured procedure. A conceptual model was developed (Chapter 3) and was translated into quantifiable performance measurement indicators for the bakery sector by literature research, qualitative research, delphi sessions, and quantitative research (Chapter 4). These indicators of IMAQE-Food were tested on reliability, validity and generalisability (Chapter 5).

IMAQE-Food is a reliable and valid instrument that measures the relations between quality management, production quality, and contextual factors. The instrument is generic for the bakery sector and is expected to be applicable in other food sectors (Chapter 5). IMAQE-Food has been used to investigate effectiveness of food quality management in the bakery sector (Chapter 6) and interdependency between context of bakeries and level of food quality management (Chapter 7).

IMAQE-Food uses the techno-managerial approach. Every construct of food quality management consists of items that measure both the extent to which technological and managerial aspects are executed or used. The integration of technology and management is of major importance in food quality management due to the specific characteristics of food production (Chapter 1) and applicability in practice. Companies can recognise practical situations in the integrated approach, which leads to commitment and a higher motivation for improvement of their food quality management.

8.3 What are the opportunities of IMAQE-Food?

IMAQE-Food can be used for several objectives: measuring effectiveness of food quality management, assessment of production quality, assessing interdependency between contextual factors and production quality, assessment of food quality management, and analysing appropriateness of QA systems in increasing the level of quality management.

8.3.1 Measuring effectiveness of food quality management

IMAQE-Food can be used for measuring effectiveness of food quality management activities to obtain an appropriate production quality within the context of the organisation (Chapter 6). Effectiveness is measured by analysis of relations between production quality, quality management and contextual factors. Food quality management is considered to be effective when a higher level of quality management was related to a higher production quality. Moreover, quality management is also effective when contextual factors and quality management were related to a higher production quality, whereas contextual factors without quality management were related to a lower production quality.

Effectiveness can be assessed for individual companies and for a group of companies by evaluation of the level of quality management and production quality. On the basis of this assessment, companies can improve production quality by improving and/or adding quality management activities that are suitable to their contextual situation. Within a group of companies, benchmarking can be used to compare the level of quality management activities and production quality. Differences in effectiveness may be an indication for how an effective food quality management can be achieved to increase production quality.

Insight in effectiveness supports food manufacturers in deciding which system is most suitable and how to achieve their objectives. This can result in a higher production quality, compliance with expectations of consumers, regaining and maintaining trust of consumers in food production quality, and maintaining and improving competitiveness of food manufacturers.

8.3.2 Assessment of production quality

IMAQE-Food can also be used to measure production quality in order to determine quality performance and how this can be improved (Chapter 2, 3, 4, 6). Indicators for production quality in the bakery sector were: percentage of rejected products; results of legislative evaluations; results of technical evaluations; and percentage of complaints about respectively product quality and availability. This study showed that bakeries did not record and collect sufficient data to develop one indicator for production quality in a broad perspective for the bakery sector (Chapter 4, 5, 6). Only "results of legislative evaluation" was measured by most bakeries (94%); the availability of the other four indicators differed in a range from 54-71% of the bakeries. Data about costs were obtained from only 48% of the bakeries. An appropriate data collection will enable the assessment of effectiveness by IMAQE-Food.
Data collection also requires execution of more activities resulting in higher costs. However, data show which failures are made in the production process, which gives insight in failure costs. In practice, failure costs appear to be higher than manufacturers expect [1, 2] and should be lowered. Prevention (e.g. quality assurance, specifications) and/or inspection (e.g. receiving inspection, process control, collection of data) decrease production failures (e.g. waste, rework, claims) resulting in a higher product quality and availability, and/or lower costs. Therefore, companies should determine an optimum of quality performance and quality costs i.e. prevention, inspection and failure costs [3]. The optimum situation for a food manufacturer is not necessarily the quality performance with the lowest quality costs, because high requirements on production quality need more prevention than what will be concluded from quality costs. Due to the higher requirements by consumers, customers and legislation, food manufacturers should prevent failures of food safety, product quality, availability and environmental aspects. Therefore, investing in quality assurance and quality management is of major importance. The optimum between quality performance and quality costs is dependent on factors like product type, company size, size of the product assortment [1]. IMAQE-Food can be used for considering the optimum situation between quality performance and quality costs.

8.3.3 Assessing interdependency between contextual factors and production quality

Another application of IMAQE-Food is gaining insight in interdependency between contextual factors and production quality to determine the required level of food quality management (Chapter 5, 6). On the basis of insight in these contextual factors, food manufacturers can select suitable quality management activities for their specific situation in order to obtain effective quality management.

Each bakery in our sample had a different set of contextual factors with respect to organisation, production process, and product assortment (Chapter 6). In practice, bakeries are often distinguished according to four contextual factors: (1) type of QA systems, (2) organisational size, (3) degree of automation, (4) type of product groups. These contextual factors revealed differences in the level of five quality management activities i.e. “control of strategy”, “allocation of supplying raw materials”, “supply control”, “planning of production”, and “control of execution of production tasks” (Chapter 7). If the interdependency between these contextual factors, quality management activities and production quality are studied, the effectiveness of these activities for the specific groups can be investigated.

Differences between companies are commonly known (Chapter 3), however it was not studied how effective food quality management could be achieved. IMAQE-Food reveals quality management activities that are required to obtain an optimal production quality within the context of the organisation. This can be used to develop effective QA systems and implementation methods for companies with a specific context, which makes them better applicable and useful. This will decrease the gap between the actual context of the company and QA systems.

In addition, IMAQE-Food can also be used for measuring interdependency between diversity in food supply chains, quality management and production quality (Chapter 3). In IMAQE-Food typical performance measurement indicators for complexity of the supply chain are enclosed like number of linkages, relationships and co-ordination between linkages, and characteristics of food production [4]. Supply chain performance should consist of the total of performances of individual linkages and an added value due to co-operation [5, 6]. This will show which partner takes advantage of the co-operation and how performance can be improved.

8.3.4 Assessment of food quality management

IMAQE-Food can be used to measure the level of food quality management (Chapter 4, 5). On the basis of the assessment, food manufacturers can decide to add or improve quality management activities. The relation between food quality management and production quality shows which quality management activities are effective.

This study revealed that effective quality management activities in the bakery sector were (1) control of strategy, (2) allocation of supplying raw materials, (3) supply control, (4) control of production, (5) control of execution of production tasks, (6) control of receiving orders, and (7) planning of distribution (Chapter 6). These quality management activities were effective in improving results of legislative and technical evaluation, and reducing percentage of rejected products and percentage of complaints about respectively product quality and availability.

Although IMAQE-Food can assess effectiveness, for some bakeries a relation between a lower level of quality management and a higher production quality was found due to presence of experience (Chapter 6, 7).

IMAQE-Food also evaluates quality management on its flexibility (Chapter 4). A company needs flexibility to anticipate unexpected or unusual situations and to comply with customer requirements. A certain extent of bureaucratic system is necessary to record methods, tasks and responsibilities in procedures. However, registration and working according to procedures can also be carried out too far, leading to an ineffective bureaucracy and a too formal organisation. Therefore, companies should find a balance between flexibility and bureaucracy, and between an informal and a formal organisation [7, 8]. For this purpose, a strategy should be developed which establishes the required quality behaviour and administrative conditions.

8.3.5 Analysis of suitable quality assurance systems

IMAQE-Food can be used to analyse the appropriateness of QA systems in increasing level of specific quality management activities. This study showed differences in interdependency between level of quality management activities and QA systems (Chapter 7).

IMAQE-Food can basically be used to measure effectiveness of these QA systems. For this purpose, IMAQE-Food should be detailed, because it has been developed for food quality systems in the broadest sense. Quality management should consist of relevant quality management activities of the QA system (e.g. risk analysis, verification), whereas production quality should contain indicators that measure the objective of the QA system (e.g. food safety) [9].

Food manufacturers have to decide which QA systems are most suitable for their specific situation. However, this decision is not completely voluntary due to external requirements by legislation and customers (Chapter 3). Legislation requires application and implementation of a food safety system like HACCP. Moreover, an increased number of customers in supply chains requires application of QA systems by their suppliers: e.g. farmers require GMP certified animal feed, and supermarkets require BRC and EUREP-GAP.

8.4 Application of IMAQE-Food in other food sectors

IMAQE-Food was considered to be generic for the bakery sector, whereas only small modifications of indicators were needed to make the instrument suitable for the vegetable and fruit-processing sector (Chapter 5). IMAQE-Food is expected to be applicable in other food sectors as well after specific modifications. For example, animal sectors have to manage other factors to obtain desired quality than for sectors of plant origin. In the last decade more food incidents occurred in supply chains of animal origin than in sectors of plant origin, indicating that the factors are probably more critical for food safety. Therefore, it is expected that IMAQE-Food will require considerable modifications to be applicable for animal sectors. The contextual factors should also include production characteristics in other linkages of the supply chain, because aspects like feed, welfare, hereditary, pre-slaughter handling and transport influence production quality of animal products [8, 10]. Quality management should consist of extra activities like exchanging information and inspection to know how quality is controlled in other linkages to minimise risk of contamination and growth of micro-organisms, residues and contaminants. In contrast to bakeries and vegetable and fruit processors, sectors of meat products collect, record and exchange more information about production quality by identification and registration systems that are integrated through the supply chain [11, 12]. More available data will increase validity and reliability of the instrument and will result in a better assessment of the effectiveness.

8.5 Conclusion

IMAQE-Food is a reliable and valid instrument that enables measuring effectiveness of food quality management in the bakery sector. The insights of this study support food manufacturers in deciding which system is most suitable for their situation and how their objectives have to be achieved. Policy makers can use this information to improve established QA systems and to develop effective implementation methods. This can result in effective quality management and an increased production quality, which will lead to more confidence of consumers in food production quality and improving competitiveness of food manufacturers. The developed methodology will also support other researchers to develop similar instruments.

8.6 Recommendations

8.6.1 Recommendations for research

IMAQE-Food could serve as a basis for other applications in the agri-food sector such as:

- specifying IMAQE-Food for other food sectors (e.g. animal production). For this purpose, qualitative research should be done to verify relevancy of current indicators for the specific sector, and indicators should be evaluated on reliability and validity using the structured procedure (Chapter 5).
- studying the effect of complexity of the food supply chain on food quality management. IMAQE-Food should be extended with the additional element “complexity of the supply chain” as a new element (Chapter 3). Current indicators have to be further specified and validated. This study will provide insight in why food quality systems of several supply chains differ in their realisation of the production quality and how they can be improved.
- measuring effectiveness of QA systems. IMAQE-Food should be detailed for specific conditions of QA systems.

For food quality management an integrated approach of technological and managerial aspects is of major importance. The interdependency between production quality and technological and managerial aspects of food quality management can be further studied to support food manufacturers in making decisions if activities should be improved regarding quality behaviour and administrative conditions and/or food characteristics and technological conditions. For this purpose, new constructs should be developed.

8.6.2 Recommendations for bakeries

Bakeries should collect, record and analyse more data about production quality to improve their food quality management and to enable assessment of effectiveness. Knowledge about quality performance and effectiveness gives insight in how production quality can be improved.

QA systems focus on different aspects of a complete quality system and differ in several aspects. Bakeries should combine specific elements of these QA systems depending on their contextual factors; each company should adjust the generic QA systems to their specific situation.

Bakeries can use IMAQE-Food for:

- measuring effectiveness of food quality management;
- assessment of production quality;
- gaining insight in interdependency between contextual factors and production quality;
- assessment of level of food quality management;
- analysing appropriateness of QA systems to their contextual situation.

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Appendix: Questionnaire

Section I: Background information about respondent and company

Name company : …………………………………………………………….
Name respondent : …………………………………………………………….
Function : …………………………………………………………….
To be employed from (dd-mm-yy) : …………………………………………………………….
E-mail address : …………………………………………………………….

Organisational structure

1. Could you show your organisational structure?
   How many levels does your organisational structure consist of?
   ……………… levels

2. What is the location of the quality manager?
   - ❑ No quality manager
   - ❑ Production manager
   - ❑ Quality assurance department
   - ❑ Staff department
   - ❑ Individual department
   - ❑ Part of the production department
   - ❑ ……

3. Does external people support your organisation?
   - ❑ No
   - ❑ Yes, support on:
     - ❑ QA system
       - ❑ Advise
       - ❑ Development / design
       - ❑ Implementation
     - ❑ Analyses
     - ❑ Hygienic evaluation
     - ❑ Maintenance
     - ❑ Cleaning and disinfecting
     - ❑ Pest control
     - ❑ Improvement of production lines
     - ❑ ……

QA systems

4. A. Has a QA system been implemented?
   - ❑ No
   - ❑ Yes,
     - ❑ GMP
     - ❑ HACCP
     - ❑ Hygiene code
     - ❑ Process control plan for Meat products (RVV)
     - ❑ ISO 9001
     - ❑ ISO 9002
     - ❑ ISO 9003
     - ❑ ISO 9004
     - ❑ ISO 9001:2000
     - ❑ ISO 14001
     - ❑ BRC
     - ❑ TQM (e.g. Dutch Quality Award, EFQM)
     - ❑ Health & Safety at Work
     - ❑ AMvB
     - ❑ Quality, Health & Safety at Work, and Environment
     - ❑ ……

4. B. Where is this system based on?
   - ❑ Norms
   - ❑ Processes

4. C. Which level of details does the QA system have?
   - ❑ Generic
   - ❑ Detailed

5. Has the QA system been certified?
   - ❑ No
   - ❑ Yes,
     System: …………………. Certified by: …………………….

6. Who has developed the QA system?
   - ❑ Director
   - ❑ QA manager
   - ❑ Product expert
   - ❑ Process expert
   - ❑ Technologist
   - ❑ Production employees
   - ❑ Packaging expert
   - ❑ Distribution expert
   - ❑ Customers
   - ❑ External organisation
   - ❑ Students
   - ❑ ……

7. Who has implemented the QA system?
   - ❑ Director
   - ❑ QA manager
   - ❑ Product expert
   - ❑ Process expert
   - ❑ Technologist
   - ❑ Production employees
   - ❑ Packaging expert
   - ❑ Distribution expert
   - ❑ Customers
   - ❑ External organisation
   - ❑ Students
   - ❑ ……

8. A. How has the QA system been implemented?
   - ❑ Once
   - ❑ In phases: ……………………………………

8. B. From which date has the QA system actually been implemented in practice?
   i.e. date from when all employees in the organisation really work according to the entire QA system.
   ………….

9. Who does inspect your organisation (extern)?
   - ❑ Keuringsdienst van Waren
   - ❑ RVV
   - ❑ Regional authorities
   - ❑ Certification / Inspection agency
   - ❑ Environment inspection
   - ❑ Voluntary inspection, like by NBC
   - ❑ Customers
   - ❑ Consumer organisations
   - ❑ ……

Mission

10. Order following dimensions according to relevancy for your company:
   (1 = most relevant, 6 = less relevant):
   - …… product quality: Compliance with product specifications and requirements of customers.
   - …… availability: Deliverance of appropriate quantity of products at the appropriate place and time.
   - …… costs: Costs incurred during purchase, production and sales.
   - …… flexibility: Ability of an organisation to respond to new situations.
   - …… reliability: Ability of an organisation to fulfil its commitments.
   - …… service: Degree of services which are provided to customers besides the delivery of the ordered product.

11. Does your company co-operate with a specific trade company or co-operation?
    - ❑ No
    - ❑ Yes,
        - ❑ Bake Five
        - ❑ Bakery Concepts:
            - ❑ Alles even lekker
            - ❑ De Gebackerij
            - ❑ Kern Bakkers
        - ❑ Bakkersland
        - ❑ BEKO-Benelux
        - ❑ CIVOBA
        - ❑ Echte Bakkers Gilde
        - ❑ Heerlijk & Heerlijk (MCB)
        - ❑ Kamps:
            - ❑ Bakker Bart Food Group
            - ❑ Bakker Bart
            - ❑ Bakerstreet
            - ❑ ‘t Stoepje
            - ❑ Quality Bakers
        - ❑ Top Bakkers
        - ❑ Verbisko
        - ❑ Warme bakkers
        - ❑ ……

12. Which outlets does your company have?
    - ❑ Petrol station
    - ❑ Bread and confectionery bakeries
    - ❑ Own store(s)
    - ❑ Own deliverance, delivery districts
    - ❑ Market stall holders
    - ❑ Driving stores
    - ❑ Independent bread merchants
    - ❑ Large customers:
        - ❑ Institutes, hotel and catering industry, canteens
        - ❑ In store bakeries
        - ❑ Supermarkets
        - ❑ Department stores
    - ❑ ……

Section II: Contextual factors

Complexity of the organisation

1. How many employees are involved in your company?
   …………… employees
   …………… part timers
   …………… temporary employees
   …………… shifts (in production) in a day

2. How many affiliates are part of your organisation?
   …………… affiliates (including stores, production, etc.)
   …………… affiliates with a department of production

3. How many suppliers of raw materials are co-operating with your organisation?
   …………… suppliers (e.g. supply co-operations, individual suppliers)

4. A. How many products are purchased by your organisation?
   …………… final products
   …………… half fabricates

4. B. How many final products are sold by your organisation?
   …………… final products

5. To how many delivery points (i.e. locations where products are delivered e.g. store, affiliate of a supermarket, a centre for distribution) are you delivering?
   …………… delivery points

6. How many customers (exclusive sales to consumers via own shop) do you have?
…………… customers

7. How many products do you sell to customers?
…………… products to customers
…………… products to consumers via own shop

8. To how many co-operations (i.e. co-operations between bakeries or between a bakery and other linkages of the supply chain, including exchange resulting in advantages for each) are you participating?
…………… horizontal co-operations (with other bakeries like Bakkersland, Bake Five)
…………… vertical co-operations (with other linkages like grower, supplier, organisation of supply, customer)

Complexity of the production process

9. How many production lines do you use for production?
…………… production lines
No production lines? Go to question 12.

10. What is the average number of times that a production line is changed (change of parameters e.g. due to change of a product group) in a day?
…………… times of changing in a day

11. What is the average number of times that a production line is adjusted (adjustment of parameters e.g. due to variations of raw materials) in a day?
…………… times of adjustments in a day

11. Which process steps are used for the production of a specific product group?

Product group	**Products**	**Process steps**
Bread and bake-off	❑ Bread	❑ Purchase of half fabricates ❑ Rising with a rest period ❑ Cutting
	❑ Prebaked bread	❑ Purchase of half fabricates ❑ Freezing ❑ Cooling ❑ Atmosphere packaging
	❑ Bake-off (pieces of dough)	❑ Atmosphere packaging
	❑ Spreaded bread	
	❑ Repacked bread	
Confectionery ((whipped) cream, fresh fruit)	❑ Crust dough / fruit pie	❑ Purchase of half fabricates
	❑ Flan	❑ Purchase of half fabricates ❑ Freezing
	❑ Other confectionery	❑ Purchase of half fabricates ❑ Freezing
Biscuits (filled, cake, cookies)	❑ Fresh	❑ Purchase of half fabricates ❑ Storage of butter dough
	❑ Long shelf life	❑ Purchase of half fabricates ❑ Freezing ❑ Atmosphere packaging ❑ Storage of butter dough
	❑ Bake-off	❑ Storage of butter dough
	❑ Repacked	

Product group	Products	Process steps
Filled snacks (meat, sausage, pizza, chicken, spicy, bacon cheese, apple, cream, and comparable products)	❑ Crust dough / turned risen dough	❑ Purchase of half fabricates ❑ Freezing ❑ In between storage
	❑ Yeast dough	❑ Purchase of half fabricates ❑ Freezing ❑ In between storage
	❑ Bake-off	❑ Freezing ❑ Atmosphere packaging
	❑ Repacked	
Bonbons and chocolate products	❑ Chocolate	❑ In between storage
	❑ Bonbons	❑ In between storage
	❑ Repacked	

12. What is the degree of automation of your production process?
    A production process is automated when no physical operations are executed.

Product group	Process step	Automated	Manual
Bread and bake-off	Supply of flour		
	Mixing		
	Division of dough		
	Preparing / filling of tins		
	Cutting / decoration		
	Transport of filled baking tins		
	Post rising	Transport	
	Baking	Mechanical moving ovens	Non-mechanical moving ovens
	Removing bread from tin		
	Transport of tins		
	Cooling of bread	Ventilators	
	Cutting / packaging		
	Putting in boxes		
	Preloading		
Confectionery	Preparation of baked half fabricates		
	Preparation of (whipped) cream, sugar containing half fabricates		
	Manufacturing of confectionery		
	Transport of confectionery		
	Preparation of dough for flan		
	Preparation of fruit filling, cream, rice pudding		
	Manufacturing of flan		
	Transport of flan		
	Cooling		
	Packaging		

Product group	Process step	Automated	Manual
Biscuits	Supply of flour		
	Moulding		
	Shaping / decoration of dough		
	Baking		
	Cooling		
	Packaging		
Filled snacks	Preparation of dough		
	Preparation of filling		
	Manufacturing of snacks		
	Cooling		
	Packaging		
Bonbons and chocolate products	Manufacturing of interior		
	Preparation of chocolate		
	Manufacturing of bonbons		
	Cooling		
	Packaging		

Complexity of the product assortment

13. How many recipes does your organisation produce?
    Bread: number of recipes is the number of types of dough with different decorations (e.g. sesame). This can be the same as the number of types of dough. For example, a type of dough with six decorations has six recipes.

Product group	Number of recipes
Bread (loaf of bread, buns, baguette)	
Filled bread	
Bake-off (atmosphere packaged bread, cooled prebaked bread and (un)risen pieces of dough)	
Confectionery ((whipped) cream, fresh fruit)	
Filled biscuits etc.	
Cake	
Cookies	
Filled snacks (meat, sausage, pizza, chicken, spicy, bacon cheese, apple, cream, and comparable products)	
Spreaded bread	
Bonbons and chocolate products	

14. How many final products are stored?
    This involves all final products that are stored for minimal one day before selling or distribution.
    …………… final products that are stored for minimal one day
    …………… final products that are directly delivered or sold

Section III: Quality Management

In this part of the questionnaire questions are asked about several plans (strategy (i.e. creation of resources and capacity), purchase plan, production plan, distribution plan. Besides, some questions are about the execution of production tasks. These aspects can be executed from simple to complex.

Strategy

In the part Strategy questions are asked about the long-term plan which describes when and which products and in which amount will be produced.

Formulation

1. Do you formulate a long-term plan?
   - ❑ No, no long-term plan
   - ❑ Yes,
     - ❑ Day
     - ❑ Week
     - ❑ 1-3 Months
     - ❑ Year

2. Is the long-term plan recorded?
   - ❑ No
   - ❑ Yes,
     - ❑ Planning system
     - ❑ Printed
     - ❑ Written

3. How do you plan for a long term?
   - ❑ Planning is always different.
   - ❑ Planning is always the same.
   - ❑ Planning is approximately the same, although major aspects will be changed if required.

4. To which extent do you plan at the same time?
   - ❑ The planning is established at different times, which results in various throughput times.
   - ❑ The planning is mostly established at the same time.
   - ❑ The planning is always established at a fixed time and has the same throughput time.

5. Which information is used for the strategy?
   - ❑ Former strategies
   - ❑ Plans of related co-operative organisations or trading companies
   - ❑ Strategic objectives, like investments, acquiring personnel, certification, co-operation, advertising, participation to expositions, adjustments of the product assortment.
   - ❑ Data of turnover
   - ❑ Delivery times of raw materials
   - ❑ Availability of raw materials
   - ❑ Promotions of suppliers
   - ❑ Promotions of customers
   - ❑ Orders
   - ❑ Previous orders
   - ❑ Level of storage
   - ❑ Forecast of customers
   - ❑ Orders by colleagues due to failures
   - ❑ Data of capacity
   - ❑ ……

6. Which aspects are included in the strategy?
   - ❑ Difference between beginning and end of the week
   - ❑ Holiday
   - ❑ Weather
   - ❑ Type of consumer
   - ❑ Maintenance, cleaning
   - ❑ Intermission of production
   - ❑ Audits
   - ❑ Process improvement
   - ❑ Costs and profits
   - ❑ Capacity (personnel, resources)
   - ❑ Failures
   - ❑ Production time (time of changing, effective production time)
   - ❑ Product order
   - ❑ Training and education
   - ❑ Innovation by other linkages of the supply chain
   - ❑ Planning by other linkages of the supply chain
   - ❑ Promotions by other linkages of the supply chain
   - ❑ Requirements by other linkages of the supply chain
   - ❑ ……

7. To what extent do you take account of innovations, promotions, and events?
   - ❑ No taking into account.
   - ❑ All aspects that directly influence the production (e.g. weather) are taken into account.
   - ❑ All aspects that directly influence the strategy (e.g. capacity, holidays) are taken into account.
   - ❑ All relevant aspects are taken into account and alternatives are established.

8. To what extent do you use data of previous plans?
   - ❑ A new plan is always established.
   - ❑ Relevant aspects of previous plans are taken into account.
   - ❑ The new plan is entirely established on the basis of previous plans.

9. A. Who is involved in the strategy?
   - ❑ Internal:
     - ❑ Director
     - ❑ Factory manager
     - ❑ Production manager
     - ❑ Department of production
     - ❑ Department of packaging
     - ❑ Department of warehousing
     - ❑ Department of expedition
     - ❑ Department of planning
     - ❑ Department of purchase
     - ❑ Department of sales
     - ❑ Quality manager
     - ❑ Trading company
     - ❑ ……
   - ❑ External:
     - ❑ Institutes
     - ❑ Consultants
     - ❑ Study clubs
     - ❑ Colleagues
     - ❑ Branch organisation of the industry
     - ❑ Other linkages of the supply chain
     - ❑ ……

9. B. To what extent are employees involved in the establishment of the strategy?
   - ❑ Several employees are sometimes involved.
   - ❑ One employee is always involved.
   - ❑ One employee is always involved, others sometimes.
   - ❑ All employees are always involved, or several persons are always involved whereas others sometimes.

Progression

10. A. Is the realisation of the strategy evaluated?
   - ❑ No
   - ❑ Yes

10. B. How is the realisation of the strategy evaluated?
    - ❑ Realisation of a number of aspects.
    - ❑ Realisation of all aspects that directly influence the production (e.g. product quality).
    - ❑ Realisation of all aspects that directly influence the strategy (capacity, sales).
    - ❑ Realisation of all relevant aspects. If required, the strategy will be adjusted or alternatives will be used.

11. To what extent are other plans established on the basis of the strategy?
    - ❑ Strategy is only used for establishment of required resources.
    - ❑ Strategy is also used for establishment of the operational production planning, purchase plan, sales plan, etc.

Supply of raw materials

In this part the questions are about selection and evaluation of suppliers, and ordering and evaluation of raw materials.

Ordering of raw materials

12. Do you buy raw materials by yourself?
    - ❑ No, purchase is executed by the trading company
    - ❑ Yes, partly by our organisation
    - ❑ Yes, completely by our organisation

13. A. Do you order raw materials by yourself?
    - ❑ No
    - ❑ Yes

13. B. To what extent do you order raw materials regularly?
    - ❑ The moment changes every time on basis of the information system of the supply organisation, level of storage or sales of final products.
    - ❑ Raw materials are always ordered at the same time.
    - ❑ Some raw materials are always ordered at the same time, other are ordered once on the basis of a contract and are delivered with a certain frequency.
    - ❑ Raw materials are ordered once on the basis of a contract and are delivered with a certain frequency.

14. What information is available before ordering?
    - ❑ Former orders
    - ❑ Data of order
    - ❑ Production plan
    - ❑ Long-term production plan
    - ❑ Production values from last year
    - ❑ Data of stock of raw materials
    - ❑ Data of stock of products
    - ❑ Specifications of raw materials
    - ❑ Storage conditions
    - ❑ List of suitable suppliers (like Ingrediëntenwijzer, preferred suppliers)
    - ❑ Data of complaints about suppliers
    - ❑ Price list
    - ❑ List of delivery times
    - ❑ List of batch sizes, packaging units
    - ❑ Price reductions by suppliers
    - ❑ Price reductions by customers
    - ❑ Capacity of distribution
    - ❑ Data of other bakeries
    - ❑ Journals
    - ❑ Information of institutes, like NBC
    - ❑ ……

15. To what extent do you anticipate on situations in which raw materials are not delivered in time?
    - ❑ No anticipation. In such case we are not able to produce. Other bakeries are contacted to purchase raw materials or to order products, or the supplier solves the problem at that moment, or on the spot another supplier is searched for who can deliver.
    - ❑ Other suppliers have been selected beforehand. These can be appealed to when suppliers are not able to deliver. Dependent on the situation raw materials can or cannot be delivered
    - ❑ Raw materials are always available: or at suppliers, or at other bakeries or sufficient raw materials are in stock to continue the production. A new agreement is made to deliver at another time.

16. To what extent does the order differ from the long-term plan?
    - ❑ The long-term plan is not used or the order differs often because ordering of raw materials is hardly to plan beforehand.
    - ❑ Sometimes, when suppliers are not able to deliver, when new raw materials are used, change by customers or when new products are developed.
    - ❑ No difference.

Contact with suppliers

17. A. Do you contact suppliers besides ordering?
    - ❑ No
    - ❑ Yes

17. B. To what extent do you contact suppliers besides ordering?
    - ❑ Only with problems
    - ❑ Regular contact
    - ❑ Frequent contact

18. About what kind of aspects do you contact suppliers (besides ordering)?
    - ❑ With problems with respect to production
    - ❑ New possibilities and developments
    - ❑ New possibilities are discussed with suppliers of the purchase organisation
    - ❑ Discussion about complaints
    - ❑ Design of improvement routes
    - ❑ Evaluation of customer satisfaction by suppliers
    - ❑ Development of specific raw materials
    - ❑ Information about specifications of raw materials
    - ❑ Formulation of product specifications
    - ❑ Exchange of information with respect to production method, product quality and application of HACCP
    - ❑ Auditing of suppliers
    - ❑ Design of production plans in consultation with suppliers
    - ❑ Requirements for the suppliers of suppliers are together designed
    - ❑ Co-operation in special offers
    - ❑ Exchange of employees
    - ❑ ……

Selection of suppliers of raw materials

19. A. Do you select your suppliers by yourself?
    - ❑ No, selection is performed by the trading company
    - ❑ Yes, partly
    - ❑ Yes, all suppliers

19. B. How do you select your suppliers?
    - ❑ Purchase via purchase organisation or trading company, or the same suppliers are almost maintained.
    - ❑ Suppliers are selected from a list of suppliers that are selected by the purchase organisation.
    - ❑ Suppliers are evaluated on criteria that influence directly production quality (e.g. price, availability). If necessary, a supplier will be visited and evaluated.

20. Based on which criteria do you select suppliers and raw materials?
    - ❑ Relation with suppliers
    - ❑ Reliability
    - ❑ Service
    - ❑ Product quality (like compliance with legislation e.g. Meelbesluit, microbiological and chemical requirements)
    - ❑ Quality of the application (e.g. baking quality)
    - ❑ Variation in assortment (product and packaging units)
    - ❑ Information about product specifications (e.g. GMO-free)
    - ❑ Information about product quality, production method
    - ❑ Development of specific raw materials
    - ❑ Price
    - ❑ Actions and special offers
    - ❑ Quantity
    - ❑ Delivery time
    - ❑ Delivery frequency
    - ❑ Flexibility (quick delivery)
    - ❑ Neighbourhood of supplier
    - ❑ Margin in capacity
    - ❑ Application of a QA system, like HACCP, ISO
    - ❑ Implementation of a QA system (results of audits)
    - ❑ Positive results of other bakeries
    - ❑ Requirements to suppliers of suppliers
    - ❑ ……

21. What information do you use to select suppliers and raw materials?
    - ❑ Evaluation of former deliveries, complaints
    - ❑ Results of baking tests, demonstrations
    - ❑ List of suppliers, like Ingrediëntenwijzer
    - ❑ Price list
    - ❑ Results of audits
    - ❑ Information of account managers
    - ❑ Image, name in market
    - ❑ Journals, exhibitions
    - ❑ Data of colleagues
    - ❑ Data of customers
    - ❑ Information by suppliers and purchase organisations (BEKO-Benelux, CIVABO)
    - ❑ Information by accreditation agencies, like ISA, Lloyds, etc.
    - ❑ Information by institutes like NBC
    - ❑ Information by branch organisations (NBOV, NVB)
    - ❑ Production plan
    - ❑ Long-term plan
    - ❑ ……

22. To what extent are (new and current) suppliers regularly selected and evaluated?
    - ❑ Suppliers are selected and evaluated every time.
    - ❑ Only new suppliers are selected and evaluated.
    - ❑ If bad experiences or evaluations, the list of suppliers will be adjusted and another supplier will be selected.
    - ❑ If bad experiences or evaluations, an agreement about an improvement method will be developed with the supplier. If no improvements, the list of suppliers will be adjusted and another supplier will be selected.

23. A. Who is involved in selection of suppliers of raw materials?
    - ❑ Internal:
        - ❑ Director
        - ❑ Production manager
        - ❑ Production employees
        - ❑ Planner
        - ❑ Supply department
        - ❑ Sales department
        - ❑ QA manager
        - ❑ Product designer
        - ❑ Trading company
        - ❑ ……
    - ❑ External:
        - ❑ Institutes
        - ❑ Consultants
        - ❑ Student society
        - ❑ Other bakeries
        - ❑ Branch organisation
        - ❑ Customers
        - ❑ ……

23. B. To what extent are employees involved in selection of suppliers of raw materials?
    - ❑ More employees are sometimes involved.
    - ❑ One employee is always involved.
    - ❑ One employee is always involved, other sometimes.
    - ❑ All employees are always involved, or more employees are always involved whereas others sometimes.

Receipt control

24. To what extent are raw materials evaluated?
    - ❑ Raw materials are not evaluated.
    - ❑ Specifications of raw materials are evaluated.
    - ❑ Spot-check procedure (i.e. raw materials are at random evaluated on compliance with specifications and conditions) or acceptance sampling (i.e. after a specific number of products raw materials are evaluated).
    - ❑ 100% Inspection: all delivered raw materials are evaluated.
    - ❑ Receipt control and analyses raw materials are always evaluated on compliance with specifications and conditions. Suppliers are also audited to evaluate registration and performance of the production process.

Agreements with suppliers

25. A. Do you make agreements with suppliers by yourself?
    - ❑ No
    - ❑ Yes, partly
    - ❑ Yes, all suppliers

25. B. How do you make agreements with suppliers?
    - ❑ This varies per order, supplier, product or subject: agreements are sometimes made or sometimes not made.
    - ❑ This varies only at specific situations (e.g. new products, changes of price).
    - ❑ Agreements with the suppliers are always made.

26. Which agreements do you make with suppliers?
    - ❑ Quality of raw materials (including absence of contamination)
    - ❑ Adjustments of products
    - ❑ Information about e.g. product specifications, shelf life
    - ❑ Providing results of audits
    - ❑ Price, bonus
    - ❑ Price reductions
    - ❑ Quantity and batch size
    - ❑ Delivery requirements
    - ❑ Delivery time
    - ❑ Delivery frequency
    - ❑ Delivery location
    - ❑ Key to deliver at night
    - ❑ Agreement about returns
    - ❑ Labelling
    - ❑ Packaging
    - ❑ Guarantees
    - ❑ Agreements about specificity of raw materials
    - ❑ ……

27. Are agreements with suppliers recorded?
    - ❑ No
    - ❑ Yes, partly, i.e.
        - ❑ Information system
        - ❑ Printed
        - ❑ Written
    - ❑ Yes, all suppliers

Order analysis

This part consists of questions about order analysis, evaluation on ability to comply with orders, processing orders and communicate data to department of production planning.

Order analysis

28. Do you produce on order?
    - ❑ No,
        - ❑ Via quotations
        - ❑ Agreements
        - ❑ On stock
        - ❑ On prognoses
        - ❑ ……
    - ❑ Yes, partly on order
    - ❑ Yes, all products on order

29. A. Do you analyse orders?
    - ❑ No
    - ❑ Yes

29. B. To what extent do you analyse orders?
    - ❑ Seldom, only orders of new customers or when failures were made last time.
    - ❑ Sometimes, this is dependent on customer, method of providing orders (fax, computer), or type of order.
    - ❑ Orders are always analysed.

30. What aspects of orders do you analyse?
    - ❑ Possibility to comply with requirements of customers:
        - ❑ Product quality
        - ❑ Availability
        - ❑ Storage and distribution conditions
        - ❑ Delivery time
        - ❑ Quantity
        - ❑ Price
    - ❑ Article number, naming by customer
    - ❑ Price reductions
    - ❑ Time of providing
    - ❑ Consistence of ordering: presence of order, exception of former orders
    - ❑ Customer
    - ❑ Fit in route
    - ❑ ……

31. To what extent do you use data of former orders for evaluation or planning of new orders?
    - ❑ Former orders are not used with the exception of failures of the computer system.
    - ❑ Orders are used to make a temporary plan.
    - ❑ Former and new orders are compared. When last times no required production quality could be delivered or when orders differ, adjustment of the order is discussed with the customer.

32. What information is sued for order analysis?
    - ❑ Product specifications
    - ❑ Process specifications
    - ❑ Data of production plan
    - ❑ Former orders
    - ❑ Data about stock of products
    - ❑ Data about stock of raw materials
    - ❑ Orders, phone lists, fax lists
    - ❑ Price reductions of customers
    - ❑ ……

Order acceptation

33. To what extent are orders accepted?
    - ❑ Each order is accepted.
    - ❑ Standards for acceptation of orders have been established, e.g. time of providing orders, presence of data (number, products), customer. When the production quality can not comply with the order, customer is informed and new agreements are made.

34. Are accepted orders recorded?
    - ❑ No
    - ❑ Yes,
        - ❑ Planning system
        - ❑ Database in computer, printed paper
        - ❑ Written

35. To what extent is anticipated on production plan during order analysis?
    - ❑ No anticipation.
    - ❑ Anticipation on capacity.
    - ❑ Anticipation on capacity and realisation. If necessary, less or more orders will be accepted.

36. A. Who is involved in order acceptation?
    - ❑ Director
    - ❑ Supply department
    - ❑ Production manager
    - ❑ Production employees
    - ❑ Sales department
    - ❑ Planning department
    - ❑ Administration department
    - ❑ ……

36. B. To what extent is employee involved in order acceptation?
    - ❑ More employees are sometimes involved.
    - ❑ One employee is always involved.
    - ❑ One employee is always involved, others sometimes.
    - ❑ All employees are always involved.
    - ❑ More employees are always involved, others sometimes.

37. To what extent are other plans developed on basis of order analysis?
    - ❑ Order analysis is not used for development of other plans.
    - ❑ Production plan, distribution plan or purchase plan are developed on basis of order analysis.

Production plan

This part consists of questions about development of production plan which described what, when, where, and by whom is produced. Production plan contains the production process from storage of raw materials to storage of end products.

Development

38. A. Is a production plan developed?
    - ❑ No
    - ❑ Yes

38. B. To what extent is a production plan developed?
    - ❑ Production plan is always new developed.
    - ❑ Production plan is developed on basis of experience.
    - ❑ Design is mainly the same, but major aspects will be changed if necessary.

39. Which information is used for development of a production plan?
    - ❑ Orders
    - ❑ Level of stored products
    - ❑ Level of stored raw materials
    - ❑ Data about delivery times of raw materials
    - ❑ Price reductions by customers
    - ❑ Former production plans
    - ❑ Long-term plan
    - ❑ Results of former productions (percentage of failures, bottlenecks)
    - ❑ Store plan
    - ❑ Distribution plan
    - ❑ Product specifications
    - ❑ Process specifications
    - ❑ Information of the trading company
    - ❑ Information of other bakeries
    - ❑ Information of institutes
    - ❑ Plans of other linkages of the supply chain
    - ❑ ……

40. On basis of which data is the production plan developed?
    - ❑ Data of orders
    - ❑ Data of stored products
    - ❑ Data of stored raw materials
    - ❑ Delivery requirements
    - ❑ Product order
    - ❑ Process specifications
    - ❑ Priority of activities (production, maintenance, cleaning)
    - ❑ Available capacity (equipment, people)
    - ❑ Delivery time
    - ❑ Production time
    - ❑ Changing time
    - ❑ Organisation of production and storage
    - ❑ Cost price
    - ❑ Customer
    - ❑ ……

41. Is the production plan recorded?
    - ❑ No
    - ❑ Yes,
        - ❑ Planning system
        - ❑ Printed paper
        - ❑ Written paper

** Product order*

42. To what extent do you establish the product order in the production plan?
    - ❑ No establishment.
    - ❑ Product order is based on experience and can change dependent on the situation.
    - ❑ Product order is established, e.g. on basis of type of product. Based on this product order the production plan is developed.

43. Which aspects determine the product order?
    - ❑ Probability on cross-contamination
    - ❑ Specific product requirements (like diet products, gluten-free, free of milk proteins)
    - ❑ Number of failures
    - ❑ Number of times of cleaning
    - ❑ Organisation of production and storage
    - ❑ Number of times changing equipment
    - ❑ Size of product
    - ❑ Preliminary treatment of raw materials (e.g. soak and well of currants)
    - ❑ Types of dough
    - ❑ Rising time
    - ❑ Baking time
    - ❑ Temperature of the oven
    - ❑ Cutting
    - ❑ Packaging
    - ❑ Cooling
    - ❑ Shelf life
    - ❑ Quantity
    - ❑ Capacity (baking tins, oven room, etc.)
    - ❑ Customer
    - ❑ Delivery time of products
    - ❑ Costs
    - ❑ ……

44. Do you anticipate on cross-contamination during production?
   - ❑ No, no anticipation
   - ❑ Yes, by
     - ❑ Temperature
     - ❑ Humidity
     - ❑ High care / low care rooms
     - ❑ Products are separated produced
     - ❑ Separated storage of products
     - ❑ Control of product flow
     - ❑ Reuse of dough: not for all products
     - ❑ Packaging
     - ❑ ……

** Time*

45. In what extent is time determined which is necessary for production?
   - ❑ Not determined.
   - ❑ Time is estimated based on experience, via capacity of equipment or is determined by testing of the production of new products.
   - ❑ Time per employee is recorded. Based on this time, standards are established and adjusted.

46. To what extent are failures and unexpected orders (rush orders, backorders, cancellations) included in the production plan?
   - ❑ No anticipation. Failures and unexpected orders cause that the plan can not be realised and no compliance with customer requirements.
   - ❑ If necessary, extra capacity will be mobilised (personnel, shift), the production time will be lengthened, or maximal capacity corresponds with the most full plan. Margins are available for more quiet days, although no margins are available for busy days.
   - ❑ Margins are included within the plan to prevent problems or beforehand agreements are made about hiring personnel or contracting out production.

Realisation

47. A. Is the realisation of the production plan evaluated?
   - ❑ No
   - ❑ Yes

47. B. To what extent is the realisation of the production plan evaluated?
   - ❑ After production the realisation of the plan is evaluated. No adjustment of the plan during production.
   - ❑ During production the realisation of the plan is regularly evaluated. Based on this evaluation the plan is adjusted during production.
   - ❑ Employees register the realisation and report when the plan is not realised or if the plan has to be adjusted. Based on this report the production plan is adjusted during production.

48. To what extent are other plans adjusted based on the production plan?
   - ❑ Production plan is not used for development of other plans.
   - ❑ Plans connected operationally on the production plan, like purchase plan or distribution plan.
   - ❑ All plans use the production plan, like purchase plan, distribution plan, sales plan, long-term plan.

Distribution plan

This part consists of questions about development of the distribution plan that describes what, when and where products have to be delivered.

Development

49. A. Do you develop a distribution plan?
   - ❑ No
   - ❑ Yes, partly: transport company designs the route, although we plan preloading by ourselves.
   - ❑ Yes, whole distribution plan

49. B. To what extent do you develop the distribution plan?
    - ❑ Distribution plan is always new developed.
    - ❑ Distribution plan is developed on basis of experience. A selection is made from known possible routes.
    - ❑ Distribution plan is mainly the same (established routes), but if necessary major aspects will be changed.

50. What information do you use for development of the distribution plan?
    - ❑ Data of orders
    - ❑ Prognosis, expected number of orders
    - ❑ Realisation of production plan
    - ❑ Realisation of long term production plan
    - ❑ Other distribution plans
    - ❑ Data of other bakeries
    - ❑ Planning of other linkages of the supply chain
    - ❑ Information about storage conditions
    - ❑ ……

51. On basis of which aspects is the distribution plan developed?
    - ❑ Customer
    - ❑ Delivery time
    - ❑ Margins of delivery times
    - ❑ Shelf life of the product, FIFO
    - ❑ Average quantity of products per customer
    - ❑ Location of deliverance
    - ❑ Regional regulation
    - ❑ Available capacity (number of company trucks, loading volume, return capacity)
    - ❑ Route
    - ❑ Required transport conditions of products
    - ❑ ……

52. Is the distribution plan recorded?
    - ❑ No
    - ❑ Yes,
        - ❑ Planning system
        - ❑ Printed paper
        - ❑ Written paper

53. To what extent do you anticipate on unexpected situations with developing the distribution plan?
    - ❑ When the plan is not realised, the problem will be solved on that moment.
    - ❑ The distribution plan anticipates on unexpected situations (e.g. by an extra chauffeur). Therefore, the distribution plan is always realised.
    - ❑ The distribution plan anticipates on unexpected situations and alternatives are developed. Therefore, the distribution plan is always realised.

Realisation

54. A. Is the realisation of the distribution plan evaluated?
    - ❑ No
    - ❑ Yes

54. B. To what extent is the realisation of the distribution plan evaluated?
    - ❑ The realisation of the distribution plan is evaluated after the distribution. The plan is not adjusted during distribution.
    - ❑ Time of deliverance is recorded and compared with margins of delivery times. When these times differ, customers are informed during distribution.
    - ❑ Time of deliverance is recorded and compared with margins of delivery times. When these times differ, the distribution plan is adjusted and customers are informed during distribution.

55. To what extent are other plans adjusted based on the distribution plan?
    - ❑ The distribution plan is not used for development of other plans.
    - ❑ Plans that operationally connect to the distribution plan, like sales plan and production plan.
    - ❑ All plans use the distribution plan, like purchase plan, sales plan, production plan.

56. To what extent do you account on cross-contamination and shelf life during transport of products?
    - ❑ No anticipation.
    - ❑ Anticipation by organisation of company truck and/or packaging of products.
    - ❑ Anticipation by organisation of company truck and/or packaging of products. Besides, transport conditions the distribution time are recorded and evaluated. If necessary, conditions will be adjusted.

57. How do you anticipate on cross-contamination and shelf life during transport of products?
    - ❑ Temperature control
    - ❑ Control of humidity
    - ❑ Separated compartments
    - ❑ Empty boxes are separated
    - ❑ Return drive for old bread
    - ❑ Distribution time
    - ❑ Packaging
    - ❑ Hygiene control of truck
    - ❑ Information about shelf life with customer
    - ❑ FIFO
    - ❑ ……

Execution of production tasks
This part consists of questions about production tasks to obtain production quality. First general questions, next quality control.

Execution (general)
58. A. Are production tasks divided among the employees?
    - ❑ No
    - ❑ Yes,
        - ❑ One department
        - ❑ Most production departments
        - ❑ Each production department

58. B. To what extent are production tasks divided among the employees?
    - ❑ Production tasks are not divided; everyone knows what have to be done. Or everyone has own tasks, but sometimes it changes.
    - ❑ Production tasks are different and are divided per day.
    - ❑ Every week employees receive a list of production tasks that have to be performed in a week. The realisation is evaluated everyday.

59. A. Are production tasks supervised?
    - ❑ No
    - ❑ Yes

59. B. To what extent are production tasks supervised?
    - ❑ All supervisors do sometimes supervise.
    - ❑ One supervisor does always supervise, other do sometimes.
    - ❑ All supervisors do always supervise.

60. Who supervises production tasks?
    - ❑ Employee
    - ❑ Other employees
    - ❑ Manager of production, foreman, assistant foreman
    - ❑ Quality manager
    - ❑ Planner
    - ❑ Sales department (visual inspection of end products)
    - ❑ Manager
    - ❑ Director
    - ❑ ……

61. How do employees know how production tasks have to be performed?
    - ❑ By internal education and training
    - ❑ On basis of experience
    - ❑ By procedures and instructions
    - ❑ By consultation
    - ❑ ……

62. How are employees instructed?
    - ❑ Tasks are demonstrated and experience is obtained during production.
    - ❑ Tasks are demonstrated and an experienced employee supervises.
    - ❑ Tasks are demonstrated and an experienced employee supervises. Besides, information is available how to perform the tasks.

Process- and product control
** Changing shifts*

63. A. Is the production handed over to another shift?
    - ❑ No
    - ❑ Yes

63. B. To what extent is the production handed over to another shift?
    - ❑ Production is not handed over.
    - ❑ Realisation and bottlenecks are written.
    - ❑ Realisation and bottlenecks are communicated by consultation. Possible problems are solved together.

** Realisation*

64. A. Is the realisation of the product quality evaluated?
    - ❑ No
    - ❑ Yes

64. B. To what extent is the realisation of the product quality evaluated?
    - ❑ By supervision
    - ❑ Realisation is recorded.
    - ❑ Realisation is recorded, evaluated and compared with standards (e.g. product is compared with a sample or it is analysed afterwards). If necessary, production will be adjusted.

65. Based on which data is the performance of production tasks evaluated?
    - ❑ Information about realisation:
        - ❑ Number of finished products
        - ❑ Number of products in storage
        - ❑ Number of raw materials
        - ❑ Product quality
        - ❑ Percentage of rejected products
        - ❑ Production time
        - ❑ Process parameters
        - ❑ Inspections and measurements during production (e.g. weight, length)
        - ❑ ……
    - ❑ Reporting of supervisors
    - ❑ Results of evaluations (audits and legislative, technical or consumer requirements)
    - ❑ Financial reporting
    - ❑ Complaints of customers
    - ❑ ……

66. A. Is the realisation of production tasks communicated to employees?
    - ❑ No
    - ❑ Yes

66. B. To what extent is the realisation of production tasks communicated to employees?
    - ❑ No communication, with the exception of situations like failures or ad hoc changes.
    - ❑ Results are shown on a publication board, the journal of the company, etc.
    - ❑ Results are always communicated and consequences are discussed by consultation.

67. To what extent are procedures or methods changed?
    - ❑ Procedures and methods are not changed, or these are generic.
    - ❑ If a procedure is not workable during more times, it will be changed.
    - ❑ If a procedure is not workable during more times, it will be evaluated and solutions will be searched for. Based on this evaluation the procedure will be changed or not.

68. To what extent are data about realisation used for adjustment of the production plan?
    - ❑ Production plan is not adjusted.
    - ❑ If the production is not realised, production plan will be adjusted.
    - ❑ If the production is not realised, production plan will be adjusted. If necessary, customers will be informed and the long-term plan will be adjusted.

69. A. Do you anticipate on possible variations in the production process?
    - ❑ No
    - ❑ Yes

69. B. To what extent do you anticipate on possible variations in the production process (e.g. by variation in quality of raw materials, influences of weather, temperature variations during rising)?
    - ❑ No anticipation.
    - ❑ Process parameters are adjusted during the production process (e.g. by a graphic T/a_w). Compliance of the product is evaluated on basis of experience or pictures.
    - ❑ Beforehand measures are taken, like mixing of batches of raw materials, adjustment of recipe, cooling of meal and dough, organisation of rising room.

70. To what extent do you make a continuous production process?
    - ❑ A continuous process is not possible due to lack of capacity.
    - ❑ The same types of products are planned on one production line or sequentially. Besides, preventive maintenance is performed.
    - ❑ The same types of products are planned on one production line or sequentially. Besides, preventive maintenance is performed and the production process is adjusted (like storage, rising with a rest period) with a minimal waiting time.

71. To what extent is the product quality and food safety controlled?
    - ❑ Quality of the product is evaluated on experience.
    - ❑ Process parameters are recorded and the end product is evaluated.
    - ❑ Process parameters are recorded and compared with a standard. Besides, the end product is compared with product specifications. If necessary, the parameters will be adjusted.

72. How is product quality and food safety controlled?
    - ❑ Recipe of products (low pH or a_w, preservatives, antileng, emulsifiers, etc.)
    - ❑ Receipt inspection (visual, analyses, conditions)
    - ❑ Evaluation of process parameters
    - ❑ Metal detector
    - ❑ Evaluation of storage conditions (parameters and organisation of storage)
    - ❑ Hazard analysis
    - ❑ Risk analysis (possibility x severe)
    - ❑ Audits
    - ❑ Evaluation of end product
    - ❑ Control of product flow
    - ❑ FIFO
    - ❑ Training of personnel
    - ❑ Evaluation of measurement equipment
    - ❑ Hygienic design of equipment and buildings (equipment after 1995 or revision of older equipment)
    - ❑ Hygienic inspection (by manager)
    - ❑ Cleaning and disinfecting plan
    - ❑ Method of piling up of products
    - ❑ Procedures and instructions
    - ❑ ……

73. What information is used for evaluation of product quality and food safety?
    - ❑ Registration of process parameters
    - ❑ Visual inspection during production process
    - ❑ Results of internal evaluations of end products
    - ❑ Results of evaluations of inspection agencies like Keuringsdienst van Waren
    - ❑ Results of technical evaluations by NBC
    - ❑ Results of analyses
    - ❑ Results of consumer tests
    - ❑ Results of evaluation by accounts
    - ❑ Results of audits
    - ❑ Results of van hygienic inspections
    - ❑ Results of competitions
    - ❑ Information by customers
    - ❑ ……

74. To what extent is the production process improved by process registrations?
    - ❑ No process improvement by process registrations.
    - ❑ Results are documented.
    - ❑ Results are documented and evaluated. When process parameters or execution have to be improved, procedures and instructions are adjusted.
    - ❑ Results are documented and evaluated. When process parameters or execution have to be improved, procedures and instructions are adjusted. This is communicated to employees by training, written announcements and/or consultation.

75. To what extent is the production process improved by product evaluations?
    - ❑ No process improvement by product evaluations.
    - ❑ Results are documented.
    - ❑ Results are documented and evaluated. When process parameters or execution have to be improved, procedures and instructions are adjusted.
    - ❑ Results are documented and evaluated. When process parameters or execution have to be improved, procedures and instructions are adjusted. This is communicated to employees by training, written announcements and/or consultation.

Section IV: Production Quality

This part consists of questions about product quality, availability and costs.

Product quality and availability

Indicator		**Product group**	**Answer**
Number of rejected products per number of produced products per 4 weeks	Number of produced products per 4 weeks	Bread	Number of bags of meal per 4 weeks
	Total number of rejected products		
	Dosing	Bread	Dough per kg
	Mixing	Bread	Dough
	Baking		
	Metal detection		
	Packaging / cutting		
	Delivering		
Number of complaints per number of products per product group per 4 weeks	Product quality	Type of complaints:	
	Availability	Type of complaints:	
Number of failed legislative evaluations per number of samples per year	Legislative requirements - Keuringsdienst van Waren (sanctions, warnings, results evaluation QA system) - RVV		
	Technical requirements: - NBC - Bakkersland - Echte Bakkers Gilde - Gilde van de Betere Banketbakkers - Topbakkers		
	External audits		
	Consumer requirements - Consumer tests		

Costs

Do you formulate a financial report?
- ❑ Yes: Could I please have a copy of the report?
- ❑ No:

Indicator		Financial data
	Returns per year excluding tax	
Costs	Total costs: Personnel, transport, accommodation, costs of organisation, costs of sales, general costs, payments, costs of interest	
	Payments: - Immovable property - Inventory - Means of transport	
	Costs of interest	
	Calculated income of entrepreneur and partner	
	Purchase - Raw materials - Half fabricates - Sales of purchased products	

Failure costs:

Indicator		Product group	Financial data	Quantity of products
Failure costs	Rejected products and raw materials			
	Overproduction			
	Returns			
	Extra deliveries (transport costs)			
	Delay of production			

Section V: Finishing question

Which effects have the application of the QA system on your organisation?

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Summary

Food quality management is of major importance in the agri-food sector due to the complex characteristics of food and unpredictable human behaviour. Food manufacturers use various QA systems to assure food quality. These systems focus on different aspects of the complete quality system. The specific characteristics of food production and the different situations of food companies require a selection of appropriate QA systems and an effective implementation. Therefore, the food sector needs an instrument that measures effectiveness.

The aim of this thesis was to develop and validate an instrument that measures effectiveness of food quality management. Knowledge about effectiveness of food quality management will support food manufacturers to select quality management activities suitable to their specific situation. Policy makers can use this information to improve established QA systems and to develop effective implementation methods. This can result in effective quality management and an increased production quality, which will lead to more confidence of consumers in food production quality and improving competitiveness of food manufacturers. The developed methodology will also support other researchers to develop similar instruments. This thesis makes a contribution to the body of knowledge in the field of food quality management by developing an instrument that measures effectiveness instead of only performance or compliance with norms and requirements.

In **Chapter 2** current performance measurement instruments were evaluated on their suitability for the development of an instrument that measures the effectiveness of food quality systems. For this evaluation, perspectives of quality, typical characteristics of agri-food production, quantification, and performance measurement of quality management were studied. In reviewing the literature, a broad range of instruments has been developed in other industries to measure performance of quality management. However, they cannot be used for measuring effectiveness of food quality systems. Three instruments were selected for the development of a conceptual model i.e. Wageningen Management Approach, Extended Quality Triangle, and the quality concept of Noori and Radford.

Chapter 3 described the development of the conceptual model that reflects the interrelationships between quality management, production quality and contextual factors i.e. complexity of respectively the supply chain, the organisation, the production process, and the product assortment. The model proposes that a higher level of quality management results in a

higher production quality. A higher complexity of contextual factors is expected to relate with a lower production quality, but a higher level of quality management is assumed to reduce the influence of the contextual factors on production quality. This model was used to develop the objective instrument to assess performance of quality management in agri-food production.

Chapter 4 aimed to identify performance measurement indicators of the instrument that measures effectiveness of food quality management, called IMAQE-Food i.e. Instrument for Management Assessment and Quality Effectiveness in the Food sector. This instrument was developed by translation of the conceptual model in quantifiable performance measurement indicators. An identification procedure resulted in 28 indicators that measure performance of quality management, production quality and contextual factors in the bakery sector. The indicators enable assessment of interrelationships between the elements.

Chapter 5 evaluated IMAQE-Food on generalisability, reliability and validity among a sample of 48 bakeries. The validity was tested on content, criterion-relation and construct to develop a robust instrument. This evaluation resulted in a reliable and validated instrument that measures the effectiveness of food quality management in the bakery sector. It is expected that IMAQE-Food will be applicable for other food sectors as well after small modifications.

Chapter 6 reported a study on the effectiveness of food quality management in the bakery sector. Effectiveness was measured by assessment of relations between quality management activities, production quality and contextual factors. The relations were studied from a generic and a specific point of view. On the generic level, performance of food quality management was related to contextual factors i.e. complexity of respectively the organisation, the production process, and the product assortment. Assessment on the specific level revealed that effective quality management activities in the bakery sector were (1) control of strategy, (2) allocation of supplying raw materials, (3) supply control, (4) control of production, (5) control of execution of production tasks, (6) control of receiving orders, and (7) planning of distribution. These quality management activities were effective since interdependency was found between these activities and indicators of production quality i.e. higher results of respectively legislative and technical evaluation, lower percentage of rejected products, and lower percentage of complaints about respectively product quality and availability. Each bakery had a different set of contextual factors. Depending on these differences in context, bakeries should select and implement specific quality management activities that are suitable to their situation to obtain an optimal production quality.

In **Chapter 7** the interdependency between contextual factors of bakeries and their level of food quality management was investigated. Contextual factors that were studied are QA systems, organisational size, degree of automation, and type of product groups. The context of bakeries revealed differences in the level of five quality management activities i.e. control of strategy, allocation of supplying raw materials, supply control, planning of production, and control of execution of production tasks. Bakeries that applied BRC, bakeries with more than 150 employees, industrial bakeries, and confectionery and biscuits bakeries performed a higher level of some of these activities. Food manufacturers can select suitable quality management activities and QA systems for their specific situation by using IMAQE-Food in order to obtain an effective quality management.

In **Chapter 8** the results of this thesis and their significance for food production systems were discussed. Possible applications of IMAQE-Food were summarised. This thesis has shown that IMAQE-Food is a reliable and valid instrument to measure effectiveness of food quality management in the bakery sector. The instrument should serve as a basis for other applications in the agri-food sector. The insights of this study support food manufacturers in deciding which system is most suitable for their situation and how their objectives have to be achieved. Policy makers can use this information to improve established QA systems and to develop effective implementation methods. This can result in an effective quality management and an optimal production quality.

Samenvatting

Kwaliteitszorg is erg belangrijk in de agri-food sector vanwege de complexe eigenschappen van voedingsmiddelen en het onverwachte gedrag van mensen. Voedingsmiddelenbedrijven gebruiken verschillende kwaliteitsborgingsystemen om de kwaliteit van voedingsmiddelen te borgen. Deze systemen richten zich op verschillende aspecten van het totale kwaliteitssysteem. De specifieke eigenschappen van de voedingsmiddelenproductie en de uiteenlopende situaties van voedingsmiddelenbedrijven vereisen selectie van geschikte kwaliteitsborgingsystemen en een effectieve implementatie. Daarom heeft de voedingsmiddelensector een instrument nodig dat effectiviteit kan meten.

Het doel van dit proefschrift is om een instrument te ontwikkelen en valideren dat effectiviteit van kwaliteitszorg kan meten. Kennis over effectiviteit van kwaliteitszorg ondersteunt voedingsmiddelenbedrijven in het selecteren van kwaliteitszorgactiviteiten die passend zijn voor hun specifieke situatie. Beleidsmedewerkers kunnen deze informatie gebruiken om huidige kwaliteitsborgingsystemen te verbeteren en om effectieve implementatiemethoden te ontwikkelen. Dit kan resulteren in effectieve kwaliteitszorg en een toename in productiekwaliteit, wat kan leiden tot meer vertrouwen van consumenten in de productiekwaliteit van voedingsmiddelen en in een verbetering van de concurrentiepositie van bedrijven. De ontwikkelde methodologie kan andere onderzoekers aanzetten om vergelijkbare instrumenten te ontwikkelen. Dit proefschrift draagt bij aan het kennisveld van kwaliteitszorg door het ontwikkelen van een instrument dat effectiviteit meet in plaats van alleen performance of het voldoen aan normen en eisen.

In **hoofdstuk 2** zijn huidige performance meetinstrumenten geëvalueerd op hun geschiktheid voor het ontwikkelen van een instrument dat de effectiviteit van kwaliteitssystemen in de voedingsmiddelensector meet. Voor deze evaluatie werden perspectieven van kwaliteit, typische eigenschappen van de voedingsmiddelenproductie, kwantificering en prestatiemeting van kwaliteitszorg bestudeerd. Uit literatuuronderzoek bleek dat er in andere industrieën een grote range aan instrumenten ontwikkeld is om de prestatie van kwaliteitszorg te meten. Deze instrumenten kunnen echter niet gebruikt worden om de effectiviteit van kwaliteitssystemen in de voedingsmiddelensector te meten. Drie instrumenten zijn geselecteerd die gebruikt kunnen worden om een conceptueel model te ontwikkelen, namelijk de Wageningse

Besturingsbenadering, de Extended Quality Triangle, en het kwaliteitsconcept van Noori en Radford.

Hoofdstuk 3 beschrijft de ontwikkeling van het conceptuele model dat de interrelaties tussen kwaliteitszorg, productiekwaliteit en contextuele factoren weergeeft. De contextuele factoren bestaan uit de complexiteit van respectievelijk de keten, de organisatie, het productieproces en het productassortiment. Het model veronderstelt dat een hoger niveau van kwaliteitszorg zal leiden tot een hogere productiekwaliteit. Er wordt verwacht dat een hogere complexiteit van contextuele factoren een lagere productiekwaliteit veroorzaakt, en dat een hoger niveau van kwaliteitszorg deze invloed van contextuele factoren op productiekwaliteit kan verminderen. Dit model werd gebruikt om het objectieve instrument te ontwikkelen dat de prestatie van kwaliteitszorg in de voedingsmiddelenproductie kan meten.

Het doel van **hoofdstuk 4** was om prestatie-indicatoren te identificeren voor het instrument dat de effectiviteit van kwaliteitszorg in de voedingsmiddelensector meet. Dit instrument is IMAQE-Food genoemd, wat een afkorting is voor "Instrument for Management Assessment and Quality Effectiveness in the Food sector". Het instrument werd ontwikkeld door het conceptuele model te vertalen in kwantificeerbare prestatie-indicatoren. Aan de hand van een identificatieprocedure zijn 28 indicatoren verkregen die de performance van kwaliteitszorg, productiekwaliteit en contextuele factoren in de bakkerijsector meten. Deze indicatoren maken het mogelijk om de interrelaties tussen deze elementen te meten.

In **hoofdstuk 5** is IMAQE-Food beoordeeld op generaliseerbaarheid, betrouwbaarheid en validiteit in een steekproef van 48 bakkerijen. De validiteit werd getest op inhoud, criteriumrelatie en construct om een robuust instrument te ontwikkelen. Aan de hand van deze beoordeling werd een betrouwbaar en valide instrument verkregen dat de effectiviteit van kwaliteitszorg in de bakkerijsector meet. Er wordt verwacht dat IMAQE-Food ook toepasbaar is in andere voedingsmiddelensectoren na kleine modificaties.

In **hoofdstuk 6** is de effectiviteit van kwaliteitszorg in de bakkerijsector onderzocht. Effectiviteit werd gemeten door de relaties tussen kwaliteitszorgactiviteiten, productiekwaliteit en contextuele factoren te analyseren. De relaties werden op een generiek en een specifiek niveau bestudeerd. Op het generieke niveau was de mate van kwaliteitszorg gerelateerd aan contextuele factoren, namelijk complexiteit van respectievelijk de organisatie, het productieproces, en het productassortiment. Uit de meting op het specifieke niveau bleek dat effectieve kwaliteitszorgactiviteiten in de bakkerijsector waren: (1) strategiebeheersing, (2) zelfstandige inkoop van grondstoffen, (3) inkoopbeheersing, (4) productiebeheersing, (5) beheersing van de uitvoering van productiehandelingen, (6) beheersing van orderontvangst en

(7) distributieplanning. Deze kwaliteitszorgactiviteiten waren effectief vanwege hun relatie met hogere resultaten van respectievelijk wettelijke en technische beoordeling, een lager percentage afgekeurde producten, en met een lager percentage klachten over respectievelijk productkwaliteit en beschikbaarheid. Elke bakkerij bevatte andere contextuele factoren. Afhankelijk van deze verschillen in context zouden bakkerijen specifieke kwaliteitszorgactiviteiten moeten selecteren en implementeren die geschikt zijn voor hun situatie om een optimale productiekwaliteit te verkrijgen.

In **hoofdstuk 7** is de relatie tussen de contextuele factoren van bakkerijen en hun niveau van kwaliteitszorg onderzocht. Contextuele factoren die bestudeerd waren zijn kwaliteitsborgingsystemen, organisatiegrootte, automatiseringsgraad, en type productgroepen. Deze bakkerijen met verschillende context verschilden onderling in het niveau van kwaliteitszorgactiviteiten, namelijk strategiebeheersing, zelfstandige inkoop van grondstoffen, inkoopbeheersing, productieplanning, en beheersing van de uitvoering van de productiehandelingen. Bakkerijen met BRC, bakkerijen met meer dan 150 werknemers, industriële bakkerijen, en banket- en koekbakkerijen voerden een hoger niveau van een aantal van deze activiteiten. Voedingsmiddelenbedrijven kunnen passende kwaliteitszorgactiviteiten en kwaliteitsborgingsystemen selecteren voor hun specifieke situatie door IMAQE-Food te gebruiken om een effectief kwaliteitszorg te verkrijgen.

In **hoofdstuk 8** worden de resultaten van dit proefschrift en hun betekenis voor voedingsmiddelenproductiesystemen bediscussieerd. De mogelijke toepassingen van IMAQE-Food zijn besproken. Dit proefschrift heeft laten zien dat IMAQE-Food een betrouwbaar en valide instrument is voor de effectiviteitmeting van kwaliteitszorg in de bakkerijsector. Het instrument zou moeten dienen als een basis voor andere toepassingen in de agri-food sector. De inzichten van deze studie ondersteunen voedingsmiddelenbedrijven in de besluitvorming welk systeem het meest geschikt is voor hun situatie en hoe hun doelen moeten worden verkregen. Dit kan leiden tot een effectief kwaliteitszorg en een optimale productiekwaliteit.

Dankwoord

Mijn interesse naar een promotieonderzoek ontstond al tijdens mijn afstudeerperiode. Toch wilde ik eerst ervaring opdoen bij onderzoeksinstituten en levensmiddelenbedrijven. Vooral toen ik met productiemedewerkers samenwerkte, zag ik in de praktijk dat het belangrijk is om de kwaliteit van levensmiddelen te beheersen met zowel technologische als organisatorische aspecten. Ook merkte ik dat de ene organisatie heel strikt bezig was met het uitvoeren van kwaliteitssystemen, en dat de andere organisatie het veel belangrijker vond om gestructureerd te werken volgens een eigen plan in plaats van het volgen van een kwaliteitssysteem. Ik vroeg me af of een kwaliteitssysteem echt nodig was in bepaalde situaties en of het soms niet zijn doel voorbij ging. Toen ik de vacature van een AIO naar de kwaliteit van kwaliteitssystemen tegenkwam, heb ik gelijk gereageerd. Nu, na ruim vijf jaar lezen, schrijven, congressen bezoeken in o.a. Vaasa, Jeruzalem en Boston, identificeren van prestatie-indicatoren, opzetten van vragenlijsten, het brengen van vele bezoekjes aan bakkers, en statistische analyses, is het einde van mijn promotieonderzoek in zicht. Ik heb in deze periode niet alleen onderzoekservaring opgedaan, maar ook veel over mezelf geleerd. Veel mensen hebben mij tijdens deze periode bijgestaan. Graag wil ik hen op deze plaats bedanken.

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Voor het kwalitatieve en het kwantitatieve onderzoek heb ik verschillende bakkerijen geïnterviewd. Ondanks de hoge werkdruk zagen ze kans om tijd vrij te maken. Ik wil alle bakkerijen bedanken die aan mijn onderzoek hebben meegewerkt.

De gegevens van de bakkers zijn in een database gebracht en gebruikt voor statistische analyses. Waldo de Boer, bedankt voor je inbreng van je statistische expertise. Het was een hele tijd zoeken om een procedure te vinden en om de database eenduidig te gebruiken. Uiteindelijk hebben we toch een mooie methode ontwikkeld om het instrument te valideren en de effectiviteit te bepalen. Saskia Burgers, bedankt voor je suggesties voor zowel de opzet van de database als de verwerking van de interviews. Martijn Fox en Lous Schedler, bedankt voor jullie hulp met mijn internetpagina. Met jullie hulp konden de bakkers een gedeelte van het interview via internet invullen, waarna de gegevens vrij makkelijk in de database gebracht konden worden.

In het kader van hun afstudeervak hebben Josée Diepstraten, Ingrid Nijssen en Anne-Cathérine Waelkens bijgedragen aan dit proefschrift. Daarnaast heeft Josée ook nog als student assistent geholpen bij het afnemen van de interviews waarbij ze met een kritische blik naar de bakkerswereld keek. Bedankt voor jullie werk en de prettige samenwerking. Jullie enthousiasme heeft mij extra gemotiveerd.

In een kwalitatief onderzoek is onderzocht of het meetinstrument ook toepasbaar is in de groente- en fruitverwerkende industrie. De experts en bedrijven die hieraan hebben meegewerkt, wil ik hiervoor bedanken.

Tijdens mijn promotieonderzoek ben ik gedetacheerd geweest op het RIKILT. Ik heb het cluster Ketenmanagement zien starten en veranderen. Ik wil Marcel en Joop bedanken voor hun suggesties voor de artikelen. Daarnaast wil ik alle (ex-)collega’s van het RIKILT bedanken voor de gezelligheid, ondersteuning en faciliteiten. Jeannette, ik ben blij dat je mijn paranimf wilt zijn.

Omdat ik gedetacheerd was op het RIKILT, bleef mijn contact met de vakgroep vaak beperkt tot overleg en leerstoelgroeppresentaties. Daarnaast nam ik af en toe deel aan de gezellige uitjes zoals promoties, borrels, barbecues en de AIO-reis naar Denemarken en Zweden. Ik wil alle mede-AIO’s en leerstoelgroepgenoten bedanken voor hun gezelligheid.

Naast mijn promotieonderzoek kon ik meerdere keren per week me op sportief vlak uitleven bij badmintonclub BC de Lobbers. In deze tijd hebben we met het eerste team mooie resultaten gehaald, waarbij de promotie naar de vierde divisie landelijk en het kampioenschap van de Nationale Districts Masters in 2002 de hoogtepunten waren. Naast de leuke trainingen, trainingspartijtjes en wedstrijden, heb ik veel steun gehad van Jochem, Huiberdien, Marian, Jeroen, Marleen, Ariënne, Mariëlle, Ivo en Henk. Ik wil jullie bedanken voor jullie gezelligheid en medeleven. Anja, bedankt voor je taalsuggesties. Huiberdien, fijn dat je mijn paranimf wilt zijn.

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Marjolein

Curriculum Vitae

Marjolein van der Spiegel werd geboren op 15 juni 1972 in Utrecht. In 1991 behaalde zij het VWO-diploma aan de Utrechtse Dag- en Avondschool in Utrecht. In datzelfde jaar begon ze met de studie Levensmiddelentechnologie aan de toenmalige Landbouwuniversiteit in Wageningen, waarin ze zich specialiseerde in de richting kwaliteitsborging en levensmiddelenchemie. Als onderdeel van haar studie deed zij afstudeervakken bij de vakgroep Levensmiddelenchemie- en microbiologie, bij Boering (Campina) in De Meern en de vakgroep Bedrijfskunde, en liep ze stage bij de afdeling Enzyme Research van Quest International (Unilever) in Naarden. In 1996 studeerde ze af. Na haar studie werkte ze drie maanden bij de afdeling Enzyme Research van Quest International in Naarden. Van februari tot en met mei 1997 deed ze onderzoek bij de afdeling Agrogrondstoffen van TNO Voeding in Zeist. Vervolgens was ze van juni 1997 tot en met januari 1998 als technoloog werkzaam bij CPC Benelux (Bestfoods) in Loosdrecht. Van augustus 1999 tot en met januari 2002 was ze als toegevoegd docent betrokken bij onderwijs in Food Quality Management bij de leerstoelgroep Productontwerpen en Kwaliteitskunde van Wageningen Universiteit. Van februari 1998 tot en met maart 2003 was ze aangesteld als Assistent in Opleiding bij de leerstoelgroep Productontwerpen en Kwaliteitskunde van het Departement Agrotechnologie en Voedingswetenschappen aan Wageningen Universiteit en was ze gedetacheerd bij het cluster Ketenmanagement van het RIKILT – Instituut voor Voedselveiligheid in Wageningen. Dit onderzoek wordt beschreven in dit proefschrift.

List of publications

Spiegel, van der M. and Ziggers, G.W. (1999). *The application of the TQM-concept in Food Supply Chains*, pp. 724-736. In: Werther, W. Takala, J. and Sumanth, D.J. (Eds.). Productivity and Quality management Frontiers – VIII. Proceedings of the International Conference on Productivity and Quality Management '99 held in Vaasa, Finland, from 14-16 June 1999. West Yorkshire: MCB University Press.

Spiegel, van der M. and Ziggers, G.W. (2000). *Development of a Supply Chain Quality Management Model*, pp. 147-155. In: Trienekens, J.H. and Zuurbier, P.J.P. (Eds.). Chain Management in Agribusiness and the Food Industry. Proceedings of the Fourth International Conference, held in Wageningen, the Netherlands, from 25-26 May 2000. Wageningen: Wageningen Pers.

Spiegel, van der M. Ziggers, G.W Luning, P.A. and Jongen, W.M.F. (2000). *Development of a diagnostic instrument for food quality systems: a conceptual model*, pp. 193-200. In: Dar-El, E. Notea, A. and Hari, A. (Eds.). Productivity & Quality Management Frontiers – IX. Proceedings of the 9th International Conference on Productivity and Quality Research, held in Jerusalem, Israel, from 25-27 June 2000. Bradford: MCB University Press.

Spiegel, van der M. Luning, P.A. Ziggers, G.W and Jongen, W.M.F. (2002). *Identification of indicators to measure effectiveness of food quality systems*, pp. 563-570. In: Neely, A. and Walters, A. (Eds.) Performance Measurement and Management: Research and Action, held in Boston, USA, from 17-19 July 2002. Cranfield: Centre for Business Performance.

Spiegel, van der M. Luning, P.A. Ziggers, G.W and Jongen, W.M.F. (2003). *Evaluation of performance measurement instruments on their use for food quality systems*. Accepted for publication in *Critical Reviews in Food Science and Nutrition* (February 2003).

Spiegel, van der M. Luning, P.A. Ziggers, G.W and Jongen, W.M.F. (2003). *Towards a conceptual model to measure effectiveness of food quality systems. Trends in Food Science and Technology,* 14 (10), 424-431.

Spiegel, van der M. Luning, P.A. Ziggers, G.W and Jongen, W.M.F. (2003). *Development of the instrument IMAQE-Food to measure effectiveness of quality management.* Accepted for publication in *International Journal of Quality & Reliability Management* (accepted at November 2003, publication in 2005*,* 22 (2)).

Spiegel, van der M. Boer, de W.J. Luning, P.A. Ziggers, G.W. and Jongen, W.M.F. (2004). *Validation of IMAQE-Food: Instrument for Management Assessment and Quality Effectiveness in the Food sector.* Submitted for publication in *Journal of Operations Management.*

Spiegel, van der M. Luning, P.A. Boer, de W.J. Ziggers, G.W and Jongen, W.M.F. (2004). *Measuring effectiveness of food quality management in the bakery sector.* Submitted for publication in *Total Quality Management and Business Excellence*.

Spiegel, van der M. Luning, P.A. Boer, de W.J. Ziggers, G.W. and Jongen, W.M.F. (2004). *How to improve food quality management in the bakery sector.* Submitted for publication in *NJAS – Wageningen Journal of Life Sciences*.

Training and supervision plan

Discipline specific activities

- Course “Food Technology and Food Safety, Module Total Quality Assurance and Quality Management”, VLAG, held in Wageningen, the Netherlands, from 6-9 April 1998.
- 3rd International Conference “Chain Management in Agribusiness and the Food Industry”, AKK, held in Wageningen, the Netherlands, from 28-29 May 1998.
- 8th International Conference on Productivity and Quality Research, ISPQR, held in Vaasa, Finland, from 14-16 June 1999.
- 4th International Conference “Chain Management in Agribusiness and the Food Industry”, AKK, held in Wageningen, the Netherlands, from 25-26 May 2000.
- 9th International Conference on Productivity and Quality Research, ISPQR, held in Jerusalem, Israel, from 25-27 June 2000.
- Symposium “Nieuwe kansen voor food innovation”, PAVO, held in Wageningen, the Netherlands, at 14 September 2000.
- Conference on BRC “Internationale ontwikkelingen rond BRC”, VMT and ISA, held in Bussum, the Netherlands, at 14 February 2001.
- Workshop “Wetenschapsdag, Thema Voeding”, Wageningen University and Research Centre, held in Wageningen, the Netherlands, at 6 October 2001.
- Conference on Traceability “Traceerbaarheid en voedselveiligheid”, VMT and RIKILT, held in Maarssen, the Netherlands, at 27 November 2001.
- 3rd International Conference on Performance Measurement and Management “Performance Measurement and Management: Research and Action”, PMA, held in Boston, USA, from 17-19 July 2002.
- Workshop “Management and Control of Food Safety”, Tempus, held in Banya Luka, Bosnia-Herzegovina, at 20 October 2003.

General courses

- Methodology of research and design, NOBO, from 14 December 1998 to 16 March 1999.
- Acquisition of research projects, Verstrate and RIKILT, from 26 March to 24 June 1999.
- English for research trainees, Wageningen University, from 7 October 1999 to 4 February 2000.
- Personal charisma and stressing the distinctive features, KLV, from 8 May to 5 June 2000.

PhD student week

PhD student week, VLAG, held in Bilthoven, the Netherlands, from 23-27 November 1998, including courses on teamwork and project-based thinking and working.

Optionals

- Preparation of research proposal.
- Food Science Study Tour in Denmark and Sweden, from 26 March to 2 April 2000, including Symposium “Technical Perspectives of Food Science” held in Lund, Sweden, at 29 March 2000.
- Presentations and meetings with respect to food safety, product design and quality management, and supply chains.

The study described in this thesis was carried out at Wageningen University and Research Centre in the Netherlands; Product Design and Quality Management Group of Wageningen University in co-operation with Supply Chain Management Group of RIKILT – Institute of Food Safety. The thesis is result of independent research by Ir. M. van der Spiegel, under supervision of Prof. Dr. W.M.F. Jongen, Dr. Ir. P.A. Luning and Dr. Ir. G.W. Ziggers. Biometris Group of Plant Research International supported statistical analyses. The work was part of the research programme of the Graduate School VLAG (Food Technology, Nutrition & Health Sciences). The project was financially supported by the Netherlands Ministry of Agriculture Nature Management and Fisheries (LNV) and LEI (Agricultural Economics Research Institute).

Cover: Conceptual model to measure effectiveness of food quality systems. Background: non-industrial bakery. Back: raw materials, mixing, rising, filled bread. Designed by Hans and Marjolein van der Spiegel

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