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Measuring Effectiveness of Food Quality Management in the Bakery Sector

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ABSTRACT *Inappropriate management of food production operations cause several quality performance problems. Therefore, the actual contribution of food quality management to quality performance has to be revealed. This article investigates the effectiveness of food quality management in the bakery sector. 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 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 legislative and technical evaluations, a lower percentage of rejected products, and lower percentages of complaints about product quality and availability. Each bakery has a different set of contextual factors such as type of QA systems, size of 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.*

KEY WORDS: Food quality management, effectiveness, performance measurement, bakery sector, IMAQE-Food, contextual factors, production quality

Introduction

Food quality management consists of activities that design, control, improve, and assure the production quality. It is rather complicated because it involves the complex characteristics of food and its raw materials, but human behaviour also plays a crucial role due to unpredictable and changeable handling (Luning *et al.*, 2002a,b).

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Inappropriate management of food production operations can cause several quality problems. For instance, inappropriate temperature control of confectionery containing, for example, cream, fresh fruit and meat causes the 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 was considered to be effective when a higher level of quality management results in a higher production quality. Moreover, quality management is also effective when it reduces the influence of contextual factors on production quality.

A broad range of instruments has been developed in other industries to measure the performance of quality management, e.g. Malcolm Baldrige National Quality Award (NIST, 2002), EFQM Excellence Model (EFQM, 1999), and instruments developed by Saraph *et al.* (1989), Flynn *et al.* (1994) and Ahire *et al.* (1996). However, these instruments cannot be used for measuring the effectiveness of food quality systems, specifically because they do not analyse all relations between production quality, quality management, and contextual factors (van der Spiegel *et al.*, 2004). Based upon these omissions, the instrument IMAQE-Food was developed (van der Spiegel *et al.*, 2005; 2007) that assesses relations between quality management activities, production quality and contextual factors (Figure 1).

When evaluating the appropriateness of an assessment method, a field of 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 (Oude Voshaar, 1994) such as reliability tests, validity tests and regression analysis.

This article investigates the measurement of the 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

Figure 1. Proposed relations between production quality, quality management, and complexity of organisation, complexity of production process, and complexity of product assortment (adapted from van der Spiegel *et al.*, 2000, 2003)

generic approach that estimates reality as best as possible by using identified indicators, and a specific approach that estimates relationships by using only statistically relevant constructs.

Measurement Method of Effectiveness

In this study, we analysed the effectiveness of food quality management on a generic and a specific level. For the generic level, content-validated indicators were used, whereas for the specific level constructs were used.

The effectiveness was measured by the assessment of relations between the quality management, production quality and contextual factors using appropriate indicators. In a previous study (van der Spiegel *et al.*, 2005), these indicators were identified and validated based on interviews with experts and (quality) managers in the bakery sector, 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 diagnostic instrument (van der Spiegel *et al.*, 2007).

Generic Approach

In the generic approach, relationships were analysed between the elements of Figure 1 using content-validated indicators.

Before identifying relationships, the internal consistency of the elements was first determined by calculating Cronbach's alpha and the total score of each element. Table 1 shows the internal consistency of the elements and the indicators that comprised the elements. An element was accepted as relevant when the 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, which reduced 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 variations within the sample. The total score of each element was calculated by adding the scores of indicators that comprise one internal consistent element. No weight factors were used.

Secondly, the relationships 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 relationships. 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.

Specific Approach

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

Table 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

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	*

Before identifying relationships, first the 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 1 shows the constructs and their internal consistency. Results show that a large number of constructs was developed all measuring other aspects. 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, relationships were assessed using the Genstat procedure RSELECT (Goedhart & Thissen, 2002). This procedure evaluates all possible relations and selects a small number of best relations, which prevents that possible relations are overlooked owing 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 , adjusted R^2 , and Mallow's Cp.

R^2 is the percentage of variance accounted for and shows the extent to which indicators of production quality are related 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 (Goedhart & Thissen, 2002). Mallow's Cp is a measure for the robustness of the relations and is related to the Akaike Information Criterion (Oude Voshaar, 1994; Sakamoto *et al.*, 1986). 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 (Goedhart & Thissen, 2002).

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 the best sets of relations was based on R^2 adjusted. Although 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 show the lowest degree of correlation.

When selection is governed by statistical criteria only, alternative sets of relations with good interpretative purposes may easily be overseen. Therefore, for indicators of production quality, three or four alternative relations (see Tables 2 and 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.

Results

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

Generic Approach

Figure 2 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

Table 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 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
<i>Complexity of the organisation</i>																
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)													+			
<i>Complexity of the production process</i>																
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								+	+	+	+	+	+			
<i>Complexity of the product assortment</i>																
Number of product groups																
Type of product groups																
<i>Quality management</i>																
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 3. Relations between eight constructs for quality management, and constructs for contextual factors obtained by regression analysis (1 to 3 = number of fitted relations, + = positive relation, – = negative relation)

Constructs	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	
	1	2	3	1	2	3	1	2	3	1	2	1	1	2	3	1	1	2
<i>Complexity of the organisation</i>																		
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)		+										–	+					+
<i>Complexity of the production process</i>																		
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		–							+							+		
<i>Complexity of the product assortment</i>																		
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

complexity of the production process. Between the level of quality management and the score of 'results of legislative evaluation' no effect was found. The complexities of organisation and production process were positively related to quality management, whereas the complexity of product assortment was negatively related.

The explained variance was low ($R^2 = 14.3\%$), which means that 'results of legislative evaluation' is associated with other unknown variables. Low orthogonal data may be the reason for the low degree of explanation.

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

Bakeries with a higher complexity of the organisation consist of a higher number of employees, relations, and customers. Possibly all these internal and external relations required a higher level of quality management. Bakeries with a higher complexity of the production process have a higher degree of automation, and a higher number of process steps, critical control points, and changes in the production line. More control and monitoring may result in a higher quality management. Bakeries with a lower complexity of the product assortment produce fewer product groups with a longer shelf life. Storage and distribution control may result in a higher level of quality management. No relations were found between quality management and the results of legislative evaluation, probably because each bakery should comply with legislative standards.

Specific Approach

To study the generic relations on a more detailed level and to examine the robustness of the instrument, we used constructs of the identified indicators. In Table 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 3 shows the relations between constructs of quality management and contextual factors.

Tables 2 and 3 show that robustness of the instrument was obtained, because a maximum of seven constructs were necessary. Moreover, these constructs explain a large part of the indicators of production quality. The explained variance varied in a range that was 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 $R^2 = 16.0-52.5\%$.

Tables 2 and 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 were related to the constructs of contextual factors.

Table 2 reveals that the relations with the '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 '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 such as delivery time, location, distribution conditions, orders and capacity, into a distribution schedule. Bakeries with a higher level of 'planning of distribution' used more information for the planning and changed their

Figure 2. Identified relations between ‘results of legislative evaluation’, quality management and contextual factors obtained by regression analysis by using the generic approach ($R^2 = 14.3\%$, $p < 0.05$) (+ = positive relation, – = negative relation, numbers express the regression coefficient)

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 2 it is also shown that ‘results of technical evaluation’ have the most stable relationships, 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. In addition, the results were positively related to the 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 the experience of bakers improved the product quality. Furthermore, ‘results of technical evaluation’ were positively related to the 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.

Effectiveness of Food Quality Management

The found relations were used to measure 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 of 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 4 shows the indicators of production quality for which the quality management activity is effective and the related contextual factors.

Table 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: <ul style="list-style-type: none"> • 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)

(Table continued)

Table 4 *Continued*

Quality management		Indicator of production quality	Contextual factors related with quality management
Effective activity	Description		
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: <ul style="list-style-type: none"> • purchase and selection of raw materials; • selection and evaluation of suppliers; • co-operation with suppliers. 	Results of legislative evaluation % Rejected products	% 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)
Control of production	Part of quality control that is focused on the production process. Items: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none">• 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, acceptance 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)

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 legislative and technical evaluations, a lower percentage of rejected products, and lower percentages of complaints about product quality and availability. The activities were effective for bakeries with various characteristics of organisation, production process and product assortment.

Discussion and Conclusions

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 the unavailability of data in the bakery sector (van der Spiegel *et al.*, 2005; 2007). 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 were assessed as one single measure, other relations could be found with effective quality management activities for more aspects of production quality.

Relevancy of Indicators

Relations were found between the five indicators of production quality and the constructs of quality management and contextual factors. The total variance explained varied in a range of $R^2 = 42.8\text{--}73.3\%$. 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, activities of quality strategy and policy, quality design and quality improvement. These variables should be evaluated on relevancy, reliability and validity using our structured procedure.

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 because most respondents measured this indicator. Typical examples of the 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 such as HACCP (Hazard Analysis Critical Control Points). Thus, legislative production quality involves the minimal requirements of a food product. The indicator 'results of legislative evaluation' is relevant and valid through interviews with experts and (quality) managers in the bakery sector. The various types of inspections increase the validity and result in a sufficient value of the legislative evaluations.

In contrast to 'results of legislative evaluation', 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.

Relations

Our 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 (Luning *et al.*, 2002a; Hendricks & Singhal, 2000; Louwes, 1996; Mainsah & Stout, 1995; Noori & Radford, 1995; Ziggers, 1993; Bots, 1991). Moreover, others describe the relation of the business environment to quality management or production quality (Gulati *et al.*, 2000; Mentzer *et al.*, 2000; Jayaram *et al.*, 1999; van der Bij & Broekhuis, 1998; Messner, 1998; Ziggers, 1997; de Groote *et al.*, 1996; Waszink, 1995; van der Loo *et al.*, 1995; Bots, 1991; Benson *et al.*, 1991; Mulder, 1991).

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. Moreover, most studies were not performed for the agri-food sector.

Effectiveness of Food Quality Management

This study shows that the 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 legislative and technical evaluations, a lower percentage of rejected products, and lower percentages of complaints about product quality and availability. This means that all these activities are necessary to obtain products with a desired production quality.

Some of these effective activities have been suggested by others as well. For example, 'supply control' and 'results of legislative evaluation'. Luning *et al.* (2002a), Ahire *et al.* (1996) and Achten & Roodhooft (1994) mention that quality of raw materials has a major influence on production quality of final products, which requires supply control. In addition, 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 (Diepstraten, 2000; Luning *et al.*, 2002a; Evans & Lindsay, 1996; Black & Porter, 1996; Ahire *et al.*, 1996; Flynn *et al.*, 1994; Saraph *et al.*, 1989; Camperi, 1994; Achten & Roodhooft, 1994; Mainsah & Stout, 1995).

Others also found that 'supply control' and 'control of receiving orders' decrease the variation of raw materials. This results in preventing 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 (van den Berg & Delsing, 1999; Black & Porter, 1996; Diepstraten, 2000; Flynn *et al.*, 1994; Zuurbier *et al.*, 1991).

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) (Diepstraten, 2000; Flynn *et al.*, 1994; Luning *et al.*, 2002a; Black & Porter, 1996; NIST, 2002; Evans & Lindsay, 1996; Zuurbier *et al.*, 1991), which may reduce complaints about availability. Anticipation on delivery times and conditions also controls the physical product quality (Luning *et al.*, 2002a; Diepstraten, 2000; Zuurbier *et al.*, 1991), 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 (Luning *et al.*, 2002a; Diepstraten, 2000; Flynn *et al.*, 1994).

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 (Luning *et al.*, 2002a; Ahire *et al.*, 1996; Evans & Lindsay, 1996; Black & Porter, 1996; Flynn *et al.*, 1994; Saraph *et al.*, 1989; NIST, 2002). Product and process control, and evaluation of assigned tasks and established procedures control performance of production tasks and consequently product quality (Diepstraten, 2000).

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 for the lower level of quality management with their experience and skills to obtain the desired production quality.

IMAQE-Food

The effectiveness of quality management activities was 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 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 for their situation in order to obtain effective food quality management.

Future Research

In future research, a 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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